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Policies for an Ecological Civilization

by
Cecilia H. Springer

A dissertation submitted in partial satisfaction of the
requirements for the degree of
Doctor of Philosophy
in
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in the
Graduate Division
of the
University of California, Berkeley

Committee in charge:
Professor David Anthoff, Chair
Professor Samuel Evans
Professor You-tien Hsing
Professor Daniel Kammen

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Policies for an Ecological Civilization

Abstract

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Doctor of Philosophy in Energy and Resources

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Professor David Anthoff, Chair

China's ecological civilization concept claims a new, Chinese model of promoting economic growth while reducing environmental pollution at the same time. This dissertation uses interdisciplinary methods to analyze two of China's flagship ecological civilization policies, the national carbon market and the Belt and Road Initiative. While the national carbon market exemplifies China's changing approach to domestic environmental policy, the Belt and Road Initiative is carrying the Chinese model of ecological civilization overseas. The first part of this dissertation focuses on China's national carbon market. I use a computable general equilibrium (CGE) model to assess the interactions between a national carbon market and China's ongoing structural economic transition, thereby yielding macro-scale evidence and policy suggestions for how China can fulfill ecological civilization goals of increasing GDP while reducing carbon dioxide emissions. Next, I investigate the carbon market from a qualitative perspective, assessing how emissions accounting is used as a foundation for policy-making. I also explore the capacity building community that sustains the carbon market, asking broader questions about how Chinese neoliberalism informs the formation of the national carbon market. The second part of this dissertation focuses on the Belt and Road Initiative (BRI), situating it in the context of leakage, or relocation of production in response to environmental regulation. Through a novel empirical study, I test the assumption that BRI projects may be better or worse for the environment than other sources of finance. I then explore potential mechanisms of Chinese overseas finance exceptionalism, informing ongoing policy and advocacy debates about how to engage with the growing scale of China's overseas investment.

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CHAPTER 1: INTRODUCTION

> “同志们！生态文明建设功在当代、利在千秋。我们要牢固树立社会主义生态文明观，推动形成人与自然和谐发展现代化建设新格局，为保护生态环境作出我们这代人的努力！”
>
> *“Comrades! What we are doing today to build an ecological civilization will benefit generations to come. We should have a strong commitment to socialist ecological civilization and work to develop a new model of modernization with humans developing in harmony with nature. We must do our generation's share to protect the environment.”*
>
> - Xi Jinping, address to the 19th National Congress of the Communist Party of China, October 18, 2017 (Xinhua 2017) [1]

The concept of ecological civilization (生态文明) is now part of China’s constitution and contributes to the ideological framework for the country. The ecological civilization concept became the guiding principle for China’s environmental policy when Xi Jinping came into power in 2013, and it was written into the Five-Year Plan in 2015. China’s leaders are increasingly presenting ecological civilization not only as a response to problems of environmental degradation within China, but as a state-led vision for the global future that applies Chinese cultural and moral virtues to technological and political goals (Hansen et al. 2018).

Ecological civilization stems from earlier concepts, such as ecological modernization, which calls for a reconciliation of the economy vs. environment dichotomy through the internalizing of environmental limits into capitalist processes (Cooper 2008), and green growth, economic growth that is environmentally sustainable (Ho and Wang 2014). Yet the ecological civilization concept also foregrounds China’s unique ability to solve this dichotomy by emphasizing China’s thousands of years of cultural heritage as well as its contemporary developmental prowess. Ecological civilization was in fact tailor-made by contemporary Chinese officials and scholars by selectively drawing on traditional Chinese texts to argue that historically, Chinese development was uniquely ecologically sound, in contrast to the Western model of development (Schmitt 2016). This parallels the widely held belief that only the Chinese Communist Party’s developmental model could have lifted hundreds of millions of people out of poverty after 1949. The notion is thus: With the Communist Party at the helm, China will show the world how to build an ecological civilization in which economic growth can continue while environmental challenges are easily overcome with technical and market solutions.

To understand China’s vision of ecological civilization, one must investigate how government leaders enact and operationalize ecological civilization: through policy. For my dissertation, I use interdisciplinary methods to analyze two of China’s flagship

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[1] Translation by Xinhua

[2] The terms ETS (emissions trading system) and carbon market are often used interchangeably. Since ETS

ecological civilization policies, ones that are frequently linked in their political discourse to ecological civilization because of their purported ability to grow the market economy and address environmental pollution at the same time. These two policies are the national carbon market and the Belt and Road Initiative (BRI). While the national carbon market exemplifies China's changing approach to domestic environmental policy, the Belt and Road Initiative is carrying the Chinese model of ecological civilization overseas.

Why focus on these two policies? Besides being closely watched on the global stage, these policies have been pushed into the limelight by bureaucratic restructuring at the national level in China. The Ministry of Ecology and Environment (MEE) assumed the responsibilities of many other departments when formed in 2018, including the management of China's carbon market, which was previously under the purview of the National Development and Reform Commission (NDRC). Around the same time, the Chinese government also formed the International Development Cooperation Agency (CIDCA) to consolidate China's overseas development and aid activities for the first time. In parallel, Chinese universities and research organizations have created new institutes, centers, and work streams to inform and analyze these policies.

The first part of this dissertation focuses on China's national carbon market. China's national carbon market has not launched according to its original timeline. Yet China's national policymakers continue to dedicate resources to the policy, and it enjoys support from high-level leaders, despite clear conceptual and operational challenges. Part One of the dissertation aims to shed light on why this is happening. First, I assess the ecological civilization premise that economic growth and environmental protection can proceed together – a key motivation for China's carbon market. I use a computable general equilibrium (CGE) modeling framework to examine policy interactions between China's national carbon market and the changing structure of China's economy. Next, I investigate the carbon market from a qualitative perspective, assessing how efforts to standardize emissions accounting and build capacity are a productive foundation for policymaking.

The second part of this dissertation focuses on the Belt and Road Initiative, a policy that increasingly faces international scrutiny for its potential environmental impacts. In a novel empirical study, I test the assumption, prevalent in media and advocacy discourse, that BRI projects are uniquely bad for the environment. Using plant-level data on coal-fired power plants in Asia, I find that plants owned, managed, or built by Chinese companies tend to have lower emissions rates and higher energy efficiency than those associated with companies from other countries. I then contextualize and extend those results by identifying potential mechanisms through which China's overseas projects might have different environmental impact than other projects.

Both parts of this dissertation are informed by broad research questions about the economic and environmental impacts of Chinese policies, and how these impacts are related to the policymaking process. I combine computable general equilibrium modeling, field-based interviews and participant observation, and empirical economic analysis to assess these policies from interdisciplinary perspectives.

PART ONE: THE NATIONAL CARBON MARKET

CHAPTER 2: ANATOMY OF A CARBON MARKET

WHAT IS A CARBON MARKET?

This chapter provides necessary context and background information for the subsequent two chapters on the carbon market in China. By doing so, it will lay out my theoretical frameworks for analysis of China's carbon market. I begin with an overview of how carbon markets work from the perspective of economic theory.

The rationale for implementing carbon pricing policies arises from the idea of externalities. An externality is an action that affects parties that have not participated in that action. Negative externalities refer to harmful impacts from transactions that aren't included in the value of the transaction, such as pollution or traffic congestion. Positive externalities include research and development, which has positive benefits to society beyond the direct value of the R&D itself. In economic theory, inefficiency arises when externalities that could be removed from an additional transaction are not removed. Carbon pricing is meant to internalize the cost of the externalities of emitting carbon dioxide, namely the economic damages associated with climate change.

There are two ways to price carbon: setting its quantity or price. Perhaps the most well-known form of carbon pricing is a carbon tax, which sets the carbon price. The other major form is known as an emissions trading system (ETS)[2], also called cap-and-trade or carbon market (though any pollutant can be regulated). This form sets a cap on the quantity of carbon dioxide (CO_2) emissions that can be emitted by regulated entities in a given jurisdiction.

In economic theory, the carbon market is meant to incentivize polluters to reduce CO_2 emissions by requiring them to purchase emissions 'allowances' that represent the amount of carbon dioxide they emit. Allowances, also known as permits, give a firm the right to emit a certain amount of emissions. With a specified cap on the total amount of emissions the regulated firms can emit, the formation of a market to buy and sell these allowances is meant to allow polluters to achieve the specified reduction at least cost.

The first operational emissions trading system was the U.S. Acid Raid Program, a sulfur dioxide emissions trading system that went into effect in the United States in 1995. In 1997, the Kyoto Protocol took steps towards establishing international mechanisms for carbon trading. The largest carbon market to date is the European Union Emissions Trading Scheme (EU ETS), first started in 2005. Since then, carbon markets have been adopted to various extents in a few other countries and subnational regions, including Kazakhstan, South Korea, the northeastern United States, California, Quebec, Australia, and New Zealand (IETA 2019). China, though, has captured international attention with the promise of the world's largest carbon market. If fully implemented according to the design proposed in its early plans, China's carbon market could cover 50% of China's

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[2] The terms ETS (emissions trading system) and carbon market are often used interchangeably. Since ETS can refer to the trading of any kind of emissions, I use the term "carbon market" in this paper to refer to specifically carbon dioxide emissions, as well as to call attention to the conceptual importance of "market" in this policy process.

energy-related CO_2 emissions, or nearly 15% of the world total.

PARTIAL REFORM

China exceeds all other countries in annual energy use and greenhouse gas emissions (Sandalow 2018). The carbon intensity of China's economy (i.e. the carbon dioxide emissions per unit of GDP) is also quite high due to the use of abundant and low-cost domestic coal resources, although major energy efficiency policies have reduced the carbon intensity of the economy significantly in the past decade. From the 11th Five-Year Plan (2006-2010) onward, binding energy efficiency and emissions intensity targets have been put forth in China's Five-Year Plans. China has also made voluntary energy and emissions commitments in other high-level policy venues, such as the United Nations climate negotiations, where this targets were formalized in their Intended Nationally Determined Contributions (INDCs).

In the 1980s and 1990s, energy and environmental regulation in China took the form of command-and-control policies, such as pollution fines and forced shutdowns of polluting facilities. Since then, environmental regulators in China have become more receptive to market-based approaches for several reasons. First, command-and-control regulation is often costly, both in an economic and political sense – shutting down facilities can harm the local economy and antagonize industry and workers. Second, as market-oriented reform has proceeded since the start of the Reform and Opening Up (改革开放) era in the late 1970s, market-based policies have enjoyed support across many sectors.

China's leaders want to see sustained economic growth alongside the reduction of emissions intensity. Economic growth is the foundation of the current government's political legitimacy, while climate change and environmental pollution are related to a complex set of domestic and international goals. Market-based environmental policy falls into a convenient middle ground between these two goals, promising economically efficient reduction of environmental harms that does not place undue burden on the economy. The ethos of market-based environmental policy meshes perfectly with the concept of ecological civilization.

The carbon market, therefore, is an emblematic ecological civilization policy. It is one of the most significant of China's suite of clean energy and climate policies over the past decade in terms of scope and political visibility. Architects of China's carbon markets have cited various motivations for the policy. The carbon market is framed as a policy instrument for achieving major national climate targets, such as reducing carbon intensity 60%-65% below 2005 levels by 2030, which is China's pledge for the Paris Agreement on climate change. At the same time, the carbon market significantly diverges from China's past command-and-control policies for energy and resource management due to its market-based approach (Duan and Zhou 2017). This effort represents a shift in regulatory strategy towards market-based mechanisms, which the Chinese government believes can achieve emissions reductions at lower cost and allow firms more flexibility in complying with regulations. In fact, the carbon market has been explicitly linked to the ecological civilization concept in its official development plan:

> “建立碳排放权交易市场，是利用市场机制控制温室气体排放的重大举措，也是深化生态文明体制改革的迫切需要，有利于降 低全社会减排成本，有利于推动经济向绿色低碳转型升级。为扎 实推进全国碳排放权交易市场（以下简称“碳市场”）建设工作， 确保2017年顺利启动全国碳排放交易体系，根据《中华人民共 和国国民经济和社会发展第十三个五年规划纲要》和《生态文明 体制改革总体方案》，制定本方案。”
>
> *“Building a carbon market is an important measure that uses the market mechanism to control greenhouse gas (GHG) emissions, as well as an urgent requirement for deepening reform of ecological civilization. It can help reduce society’s costs of emissions reduction, and promote the green and low-carbon economic transition and upgrading. To advance the development of a national emission trading scheme (ETS) and ensure its launch in 2017, this plan is formulated based on ‘The People’s Republic of China’s 13th Five-Year Plan for Economic and Social Development’ and ‘The Overall Plan on Ecological Civilization Reform.’ ”* (NDRC 2017)[3]

International scholars and media tend to highlight the international cooperative motivations of China’s carbon market, which has been lauded by Western institutions and frequently discussed in global forums such as the United Nations Framework Convention on Climate Change (UNFCCC) (Goron and Cassisa 2017). China’s carbon market has also been linked symbolically to narratives about China’s national development and security interests, the carbon market serving as “an integral part of the country’s climate change policy discourse that is shaped by international debates and wider geopolitical narratives” (Lo 2015).

However, China has a mixed record of success in using market-based solutions to address environmental problems. China’s sulfur dioxide emissions trading system, piloted in the 1990s, never became an institutionalized policy in the provinces that were supposed to adopt it (Tao and Mah 2009). It is important to note that although China’s economic reforms liberalized the structure of a number of industrial sectors, several key sectors the national carbon market proposes to regulate have either a dual-track system[4] or a partially reformed pricing structure.

In particular, the electric power sector – the first sector the national carbon market will regulate – poses challenges for the design and efficacy of the carbon market policy. China’s wholesale electricity markets, which are regionally managed, are not competitive in structure, meaning that the marginal cost of producing electricity does not determine the electricity price or the dispatch order for power generators. Thus, a carbon price imposed by the carbon market will not affect generator behavior by proportionally making more carbon-intensive generation more expensive, as is intended by the

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[3] Translation by the Energy Foundation – see reference link

[4] China established the dual-track system (双轨制) during the reform era. The dual-track system allows coexistence of a planned pricing system and a market pricing system at the firm or sector level, with a share of production being sold in each track (Naughton 1995).

theoretical policy design. In order to pass on the carbon price to electricity consumers, several of China's carbon market pilots require that large consumers of electricity must purchase and retire allowances for the electricity they consume, though this is not as effective as power sector reform (Munnings et al. 2016). While China's carbon market policymakers are working on a cost pass-through mechanism for applying a carbon price to power generators for the national carbon market, the extent to which China's electricity market hampers effectiveness of carbon pricing and whether efficient workarounds are possible remain unclear.

Even if an effective mechanism is developed, there is still ongoing emblematic tension between the non-market nature of the reforming power sector and the theoretical assumption of competitive market structure for an effective carbon market. This market vs. non-market tension, intractable in economic theory, has been explored in the literature as a harbinger of counterproductive and excessive state intervention in China's carbon market to compensate for the lack of a true market mechanism (Lo 2013) (Goron and Cassisa 2017).[5] In addition, this tension highlights the need for China's ongoing power sector reform to occur in tandem with the development of a carbon market, although the policy processes are effectively separate.

Yeh and Lewis describe the contradictory logic in the management of China's electric power sector, with policymakers claiming to want competition, foreign investment, and privatization, all while still setting prices, limiting foreign ownership, and keeping state-owned power generation companies in the hands of small political networks (Yeh and Lewis 2004). Despite attempts at textbook power sector reform, structural political and institutional forces in China have created this contradictory logic (Victor and Heller 2007). The hybrid form of many sectors of China's economy, stuck somewhere between market and non-market, is termed "partial reform equilibrium" by political scientist Victor Shih, and further attributed to the political incentives for policymakers whose careers stand to benefit more from an 'inefficient', state-controlled approach (Shih 2007). In addition to the scale of the policy and its link to ecological civilization, it is this context of so-called partial reform that drives my interest in and analysis of China's carbon market.

KEY INSTITUTIONS

Starting in 2011, China established seven provincial and municipal carbon market pilots around the country that varied in their design elements as a step towards a national system (Duan, Pang, and Zhang 2014). While some of the current carbon market pilots auction emissions allowances and generate revenue, many pilots and the current plan for the national carbon market are starting with free allowance allocation, with the goal of eventually shifting towards auctions. This has important implications for the generation of revenue from the carbon market, as discussed in Chapter 3. The carbon market pilots have faced challenges in enforcing compliance while maintaining a robust carbon price

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[5] It is important to note that few if any electricity markets operate perfectly competitively – a rich empirical literature explores ongoing problems with firms exercising market power and monopoly even in purported 'market' economies and sectors (see e.g. Kolstad and Wolak 2008, Fabra and Reguant 2013).

(Jotzo and Löschel 2014) (Zhang et al. 2014) (Munnings et al. 2016). While the national carbon market presents an opportunity to learn from the experience of the pilots and improve key design elements, compliance problems are unlikely to change fundamentally in the transition from the provincial to the federal level. According to current plans, the national carbon market will eventually cover eight industrial sectors representing over 50% of China's CO_2 emissions (Goulder et al. 2017). The national carbon market was officially launched at the end of 2017, with the first phase focusing on capacity building. Actual transactions are unlikely to occur until 2020 or 2021 earliest.

The National Development and Reform Commission (NDRC), the economic planning agency of the State Council of China, previously developed the design of the national carbon market, and was responsible for overseeing provincial and municipal carbon market pilots. In their seminal book on policymaking in China's energy sector, Lieberthal and Oksenberg argue that Chinese bureaucratic structure is a key determinant of political process and outcome (Lieberthal and Oksenberg 1988). China's carbon market can be seen as representative of this model – the ultimate form of the policy as an emissions trading system rather than a tax was supposedly the result of a power struggle between bureaucratic structures:

> *"The struggle over the form of emissions pricing was not simply a disagreement about the type of approach that would be most effective; it was also a contest for authority over climate policy. Given the defined institutional responsibilities, the NDRC would clearly have domain over an ETS. In contrast, authority over a carbon tax would reside with the Ministry of Finance. The NDRC prevailed in this contest."* (Goulder et al. 2017)

The NDRC further sought to consolidate its authority over the carbon market by restricting the use of carbon trading derivatives, which would have required some oversight by the Ministry of Finance, despite the theoretical importance of such products for the robustness of the carbon market.

Within the NDRC, the National Center for Climate Change Strategy and International Cooperation (NCSC) is primarily responsible for design of the carbon market, with support from other sub-departments like the Energy Research Institute. The NCSC convened working groups to discuss policy design, staffed primarily with academics, industry associations, government agency representatives, and some consultants. The academics involved are topical experts, mostly with training in engineering and/or economics, from prestigious Chinese institutions like Tsinghua University. Industry associations are organized by sector (e.g. the China Electricity Council for the power sector). A limited number of financial institutions are involved in the carbon market, such as local carbon exchanges that facilitate transactions for the carbon market pilots.

In early 2018, the Ministry of Environmental Protection was reorganized, renamed to the Ministry for Ecology and Environment (MEE), and given new responsibilities, including management of the carbon market.[6] This re-organization came at a critical moment for the national carbon market, just after its official launch but before actual carbon trading has started. At the time of this writing, the working group process had been suspended temporarily while the re-organization occurs. Some speculate that this shift in authority is meant to emphasize the carbon market as an environmental rather than solely economic policy.

These complex dynamics should challenge researchers of China's carbon markets to carefully consider what methods they use. In the next section, I lay out my multiple methodological approaches for analyzing China's carbon market.

ANALYZING CARBON MARKETS

In order to assess if China's carbon market can fulfill the ecological civilization premise of economic growth united with environmental protection, I began with a CGE analysis of economy-wide policy interactions between the carbon market and broad economic policy (see Chapter 3). Computable general equilibrium (CGE) models are a class of economic models that have a rich history of use as policymaking tools. CGE models combine social accounting matrices of economic data in a given region and time period with microeconomic theory to solve numerically for supply, demand, and prices for the interconnected markets in that economy. The computational foundations of CGE models owe much to Wassily Leontief's work on input-output accounting, the precursor to social accounting matrices. Leontief saw his input-output models as a critical planning tool for growing economies. He defined planning as "the organized application of systematic reasoning to the solution of specific practical problems" (Leontief 1986). Leif Johansen, who built upon Leontief's input-output models by adding the ability to simulate behavior of individual agents, also saw his models as a large-scale planning tool for country-level decision-making. Johansen's approach to CGE models allowed rapid development of more advanced functional forms given the relatively intuitive structure of his log-linear equations (Dixon et al. 2010). Separate advances in CGE modeling at the World Bank led to a 'school' of CGE models that used advances in computation to model a general equilibrium economy as a nonlinear system of equations, allowing precise policy analysis that represented a shift away from their early use as broad planning tools (Taylor 2016).

CGE models are often criticized as 'black boxes' because their complex structure can easily obscure major assumptions, yet they are commonly used by development banks, applied research groups, and government agencies for policy analysis (Wing 2004). Various schools of CGE thought have proliferated, but the sheer scale of CGE modeling research warrants further investigation into their role in the policymaking process. What is a model? John Harte describes a model as a narrow version of a scientific theory, which is a broader system of knowledge (Harte 2011). Computational models can be thought of as simplifications of phenomena or theory into mathematical applications. Modeling an economic system necessarily sacrifices some information to clarify and condense ideas, much like a metaphor for a complex concept (Krugman 1997). For

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[6] Throughout Part 1, I have written agency names as they were depending on what point in time a given anecdote occurred.

academic economists, the pendulum has clearly swung towards empirical economics and reduced-form models in recent years (Angrist and Pischke 2010), but in the policymaking world, structural models like CGE are still prominent, in spite of (or perhaps because of) being black boxes to most policymakers. Neither method is complete as a policymaking tool. As such, the developers and users of models must be as up front as possible about how results are entirely conditional on the model chosen (Dawkins et al. 2001).

Researchers who study models in policymaking range from cautious embrace of the usefulness of models, if used with some guidelines, to highly critical approaches that question the very premise of a model. Efforts to improve models through calibration, validation, sensitivity analysis, and other considerations of how to build, use, and communicate the results of models illustrate a faith in the ability of models to guide policy. At the other end of the spectrum, science historians like Naomi Oreskes argue that it is logically impossibly to verify or validate a model, and models are best used to narrowly advance critiques and hypotheses rather than to represent truth (Oreskes et al. 1994). Other authors see models more broadly as objects of knowledge within a knowledge infrastructure, just one of many tools to build a social understanding of a topic such as climate science (Edwards 2010). The trend towards quantification and modeling in policymaking today can be seen as a social process, in which politicians and professionals turn to models to build validity and mechanical objectivity in the face of sociopolitical pressure for accountability (Porter 1996).

This context about CGE models and models in policymaking more broadly is important for situating and critiquing my own modeling work, which uses a CGE model to analyze China’s carbon market. Indeed, a CGE approach is useful for examining policy interactions in a consistent framework, as shown in Chapter 3. During a research exchange in China in 2017, however, early efforts to validate my CGE analysis quickly revealed where the model departed from reality in the policy context of China’s carbon market. In particular, it quickly became clear that many types of models, including CGE models, would require extra work to reflect the actual context of China’s markets (i.e. finding a way to simulate cost pass-through mechanisms for a non-competitive power market), or else risk misconstruing results. This led me to turn to qualitative methods to examine the broader conception and use of scientific models in policymaking in China, which in turn led to even larger questions about the nature of policy decision-making for China’s carbon market (Chapter 4). Thus, the selection of these methods and frameworks is highly sequential, with Chapter 3 following a CGE framework to examine scenarios for economic growth and decarbonization, and Chapter 4 stepping outside of economics and using interviews and participant observation to understand how the ecological civilization policy of the carbon market is made.

CHAPTER 3: MODELING CARBON MARKETS AND STRUCTURAL ECONOMIC CHANGE[7]

INTRODUCTION

China's economy has dramatically transformed since the initiation of economic reforms in 1978. By 2015, China had lifted more than 800 million people out of poverty and achieved all the Millennium Development Goals. By many metrics, however, China remains a developing country. GDP per capita is still 25% that of the United States (World Bank 2016). Sustained economic reform still underpins China's efforts to transition from middle-income to high-income status. In recognition of this, central government strategy in China has focused on promoting structural economic transition as one of the most important national economic policies, one that is supported by ideological frameworks like ecological civilization. Structural economic transition emphasizes two fundamental policy adjustments: 1) increasing the contribution of domestic consumption to GDP relative to investment and exports; and 2) shifting the supply side of the economy from heavy industries to services (Qi et al. 2014). Both objectives are closely linked, and in this chapter I explore the relationship between post-industrial economic transition and the national carbon market in China. The link between economy and environment is recognized at the highest levels in China, and is embodied in the concept of ecological civilization. This chapter quantitatively analyzes China's national carbon market and its interaction with economic transition in China. In order to examine the interactive effects of the carbon market and structural economic transition, we examine the economy-wide effects of each policy separately and in a combined scenario.

We begin by characterizing the structure of China's economy in comparison with post-industrial, high-income economies. China's GDP composition is still far different from that of high-income countries. The relative contribution of consumption to China's GDP is only half the OECD average (Figure 1), and investment is much more dominant. Two main reasons for China's low consumption-to-GDP ratio are relatively low labor value added, which limits household income and consumption, and relatively high household savings rates, which also inhibit consumption but stimulate investment. Chinese household saving rates are among the highest in the world, a phenomenon which both limits consumer spending and fuels over-investment. Empirical evidence suggests that Chinese households devote a large portion of their income to savings as a way to self-insure against uncertainty in quality and reliability of China's social services, such as education, health care, and pensions (Cristadoro and Marconi 2012).

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[7] A version of this chapter was previously published in the journal *Applied Energy* with co-authors Sam Evans, Jiang Lin, and David Roland-Holst (see Springer et al. 2019). I acknowledge these co-authors' contributions and thank them for permitting me to reproduce and adapt this material as part of my dissertation.

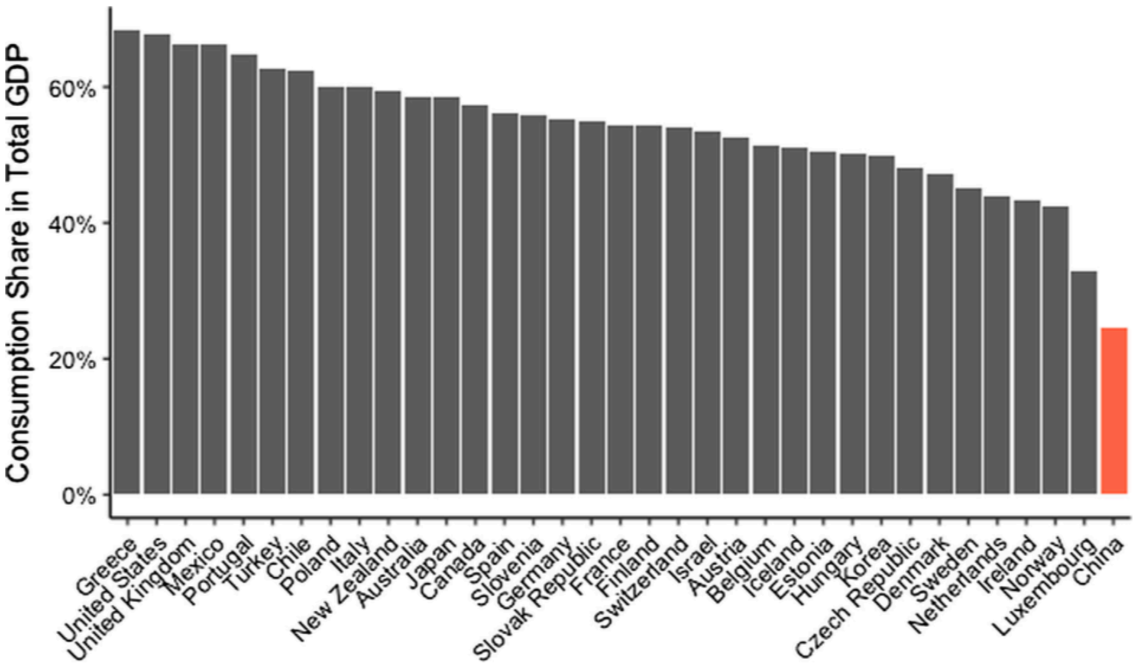

Figure 1: **Share of Consumption in GDP of OECD Countries and China, 2012**
We compared the consumption share in GDP in the year 2012, the baseline year for our model. We used data on GDP shares in China from our model dataset and compared it with data from the OECD.Stat database.

Of the money that people in China spend rather than save, less of it goes to the service sector than in OECD countries. As consumers grow wealthier, they tend to shift marginal expenditure toward services and higher value-added goods. Figure 2 illustrates value-added from services as a percentage of GDP for the OECD countries (in gray) and China (in red). While spending on services has increased in the past few decades, China has not yet reached OECD expenditure shares for services. Service sector expansion will be the key to China's economic transition, as economic structure moves away from heavy industry and export-oriented manufacturing. In contrast to low-wage, low-skill manufacturing jobs, service industries encourage a diverse, productivity-based and compensated workforce that recycles higher income across the economy. In contrast, traditional investment is less skill- and job-intensive, with most value added going to capital rather than labor, which further restricts consumer spending.

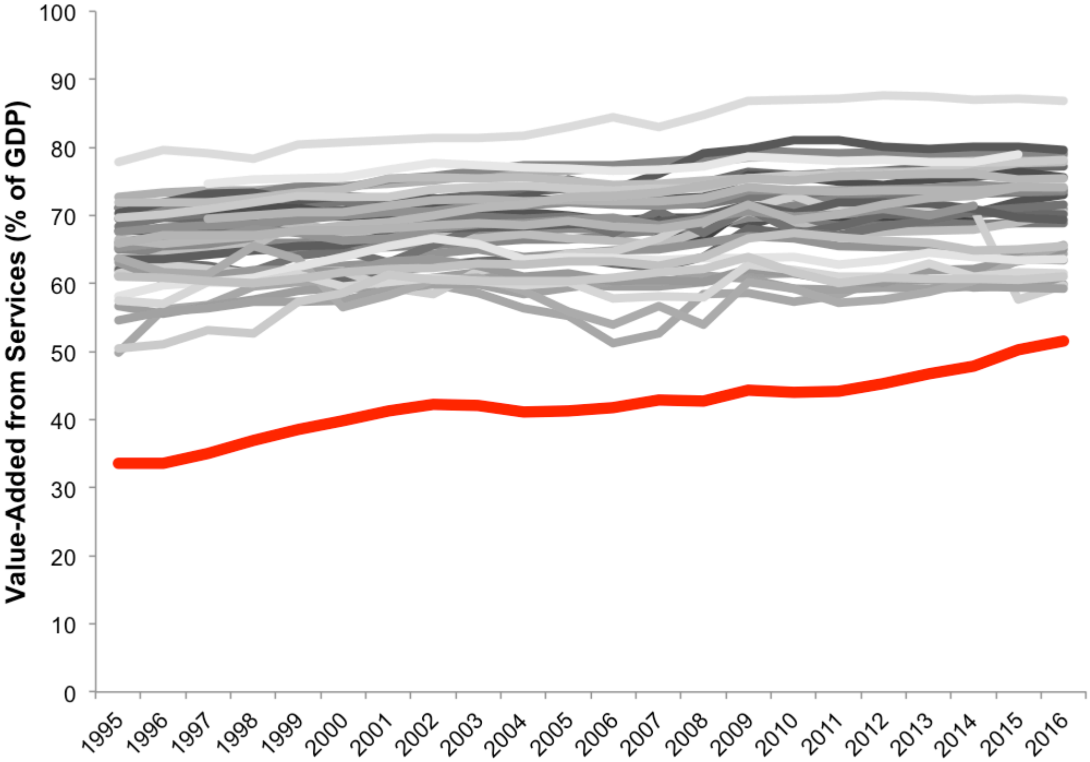

Figure 2: Share of Value-Added from Services in GDP, OECD Countries (gray) and China (red)

In this introduction, we have shown how the structure of China's economy in terms of consumption, labor compensation, and value-added from services is not yet on par with post-industrial, high-income countries. We also introduce an important instrument – the household savings rate – for stimulating transition. The rest of the chapter is organized as follows. The literature review establishes the link between economic structure, economy-wide energy use, and CO_2 emissions, and reviews the relevant CGE-based literature. The methods section introduces our CGE model and modeling framework, and presents the scenarios in our model. Finally, we present our results and discuss them in the context of limitations, future work, and expansions towards a more critical lens.

LITERATURE REVIEW

Although China exceeds all other countries in annual energy use and greenhouse gas emissions, many of China's international pledges on climate and energy are expressed as intensity targets rather than absolute targets. For example, under the Paris Agreement, China pledged to lower the carbon intensity of GDP by 60-65% from 2005 levels. These intensity-based targets allow for economic growth more easily than absolute targets, as long as changing technology and economic the lower emissions intensity of the economy. Indeed, China's economic transition towards the service sector will lead to a lower energy intensity economy-wide, since the service sector is generally less energy-intensive than heavy industry (Figure 3). China's economic policies for structural transition will thus have a huge bearing on China's energy systems and environment.

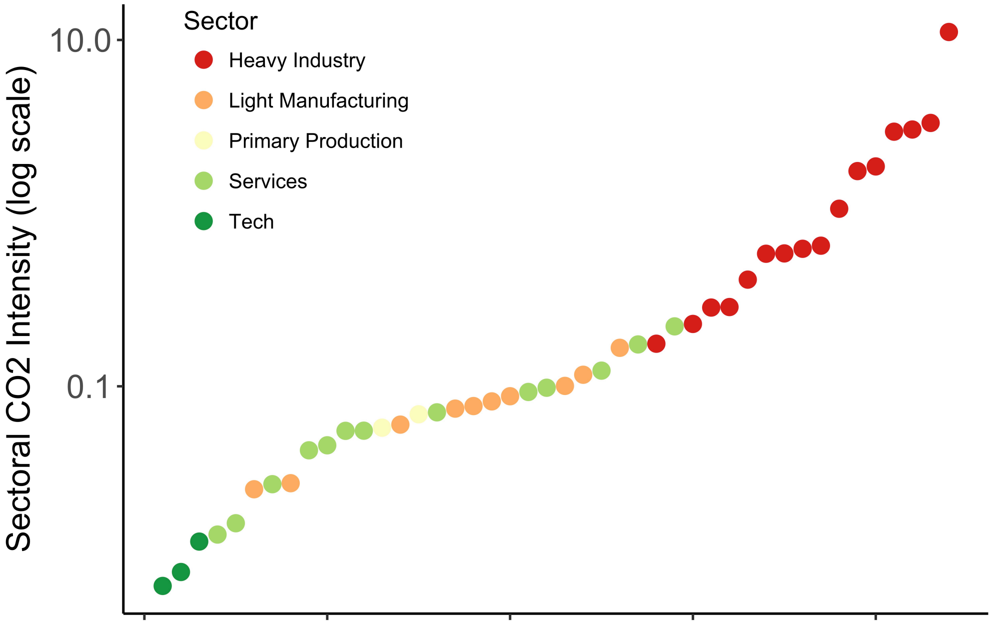

Figure 3: CO_2 Intensity (tons CO_2/10,000 yuan) of Production in China, 2012
We used the social accounting matrix from our model and data from the China National Bureau of Statistics to rank each of our model's 42 sectors by their CO_2 intensity.

A changing industrial structure in China can theoretically reduce CO_2 emissions while maintaining strong economic growth (Mi et al. 2015). In doing so, the trajectory of CO_2 emissions over time in China would follow the environmental Kuznets curve, which hypothesizes that environmental quality (by a variety of metrics) rises and then falls as income increases in a given area. Empirical evidence for the environmental Kuznets curve has not been found for all types of environmental ills. For example, while there is some evidence that sulfur dioxide emissions have followed the Kuznets curve, access to water for household sanitation has monotonically improved as income increases (Ho and Wang 2014). CO_2 emissions have for the most part increased within countries as they grow richer, especially when considering consumption-based emissions rather than production-based emissions, which obscure the emissions associated with imported products (Moran et al. 2018). Some researchers hypothesize that local pollutants like sulfur dioxide are more likely to follow a Kuznets curve while global pollutants like carbon dioxide may not (Stern 2004). There is still discussion and debate about the trajectory of CO_2 emissions and whether or not they will reach an apex and then decline. Recently, China has clearly expressed targets and policy goals that would make China's CO_2 emissions follow a Kuznets curve in terms of absolute emissions and not just intensity, such as the goal of peaking their CO_2 emissions by 2030. Thus, in this chapter, we evaluate the premise of simultaneous economic growth and decarbonization promised by the Kuznets curve and China's ecological civilization ethos.

As discussed in Chapter 2, one of China's main policies to promote an efficient and lower-emissions energy system is the national carbon market, which will likely begin trading in 2020 or 2021, and will follow nearly a decade of experience with pilot carbon markets in seven Chinese municipalities and provinces. Many studies have analyzed the predicted effects of China's national carbon market on macroeconomic and environmental indicators such as GDP, sectoral emissions, abatement costs, and income (see review by Jiang et al. 2016). There is a robust literature that uses computable general equilibrium (CGE) models of the Chinese economy to simulate the effects of a national carbon market (Fan et al. 2016) (Tang et al. 2016) (Li and Jia 2016). The CGE framework allows for convenient simulation of policy shocks relative to a baseline over time. CGE models can also capture complex dynamics, like income and expenditure effects, which are important factors in analyzing China's economic and environmental policies (Qi et al. 2016). In addition, CGE models can be used to assess options for some aspects of the design of a carbon market. For example, prior CGE analyses of the national carbon market in China have found that expanding geographical and sectoral coverage of a national system can reduce abatement costs (Cui et al. 2014) (Mu et al. 2017) (Qian et al. 2018). CGE models have also been used to assess the interaction of China's carbon market and different electricity pricing regimes, finding that revenue recycling can offset the efficiency losses from a regulated electricity market (Li et al. 2014).

A few papers have used CGE models to analyze structural economic transition in China. Researchers at the World Bank, in collaboration with China's Development Research Center, used a 2004 dynamic CGE model of China to analyze the idea of 'rebalancing growth' in the Chinese economy in terms of overall economic and industrial structure (He and Kuijs 2007). They simulate several scenarios (Table 1) for policy reforms, finding China can continue to grow in the long term by shifting towards services and through efficiency gains. These scenarios are used to illustrate the possibility of maintaining growth while rebalancing the economy in China. They also find that across scenarios, investment will still represent a relatively high share of GDP compared to other advanced economies.

Several CGE modeling efforts have specifically focused on the link between economic transition and energy use and emissions. Feng (2016) uses an adaptation of the MONASH model for China using 2012 data to assess the relationship between rebalancing and emissions, finding that rebalancing would reduce emissions 17% by 2030 through general equilibrium effects of reducing emissions intensity and increasing the price of industrial products. Qi et al. (2014) use a global CGE model to examine the effects of economic rebalancing on emissions associated with Chinese exports, finding that economic transition policies may reduce emissions domestically by shifting them overseas (see Chapter 5 on leakage). In order to make transparent the assumptions used to simulate structural economic transition, Table 1 describes how these papers implemented structural transition policies in a CGE framework.

Table 1: Review of CGE Implementation of Structural Transition Policies

Paper	Scenario	Implementation

He and Kuijs 2007	“Rebalancing”	• Shift government spending from investment to health, education, and social services • Reduce marginal propensity to save • Increase TFP for all sectors, and more for service sectors • Increase government revenue from health and education spending • Appreciate RMB • Impose energy tax • Remove subsidy of capital for manufacturing • Increase labor migration from agriculture • Increase rate of land transfer from agricultural to non-agricultural use
He and Kuijs 2007	“Ambitious Rebalancing”	• All of the above from “Rebalancing” • Increase depreciation rate of capital stock • Raise corporate income tax and distribute revenue to poor rural households
Feng 2016	“Policy Rebalancing”	• Increase consumption and investment shares in GDP • Shift agriculture, industry, and service sector shares in total value-added • Endogenize TFP, average propensity to consume, capital rate of return, and sectoral input-demand shifters so that the above variables can be exogenized
Qi et al. 2014	“Rebalance”	• Impose sectoral GDP contributions based on 12th FYP goals by applying endogenous output taxes/subsidies by sector
Qi et al. 2014	“Demand”	• The above from “Rebalance” • Decrease China’s trade surplus by exogenously decreasing capital account deficit in China and increasing it in other regions

Qi et al. 2014	"Export Tax"	• Double export taxes for energy-intensive sectors

METHODS

MODELING FRAMEWORK

To generate predictions about the carbon market policy and its interaction with structural transition, we use the People's Republic of China Aggregated National Development and Assessment (PANDA) model, a dynamic recursive CGE model of China.[8] The current version of PANDA is calibrated to 2012 national accounts, and can make yearly projections to 2050 based on assumptions of population growth, factor productivity, and capital formation. The model treats China as a single region that trades with a single rest-of-world trading partner. Production is comprised of 42 different sectors, with 8 different electric power generation technologies (coal, natural gas, oil, nuclear, hydropower, wind, solar, and biomass). The 42 production sectors are described below in Table 2, using the meta-categories from Figure 3. PANDA is based on a balanced social accounting matrix (SAM), which represents the inputs and outputs of each sector and the flows between economic agents. We use China's 2012 input-output table from the National Bureau of Statistics as the basis for our SAM (NBS 2012). Trade data is from version 8 of the Global Trade Analysis Project (GTAP) database. Households are disaggregated into 12 types by income level and region (rural or urban), while labor is disaggregated into two types, skilled and unskilled.

Table 2: PANDA Sectors

Category	Sector
Heavy Industry	Chemicals
	Coal Mining Products
	Gas Production and Supply
	Electric Power (8 subcategories)
	Metal Mining Products
	Metal Products
	Metal Smelting and Refining
	Nonmetal Mining
	Nonmetal Products
	Oil and Gas Production
	Other Manufacturing
	Paper Production
	Refineries
	Transportation Services

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[8] The PANDA model was developed in 2006 by David Roland-Holst (see Roland-Holst 2006) and has been modified and updated with a variety of collaborators since then.

Light Manufacturing	Apparel Construction Electrical Equipment General Equipment Machine Repair Specialized Equipment Textiles Transportation Equipment Waste and Scrap Wood Products and Furniture
Primary Production	Agriculture, Forestry, Farming, and Fishery Products Food and Tobacco
Services	Business Services Education Environmental Services Finance Healthcare Hotels and Restaurants Public Administration Real Estate Recreation and Entertainment Research and Technical Residential Services and Repairs Water Distribution Wholesale and Retail
Tech	Information and Communication Technology Equipment Information and Communication Technology Services Instruments and Meters

The following paragraphs describe the basic structure of the PANDA general equilibrium model. In the production block, the constant elasticity of substitution (CES) function, the most common non-linear function for CGE models, is used to represent the different substitutions across different inputs in each sector. The production structure is shown in Figure 4. The non-energy intermediate demand bundle is combined with a capital-energy-labor bundle to generate the final output. The split of non-energy intermediate demand into intermediate demand follows the fixed proportion input-output relationship (Leontief function). This assumption can be considered as a special form of the CES function wherein the substitution elasticity is 0. The capital-energy-labor bundle is split between a capital-energy bundle and a labor demand bundle. In the third level, the labor demand bundle is split into labor demand by skill type while the capital-energy bundle is split into energy and capital. In the fourth level, the energy demands by fuel type are combined to generate energy output.

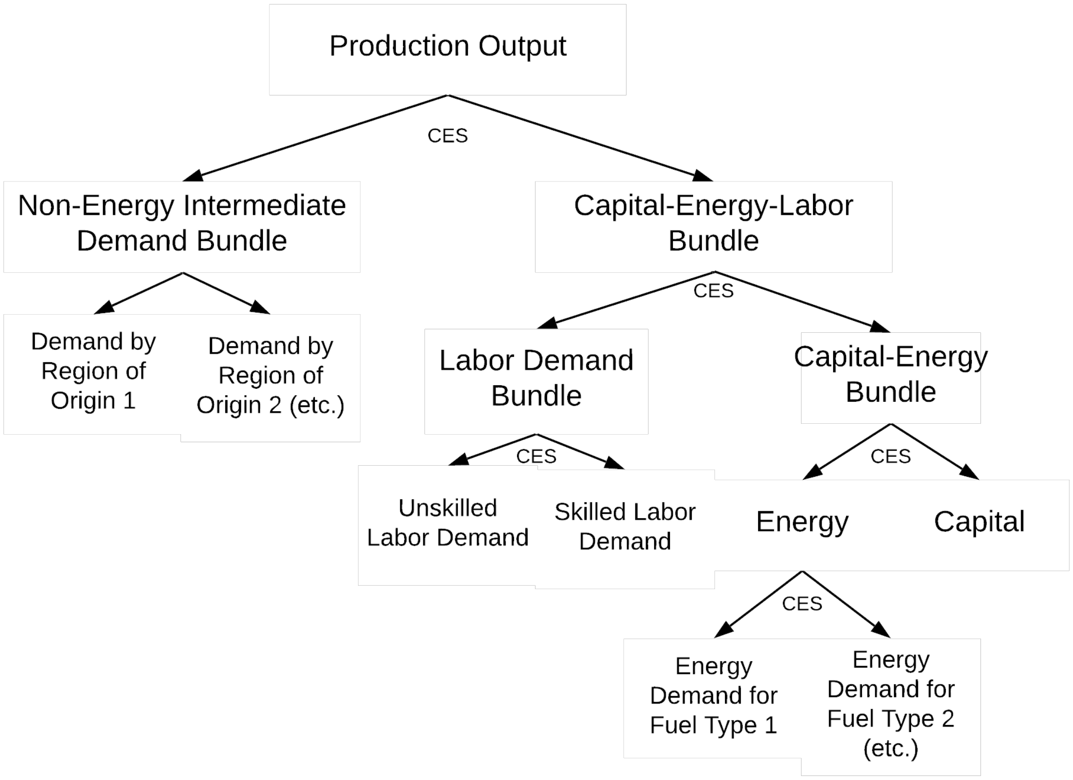

Figure 4: PANDA Production Block CES Nesting

In the consumption block, the PANDA model includes two representative consumers, households and government. Household income is from labor wages, investment income, and transfer payments, and their income is allocated to goods and savings by an exogenous rate that is calibrated to the social accounting matrix. Each representative household is assumed to maximize utility by consuming different goods and services as modeled by the Linear Expenditure System (LES) specification. The government receives revenues from a variety of tax instruments (income, indirect, trade, and factor taxes), net of subsidies and transfers. Government income is allocated to goods and services and the aggregate expenditures are fixed in real terms.

For international trade, the Armington assumption allows for differentiation between domestic products, imports, and exports. This differentiation is modeled as an aggregate, with one domestic Armington agent for each product category using CES and constant elasticity of transformation (CET) functions to represent the import and export sides, respectively.

Emissions in PANDA are modeled by sector (EF_i) as the input of different energy sources in each sector ($xap_{i,e}$) multiplied by the emissions factor of the energy source ($emit_e$). Since some industries use energy inputs as feedstock rather than as fuel (such as the chemical industry), we correct for this proportion of energy feedstock by subtracting the $feedstock_{i,e}$ parameter (Equation 1). The total CO_2 emissions of a country (EFT) equal the sum of emissions from the production sectors (Equation 2).

$$EF_i = \sum_e emit_e * xap_{e,i} * (1 - feedstock_{i,e}) \quad \text{(Eq. 1)}$$

$$EFT = \sum_i EF_i \quad \text{(Eq. 2)}$$

SCENARIOS

We model four scenarios: baseline (RF), a carbon market policy (ETS), structural transition (SR), and a carbon market and structural transition (ETS+SR). Our baseline is calibrated to data from the Reinventing Fire project (hence the abbreviation RF), and represents what is commonly known as the business-as-usual, or BAU scenario. The Reinventing Fire technology model was developed by China's Energy Research Institute, the Lawrence Berkeley National Laboratory's China Energy Group, and the Rocky Mountain Institute (ERI 2016). We use outputs from the Reinventing Fire technology model on projected annual autonomous energy efficiency improvement (AEEI), the projected composition of China's electric power portfolio, and primary energy use target shares for key heavy industries to calibrate our baseline forecast.

The carbon market in PANDA is simulated by making total emissions endogenous and subject to an exogenously imposed cap on emissions ($EFcap$) (Equation 3). The carbon price is expressed as an industry-specific tax ($ctax_{i,e}$) on carbon emissions by multiplying the cap-induced shadow carbon price in RMB/ton (μ) by the sector-specific emissions factor (Equation 4). The revenue from the emissions trading system ($ETSR$) comes from the emissions permits purchased by the production sector, simulated in Equation 5.

$$EFcap \leq EFT \quad \text{(Eq. 3)}$$

$$ctax_{i,e} = \mu * emit_{i,e} \quad \text{(Eq. 4)}$$

$$ETSR = \sum_i \sum_e ctax_{i,e} * xap_{e,i} \quad \text{(Eq. 5)}$$

The carbon tax is applied to production sectors ($xap_{e,i}$) by being inserted into PANDA's constant-elasticity-of-substitution production function equations. As currently set up in PANDA, allowances are assumed to be fully auctioned, and the revenue is collected by the government and recycled to households as a lump-sum transfer. China's national carbon market will first cover the power sector, and phase in at least seven other sectors over time; in our model, we apply the cap to all production sectors. The carbon market policy begins in 2020, matching the expected start date for the national carbon market in China. For the cap, we specify a 20% reduction in economy-wide emissions below baseline by 2030 and a 30% reduction by 2050, with the annual cap scaling linearly between these targets each year. We selected these targets based on rough calculation of the emissions that will be mitigated, in percentage reduction terms, from the current draft power sector benchmarking plan for the national carbon market, which we assumed could be scaled and applied to other sectors by 2030, and increased in stringency by 2050. We believe our implementation of the carbon market in the PANDA models represents a medium- to long-term vision of China's carbon market as an ambitious economy-wide instrument in competitive markets, and one that drives much of the mitigation over this period.

The structural transition in PANDA is simulated by linearly reducing the household savings rate each year. This is meant to address the common notion among macroeconomists that the overall household savings rate in China is relatively high, which dampens consumption and leads to overinvestment in capital, slowing the progression of the economy towards an OECD-like composition (see Introduction). We simulate structural transition via reduced savings rate alone (SR), and alongside the carbon market (ETS+SR). The ETS and structural transition scenarios are designed to simulate increased consumer spending in low carbon intensity sectors.

RESULTS

We find that it should be feasible for China to reconcile its aggregate growth and environmental goals, sustaining higher GDP per capita and lowering emissions, while shifting the structure of its economy. By 2040, we find that the structural transition scenarios (ETS+SR and SR) both have a GDP growth rate of 2.1% per year, which is slightly lower than the assumed baseline growth rate of 2.3% per year by 2040. The ETS scenario slightly increases GDP level due to the consumption-boosting effect of the recycled revenue from the carbon market (Figure 5). Thus, in the combined scenario, ETS+SR, the carbon market helps mitigate the dampening effects of structural transition on GDP growth. Naturally, these results rest on the validity of our assumptions related to carbon market policy design (namely, that revenue is generated through auctions) and the impact of allowance redistribution (lump-sum transfers). While China doesn't use an auction mechanism currently, policymakers have expressed the goal of moving in that direction, as well as using revenue recycling to achieve various policy aims.

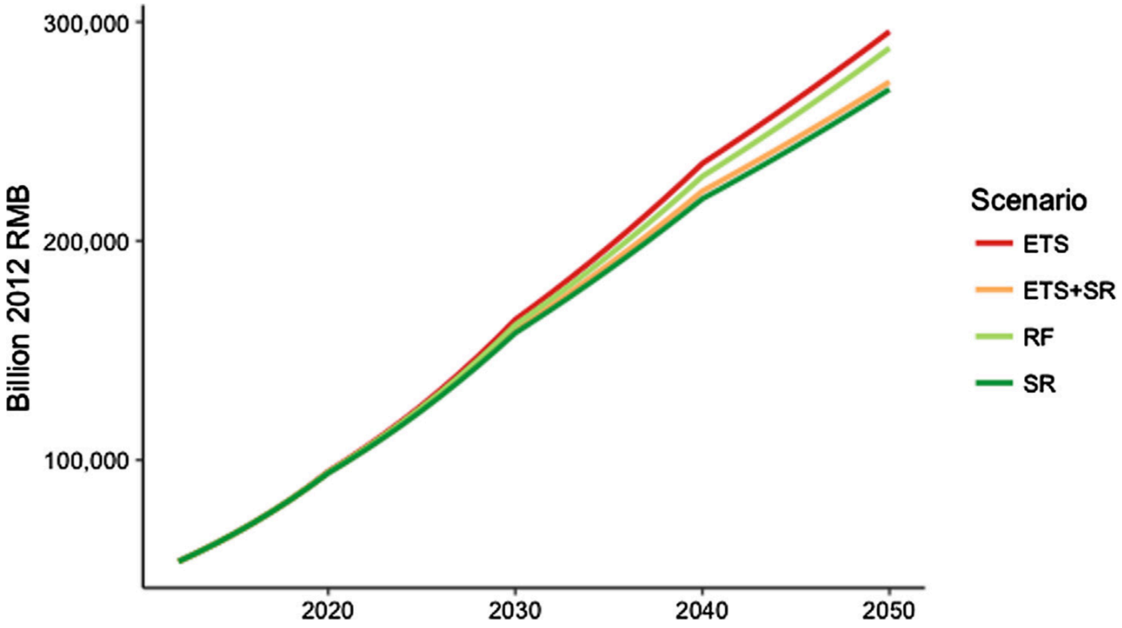

Figure 5: China's Real GDP at Market Prices by Scenario, 2012-2050

While the GDP trajectories for each scenario show only slight deviations by 2050, the composition of GDP drastically shifts by 2050 in the structural transition scenarios, demonstrating that the savings rate instrument is a highly effective lever for structural transition. Figure 6 shows that our implementation of structural transition in PANDA achieves OECD-like GDP composition shares by 2050, with consumption increasing as a share of GDP and investment decreasing.

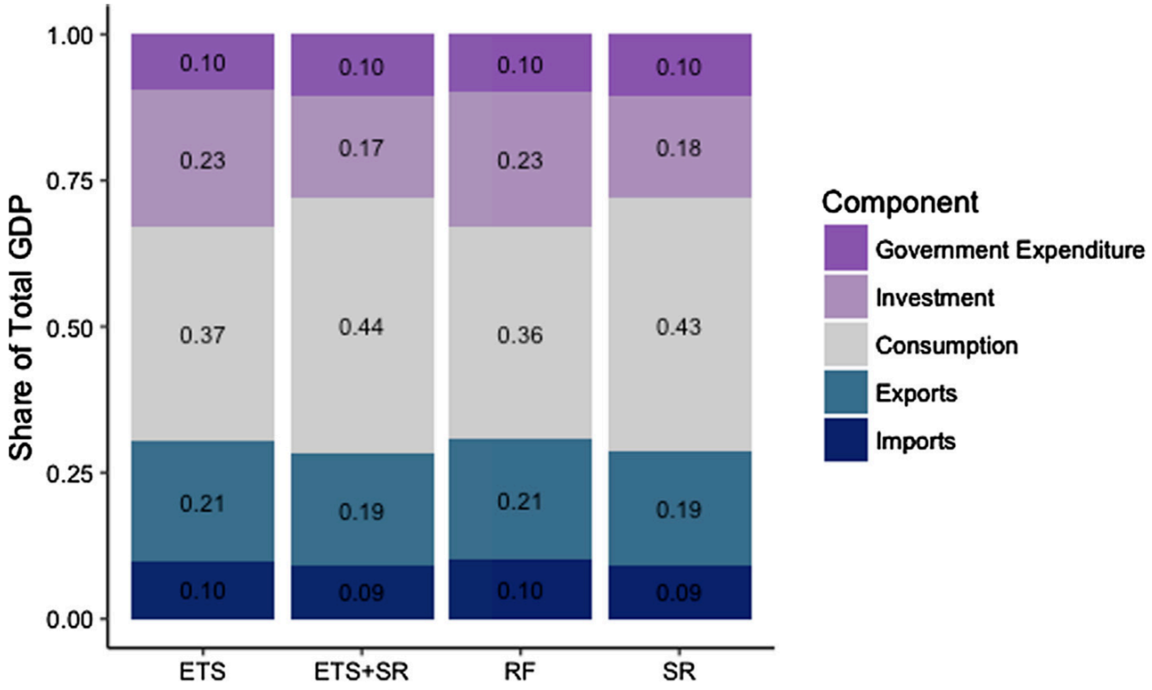

Figure 6: Components of GDP by PANDA Scenario in China, 2050

Increasing consumption drives growth in GDP in the structural transition scenarios. Without adjusting the savings rate, both the baseline and ETS-only policies show modest growth in each of the GDP components, while overall growth in the structural transition scenarios is driven by an increase in consumption that offsets a decrease in investment. The ETS+SR scenario has the greatest increase in consumption share, demonstrating the interacting effects of the policies, with the carbon market further stimulating consumption via revenue recycled to households. The percent change from the baseline scenario in 2050 is shown for each GDP component in Table 3 below.

Table 3: Effect of Policy Scenarios on GDP Components (% Change from Baseline) in 2050

GDP Component	ETS	ETS+SR	SR
Government Spending	+1.1%	-1.6%	-2.5%
Investment	+5.9%	-31.2%	-33.9%
Consumption	+3.6%	+13.8%	+10.9%
Exports	+2.1%	-13.2%	-14.5%
Imports	-0.4%	-17.4%	-17.4%
Total Real GDP	*+3.8%*	*-4.1%*	*-6.4%*

As laid out in the Introduction, structural economic transition refers to changes in both GDP composition and industrial structure. Our model demonstrates that a lowered household savings rate will shift GDP composition towards an OECD-like structure by 2050. At the same time, this transition will also move the industrial structure away from heavy industry and towards services (Table 4). Production in the service sector increases across all scenarios, with the greatest increase coming from the ETS+SR scenario. This shift towards services is driven by increased overall consumer spending combined with heavier regulation of more emissions-intensive sectors, sending consumers towards lower emissions-intensity sectors, namely services.

Table 4: Effect of Policy Scenarios on Sector Production (% Change from Baseline) in 2050

Sector	ETS	ETS+SR	SR
Primary Production	+1.5%	-16.3%	-17.2%
Heavy Industry	-5.7&	-20.8%	-18.4%
Light Manufacturing	+3.2%	-26.1%	-27.7%
Services	+1.9%	+7.6%	+6.1%
Tech	+2.1%	-9.3%	-10.7%

Our model baseline indicates that CO_2 emissions in China will peak in 2030, which is in line with China's climate targets. With a carbon market, we find that China's emissions peak earlier (in 2025) and at a lower level (Figure 7). The ETS and ETS+SR scenarios both reduce emissions the same amount, that is, the amount specified by the emissions cap. In other words, the emissions cap is the binding constraint even when structural transition is taken into account. The SR scenario alone reduces emissions by 16% relative to baseline due to the shifting structure of the economy away from heavy industry and towards services. This is more than half of the reductions achieved by the carbon market alone, a finding similar to results from Feng (2016).

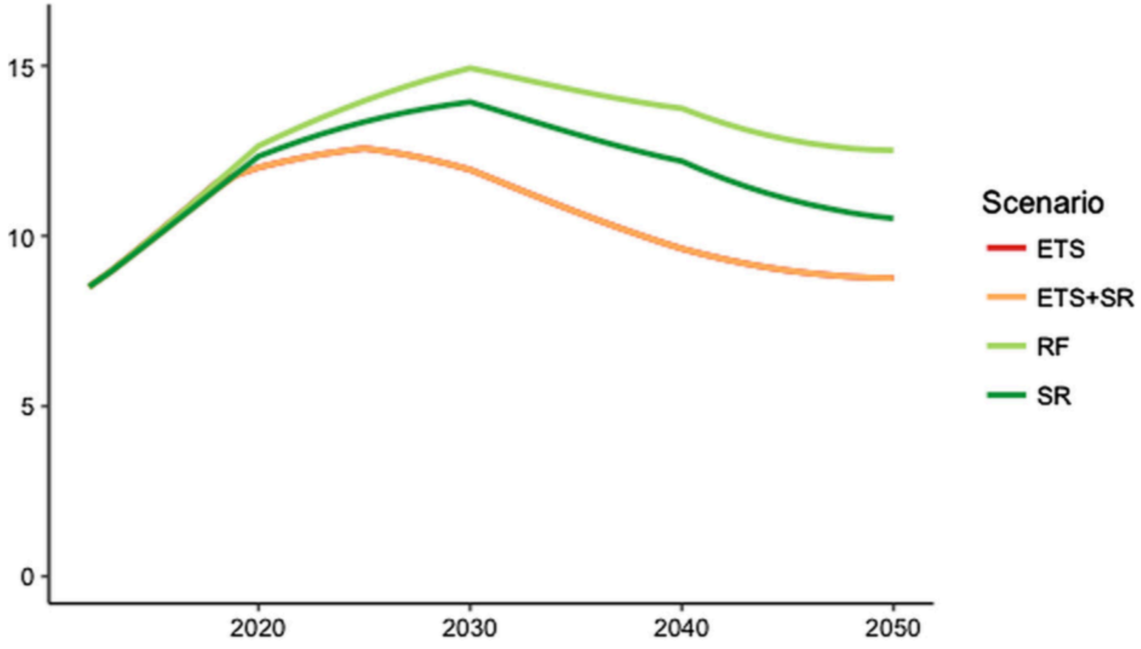

Figure 7: Annual CO_2 Emissions in China by Scenario (Gt CO_2), 2012-2050

It is important to note that the ETS emissions reductions are achieved at significantly different mitigation costs for regulated firms based on the scenario. Emissions reductions are achieved at a much lower carbon price when the structural transition scenario interacts with the ETS, compared to the ETS alone (Figure 8). As shown in Table 4, the structural transition scenario shifts the economy towards less emissions-intensive service sectors, leading to complementary emissions reductions.[9] In 2030, the ETS alone induces a carbon price of 96 RMB/ton, while the ETS+SR scenario has a carbon price of 64 RMB/ton the same year. In 2050, the ETS-only carbon price rises to 343 RMB/ton, while the ETS+SR carbon price is less than half this, at 165 RMB/ton. The ETS and SR policy scenarios are complementary and work toward consistent purposes.

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[9] For a discussion of potential emissions leakage, see Chapter 5 and the concluding chapter

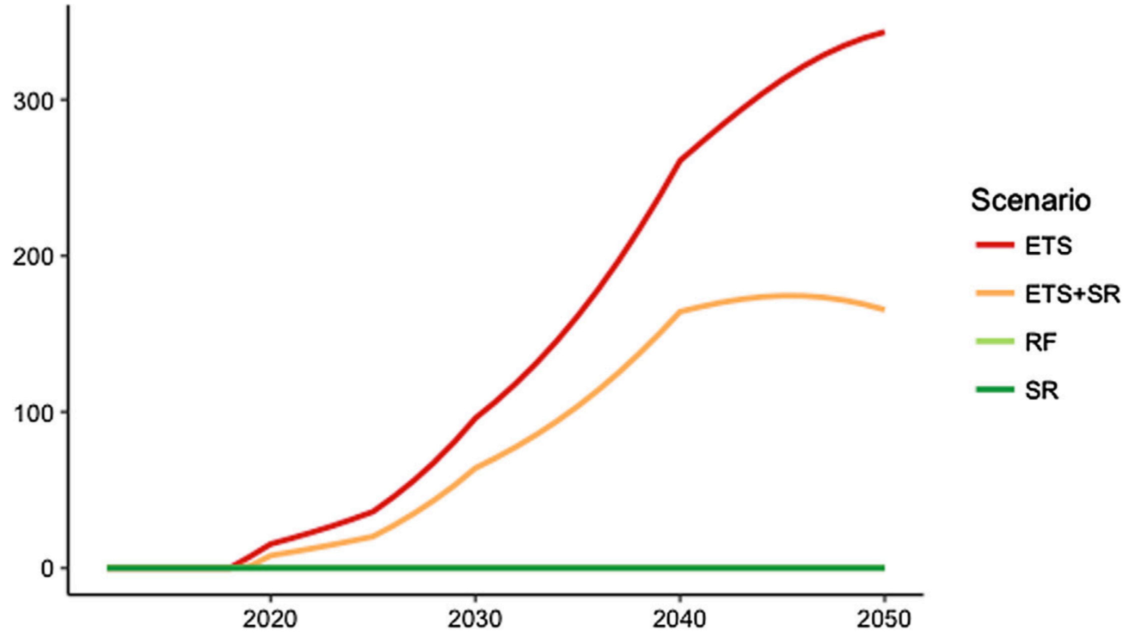


Figure 8: ETS Carbon Price by Scenario (RMB/ton CO_2), 2012-2050
Note: The RF and SR scenarios do not have a carbon pricing structure

DISCUSSION

LIMITATIONS AND FUTURE WORK

This study provides a CGE-based assessment of China's carbon market and its interaction with structural economic transition. Although we consider detailed economic structure and complex linkages between policy, emissions, and industrial structure, there remain important limitations that need to be addressed in future work. Firstly, in this study, the carbon market is centralized and simplified. Without auctions, the carbon market will not directly generate revenue. Our results assume that China’s national carbon market will eventually use an auction mechanism, which some of the pilots are currently experimenting with. The allowance allocation mechanism for the power sector at the national level is still under consideration at the time of the writing. Secondly, although we model an economy-wide carbon market, the national carbon market in China will first cover the power sector, and it is still uncertain when coverage will be expanded to other industries. As indicated by current plans, the national carbon market will eventually cover 8 sectors representing over 50% of China’s emissions. The estimated revenue from our model is proportional to the emissions covered by our assumed carbon market policy design. Thus, our results represent a maximum estimate for the amount of revenue that can be generated from a national carbon market in China that auctions allowances and has economy-wide coverage. In addition, it is important to note that China’s power sector is still highly regulated. Even though policy innovations can help integrate a carbon price into China’s power markets, there will be massive efficiency gains from restructuring the power markets alone, and a more competitive wholesale electricity market is critical to passing on the price signal of a carbon market (Lin et al. 2018) (Teng et al. 2017). Therefore, to make the study more consistent with the current carbon market situation, the carbon market can be calibrated more precisely to present conditions, as in Li et al. 2014 or Li et al. 2018, for example.

Finally, we use a single policy instrument – the household savings rate – to simulate economic transition. We assume a single savings rate across different household types, but future modeling exercises could allow for more detailed and accurate representation of household savings rates using econometric estimates from the literature. In addition, economic transition policies beyond the savings rate could be elaborated to more fully reflect China's long-term goals. This paper shows that carbon market and economic transition policies offer an extensive spectrum of opportunities to advance economic and social objectives, but precise and optimal characteristics of these policies need to be supported by further analysis.

CONCLUSIONS

China's national carbon market and structural economic transition policies will both significantly affect the energy and emissions intensity of China's economy. Prior literature has explored the interaction of complementary policies with a carbon market; however, the even larger link between emissions and basic economic structure has been underexplored. In this paper, we use a CGE framework to explicitly model the interactions between structural economic transition and a national carbon market. Our findings have implications for the design of the national carbon market. We find that when structural economic transition is taken into account, mitigation costs for firms from a national carbon market will be significantly lower. To maintain a robust carbon price, policymakers should consider this effect when determining carbon market design features.

From within a CGE framework, this research provides a quantitative proof of concept for ecological civilization policies – that economic growth can occur even as environmental ills are reduced. In the scenarios we model, long-term growth is maintained even as CO_2 emissions decrease. While the GDP growth rate is slightly lower in the structural transition scenarios, the composition of the economy dramatically shifts towards a more OECD-like structure, with low emission-intensity service sectors showing the most growth. This shift matches the increasing emphasis Chinese leaders are placing on quality rather than speed of growth. It is a demonstration of the theorized composition effect of GDP growth on the environment – a change in the structure of economic activity towards cleaner sectors. In addition, we find that a carbon market with revenue recycling to households helps to mitigate the GDP-dampening effects of structural transition by stimulating consumption. These results can be useful to other energy and economic modelers considering how to incorporate consideration of structural economic transition in their research, as well as to policymakers looking for guiding theory on how emissions policies will interact with a transitioning economy.

Former Chinese Premier Wen Jiabao said in 2013, "We should unswervingly take expanding domestic demand as our long-term strategy for economic development," and the current Chinese leadership clearly recognizes the need to stimulate consumption (Yao and Wang 2013). In this paper, we demonstrate that a lower household savings rate significantly stimulates consumption and drives economic transition, shifting the structure of China's economy in terms of consumption, labor compensation, and value-added from services to a structure that is more similar to post-industrial, high-income countries. The Chinese government should encourage a lower household savings rate in order to capture the economic and environmental benefits of structural transition. In addition to the high-level strategic commitment to increasing consumption, China must also invest in social policies that improve public education, healthcare, and pensions, which will encourage consumers to spend more by freeing them from the need to self-insure. However, social and environmental policies need not be considered separate. Our research indicates that policies that support structural economic transition will also reduce emissions and lower the cost of environmental regulations like a national carbon market.

TOWARDS A CRITICAL ANALYSIS

Our analysis sheds light on broad potential mechanisms of interaction between a carbon market and structural economic transition. However, this analysis also rests on deep methodological assumptions. CGE models and indeed the economic theory of carbon markets abstract the process of transforming material emissions into a commodity, assuming this process is perfect and frictionless. Most CGE modeling exercises assume a competitive power market structure, although this is not the case in China, as discussed in Chapter 2. Incremental improvements in modeling China's power market can be made, and policy innovations can occur to get around the cost pass-through issue. However, fundamental discrepancies between the economic theory of many models and the reality of China's power market structure remain.

In order to establish an emissions trading system, pollution must be transformed into a commodity - first envisioned as a measurable unit, then embedded within a legal and regulatory structure that allows universal exchange. Industry groups, academics, and other stakeholders advocate for standardized carbon markets around the world. One stated mission of the International Emissions Trading Association is to "establish effective market-based trading systems for greenhouse gas (GHG) emissions that are fair, open, efficient, accountable and *consistent across national boundaries*" (emphasis my own) (IETA 2018). This universal model of a carbon market is being promoted in many places. Many carbon market advocates believe that eventual linkage of carbon markets and a single carbon price would be the most economically efficient system. Although carbon markets are typically implemented at the national or subnational level, they are increasingly linked across jurisdictions. These linkages are not only direct, such as the linkage of the California and Quebec carbon markets, plus many other proposed linkages (Ranson and Stavins 2016), but there are also intangible linkages in terms of the network of institutions and people who trade expertise across carbon markets. The regulatory regime of carbon markets is a complex network of actors from academia, NGOs, the private sector, etc. who trade research, data, know-how, and mental/computational models of how to manage carbon markets. In addition, the physical aspects of carbon markets are increasingly globalized from the bottom up. Regulated entities (such as power plants) receive cross-border capital and technology, while the technologies for implementing carbon markets, such as monitoring software and tools, are also traded across borders. In this way, carbon markets are, to an extent, defined by infrastructural globalism – they are “projects for permanent, unified, world-scale institutional-technological complexes that generate globalist information” (Edwards 2010).

The establishment of a carbon market deliberately removes local context by treating carbon dioxide emissions reductions as a uniformly tradable good. Doing so “abstracts from where, how, when and by whom the [emissions] cuts are made, disembedding climate solutions from history and technology and re-embedding them in neoclassical economic theory, trade treaties, property law, risk management,” and other global thought paradigms (Lohmann 2009). According to environmental and economic theory, a ton of carbon dioxide has the same environmental impact no matter where it is emitted, which sets it apart from other emissions such as air pollutants. This theory represents what Michael Hulme calls “the view from everywhere”, a globalized knowledge that ‘erases geographical and cultural difference and in which scale collapses to the global’ (Hulme 2010). In the next chapter, I seek to understand how this transformation of carbon dioxide molecules into emissions allowances actually occurs, and how it is shaped by local context in China - a local context that is often overlooked in quantitative analyses of China’s carbon market.

CHAPTER 4: BECOMING A CARBON MARKET: DATA, EXPERTISE, AND CAPACITY BUILDING

INTRODUCTION

WAITING FOR THE MARKET

This chapter advances two main ideas. First, I argue that the national carbon market in China is a highly productive policy market even though it has yet to deliver its policy goals. Second, I argue that this productivity arises from attempts to standardize carbon management. Challenges in doing so have been previously portrayed as evidence of governance failure amidst irreconcilable state vs. market tension. In this section, I introduce the first idea – that the national carbon market is productive in its perceived state of delay and downsizing.

The proliferation of carbon markets around the world waxes and wanes with political tides. Some carbon markets have struggled to maintain high and stable carbon prices. Yet since the announcement of the policy in China, China's national policymakers have unswervingly supported and promoted the pilot and national carbon markets, even as conceptual and operational challenges have arisen. Despite these challenges, the carbon market is a productive locus of political and economic opportunity as a policy in the making.

China's national carbon market was originally supposed to begin in 2017, according to earlier high-profile and high-level statements, such as the U.S.-China Joint Presidential Statement on Climate Change between Obama and Xi in 2015: "China also plans to start in 2017 its national emission trading system, covering key industry sectors such as iron and steel, power generation, chemicals, building materials, paper-making, and nonferrous metals" (White House 2015). Several factors contribute to what many call a delay: lack of reliable emissions accounts (*Platts* 2018), excessive state intervention, and the NDRC-to-MEE transfer of responsibility. Although the national carbon market was officially launched at the end of 2017, no actual trading activity occurred at the national level as had been anticipated. The launch of the carbon market was instead divided into phases, with the first phase focusing on foundation building (基础建设期). Actual transactions are unlikely to occur until 2020 or 2021 earliest.

In addition to a shifting timeline for the onset of actual carbon trading at the national level, there has also been a narrowing of scope of the policy. The number of sectors that an emissions trading system covers plays a large role in the overall cost of mitigating the cost of those emissions, and is thus an important design element for the national carbon market (Mu et al. 2017). However, the proposed sectors to be covered by China's national carbon market have been successively reduced since the initial draft plan by the NDRC in January 2016. Earlier policy documents suggested that China's carbon market was going to cover 14 sectors. The January 2016 NDRC draft plan for the national carbon market proposed covering 8 sectors: electricity, chemicals, iron and steel, cement, metallurgy, papermaking, aviation, and building materials. The May 2017 draft plan proposed covering just 3 sectors: electricity, cement, and metallurgy. As of now, the national carbon market will only cover one sector, the electric power sector. Other sectors are meant to be eventually phased in, but the stated ambition has significantly changed.

After the Obama-Xi statement in 2015 and the Paris Agreement in 2016, "everyone was filled with hope and brilliant expectations" for China's carbon market, as one consultant put it. Now, because of the perceived delays in setting up the national carbon market, some people have left China's carbon market industry. Nevertheless, state investment and political commitment are expanding, even as the scope of the policy has narrowed, the timeline has shifted, some players have exited the field, and global enthusiasm for carbon markets wavers. China is now the beacon of hope for carbon market supporters around the world.

This chapter is a story of becoming. It is not a glowing endorsement of the savior carbon market, nor a bleak picture of things inevitably failing because of China's poor data quality, inefficient bureaucracy, and incomplete marketization, as much of the literature and media have portrayed the story. In the midst of so-called delay and downsizing, many productive things are occurring. The process of becoming and waiting for the carbon market has itself transformed into a market, as national policymakers legitimize and promote standardization and capacity building. In the carbon market's state of perceived delay, capacity building keeps optimism alive by focusing on the aspirational future that is yet to come. Policymakers adjust policies when difficulties arise, regulated firms adapt to regulation (上有政策，下有对策), and consultancies find opportunities within this dance. Policies like the carbon market can take decades to become functional, making it difficult to ascribe success or failure when the market is very much still in a state of becoming.

FROM MARKETIZATION TO STANDARDIZATION

In this section, I introduce my framing of the process of developing a national carbon market in China not simply as marketization, but more so as a standardization process that solidifies top-down power and knowledge structures. In the broader political economy literature, markets are increasingly being recognized as embedded institutions sustained by extensive government intervention (Vogel 2018), rather than self-assembled entities guided by an 'invisible hand' that aligns supply and demand. However, the qualitative literature on China's carbon market focuses primarily on factors – whether political, economic, or otherwise – related to the carbon market's ascribed success or failure as a traditional economic policy instrument seeking cost-effective reduction of carbon dioxide emissions. Lo (2016) explores the political economic context of China's carbon market, highlighting incomplete regulatory infrastructure and excessive government intervention as major challenges to a "finance-led" carbon market. Lo and Howes (2013) thoroughly investigate the nature of state intervention in China's pilot carbon markets, again characterizing China's carbon market as a deviation from a neoliberal norm (Lo and Howes 2013). Goron and Cassisa (2017) define a "paradox" for China's carbon market:

> *"What consequences can be teased out from [the pilot carbon markets] regarding whether China's ETS can serve the goals of global climate change governance? A preliminary step is to recognize a paradox in China's ETS policy-making. On the one hand, it is perceived to rest on the power of the state rather than the market. On the other hand, [the carbon market] is also expected to reform China's 'command-and-control' environmental governance system."* (Goron and Cassisa 2017)

The authors then investigate on the role of local regulatory institutions in shaping the operation of the pilot carbon markets in China, juxtaposing local governments with the ability to achieve globally acceptable "climate change governance". This assertion of "paradox" for market-based environmental policy in China was solidified over a decade ago in Tao and Mah's 2009 paper on governance "dilemmas" in China's sulfur dioxide emissions trading system (which is analogous in structure to the carbon market). Tao and Mah identify four "dilemmas" of governance in China that affect market-based environmental policies like the sulfur dioxide market: state control vs. market competition, welfare provider vs. market regulator, centralization vs. decentralization of environmental responsibility, and vertical control vs. horizontal coordination of actors (Tao and Mah 2009). This language of tension, dilemma, and paradox characterizes much of the political economic literature on China's carbon market.

Such framings fix the carbon market as a policy instrument, one that can be analyzed from many frameworks, but primarily for its success or failure in reducing carbon dioxide emissions according to global norms. However, few studies focus on the carbon market as a process. This chapter examines the process of creating the carbon market, while also seeking a more capacious representation of China's carbon market. I deliberately move outside the equilibrium/disequilibrium framework of Chapter 3 to tell the story of how China's carbon market has been created not necessarily in tension with a more ideal form of market, but as a particular translation process of the global, neoliberal logic of carbon markets to a Chinese context. The carbon market is but a microcosm of China's state-guided market liberalization, wherein the Chinese government uses neoliberal logic to serve its own interests. Thus, this chapter speaks to the nature of neoliberalism in China, which is often portrayed as being a non-market, socialist market, or marketizing economy. I frame the process of developing a national carbon market in China not as 'marketization' – imposing a market structure on a previously non-market system – but rather as a standardization process that solidifies top-down power and knowledge structures.

China has a long and rich history of using standardization to inform its policymaking through 'state simplification', rationalizing social processes into administratively convenient formats for governments. By the 4th century BC, the Qin dynasty (China's first dynasty) imposed surnames among commoners who previously lacked them, which allowed enumeration for taxes, forced labor, and so on, to be passed on through the generations patrilineally. The term for 'commoner' in Chinese, 老百姓, or 'old one hundred names', may have originated from this initiative (Scott 1998). In more modern Chinese history, Tong Lam traces the rise of social surveys and a 'culture of fact' in the early 1900s as a key part of the nascent Chinese state's modernizing and civilizing initiatives. These social surveys, built on Western models, also helped legitimize managerial social science across the country and contributed to “the honing of the arts of governance of the emerging nation-state” (Lam 2013). Arunabh Ghosh explores the link between the institutionalization and practice of statistics in the first decade of the People’s Republic of China and the ideologies of its leaders (Ghosh 2014), when the need to carry out national economic planning required the establishment of statistical and economic capacities. In the 1950s, Chinese planners and policymakers adopted Soviet analytical techniques of input-output accounting and material balance planning, (Riskin 1987), which specifies output targets for producers and a supply plan for allocating resources among them.

This chapter opens up avenues of inquiry into practices of standardization for policymaking of China’s national carbon market, connecting these practices to neoliberal visions of carbon markets. I hypothesize that capacity-building processes attempt to smooth the unruly, politicized landscape by bringing a globalized and standardized approach to carbon management. In this chapter, I show how the process of creating the market is characterized by a mediation of the heterogeneity of actors in this space and the homogenizing attempts of capacity building to create a carbon market standardized to global and Chinese state norms. The national carbon market, as one of China’s most prominent climate, energy, and environmental policies, and one that is also deeply connected to economic reform, translates a globalized neoliberal vision of carbon markets into a Chinese ecological civilization policy (see Chapter 1). To put it another way, the neoliberal logic of carbon markets, upon arrival in China, has been transformed so as to meet the interests of the many actors involved. My research aims to delineate this local formation and expression of China’s national carbon market.

In 2017 and 2018, I conducted interviews of stakeholders in China’s national carbon market from Chinese universities, the private sector, the national Chinese government, and Chinese civil society primarily in Beijing, but also in several pilot carbon market jurisdictions. These interviewees were identified through snowball sampling of my networks. I began my snowball sampling with computer modelers, because I found that our shared skillset enabled ease of conversation, and these people often had hands-on experience working with data relevant for the carbon market design process. Interviews were semi-structured and conducted in English, Chinese, or both languages, depending on the subject’s preference. I also conducted participant observation at publically accessible events relevant to the carbon market. I took extensive field notes, inspired by ‘classic ethnography’ approaches (Adler and Adler 2008) that allow researchers to tease out mechanistic processes. I coded and analyzed my data drawing from an exploratory, iterative grounded theory approach. This research is CPHS/IRB approved. Names and identifying information are changed throughout the chapter.

The first step in establishing a carbon market is collecting information about the enterprises to be regulated. In the first section of this chapter, I lay out the emissions ‘datascape’, which encompasses the actors, processes, and information that form China’s CO_2 emissions accounting systems. I characterize the great variation in data quantity and quality, and the ways in which different actors are affecting this variation. In the second section, I show how data are used to inform decisions about the design of the national carbon market, and in particular how expertise and authority are generated through data access and modeling tools. Finally, I discuss the entire capacity building machine that sustains China's carbon market, showing how the engine of capacity building is promulgated by carbon market policymakers to make the carbon market economically productive in lieu of actual carbon trading.

THE EMISSIONS DATASCAPE: BUILDING EMISSIONS MONITORING, REPORTING, AND VERIFICATION SYSTEMS

According to economic theory, markets rely on information. Transparent information allows market participants to settle on efficient prices. Global climate policy often operates in the economic framework of maximizing emissions reductions while minimizing costs. Greenhouse gas emissions accounting is thus a fundamental part of the global climate policy regime – specifically, trustworthy accounting of emissions at the national and subnational levels to enable policy formulation and evaluation. The UNFCCC has called for regular, accurate, and transparent emissions accounting at the country level in order to set national emissions reduction targets (INDCs) and assess progress towards these targets. For more than a decade, groups like the IPCC and the World Resources Institute have promulgated greenhouse gas accounting protocols to help companies, countries, and other institutions around the world establish standardized emissions accounting processes. Many countries have gone on to adopt mandatory emissions reporting systems with varying degrees of granularity and accuracy.

China has faced past challenges in energy and emissions reporting. In 2015, the National Bureau of Statistics was accused of underreporting coal consumption by around 17% (Buckley 2015). In 2012, an international team of researchers from China, the UK, and the U.S. found a massive discrepancy between national and provincial datasets on energy use in China, which form the basis for estimating carbon dioxide emissions (Guan et al. 2012). China's National Bureau of Statistics annually publishes national and provincial Energy Balance Sheets, which report energy inventories and final energy consumption data that can be used to calculate carbon dioxide emissions. The national-level emissions, which should have been equal to the sum of the provincial data, were in fact 20% lower in the 2010 inventory. This discrepancy amounted to 1.4 gigatons of carbon dioxide, or 5% of the world's total emissions that year. The researchers identified this discrepancy as stemming from small coal producers that only reported to provincial authorities, as well as systematic under-reporting from provincial to national authorities. In light of this discrepancy, the national government recently updated historical statistics on coal use, a significant upwards revision (Zhang et al. 2019).

In the UNFCCC negotiations as well as other venues, there has been marked criticism of China for the low quality and availability of its emissions data. The growing international consensus on emissions accounting is well understood by the NDRC and now the MEE, which recently took over greenhouse gas emissions-related responsibilities from the NDRC. For carbon markets, the most essential data for regulation are firm-level carbon dioxide emissions, which must be monitored, reported, and verified (MRV) each year as part of the regulatory process. Emissions accounting and MRV allows policymakers to track progress, enforce the regulation, and determine the size of the market (i.e. how many allowances will be traded). As one of Michael Bloomberg's favorite sayings goes, "If you can't measure it, you can't manage it."

Given the shifting timeline and scope of the national carbon market, policymakers have made it clear that more complete and accurate emissions inventories from regulated sectors are needed in order to design key features and expand the scope of the national carbon market. Thus, many capacity building efforts in China focus on enabling firms and their regulators to complete the MRV process. As with the broader, globalized concept of a carbon market, China's approach to emissions accounting as the foundation of its carbon market has also taken on local forms. This section describes the process of transforming physical emissions from an industrial plant in China into a commodified carbon allowance that can be traded in China's carbon market(s). This process of making emissions commensurable is a momentous task across the heterogeneity of China's industrial landscape – creating carbon allowances that someday will allow a Zhejiang steel plant to pay a coal plant in Xinjiang to emit one less ton of carbon. I focus specifically on the role of data, showing how the emissions accounting process for China's carbon market sometimes enables, sometimes stymies standardization. The goal of this section is to lay out the 'datascape' that underlies China's national carbon market. In this framing, I draw from Ingmar Lippert's discussion of the environment as a materially, semiotically shaped datascape that joins carbon dioxide molecules to the carbon economy as produced by those doing the emissions accounting (Lippert 2015). Here, I conceptualize the datascape as a living landscape of emissions information, including the actors and processes that create and manage that information, and describe the datascape of China's carbon market, from emissions accounting to MRV.

A TALE OF TWO COAL PLANTS

The threshold for a power plant's inclusion in the national carbon market is emitting more than 26,000 tons of greenhouse gases (CO_2e) or consuming more than 10,000 tons of coal equivalent (tce) per year. This applies to electricity generating industries (发电行业), enterprises (企业), and economic organizations (经济组织), as well as other sectors with electric power plants on-site (其他行业自备电厂) (NDRC 2017). About 1,700 power plants nationwide are above this threshold and will be covered by the national carbon market (Timperley 2018). For now, this means that they are required to submit data on their emissions to their provincial or municipal governments, which then validate and report this information to the national authorities. Two separate third-party verifiers, as organized by the provincial or municipal governments, audit the emissions data for each plant.

Although the power sector is the first sector being covered by the national carbon market, China has collected annual emissions data from some to-be regulated sectors for several years. In the past, emissions data were unreliable, and energy and emissions data didn't match (as the previously discussed "gigaton gap" report found), so the ongoing process of collecting this data is meant to establish a correct baseline for the carbon market. In 2012, the NDRC first published guidelines for enterprises to account for and report their emissions, which were used to collect data from enterprises in 24 industrial sectors across China in 2013, 2014, and 2015. These basic guidelines were further clarified and expanded in the NDRC's 2014 "Interim Measures on the Administration of Carbon Emissions Trading" for MRV, and a further notice in 2016 that had more detailed reporting and verification requirements for the already-collected data from 2013 to 2015. These later policies required enterprises to come up with an emissions monitoring plan to be approved by local officials, which is meant to guide the annual reporting process. In 2016, provincial and municipal governments began to verify the 2013-2015 emissions accounts. Together these documents form the legal framework for the national carbon market and lay out the basic MRV requirements, although there is concern about lack of clarity in some of the calculations and requirements, as well as lack of legal force (Tang et al. 2018).

The following tale of two power plants illustrates, hypothetically, the potentially vast differences in the process of establishing emissions inventories. First, we visit a natural gas plant in Beijing. This plant is one of the few thermal power plants still inside the city of Beijing – air pollution regulations have driven most of these plants outside the city limits or out of business. With its landscaped lawn and gleaming lobby filled with light-up models of the power plant's technology, the plant is frequently visited by students on field trips. The plant is owned by one of the five major state-owned power generation companies in China, a conglomerate like Shenhua or Huaneng. Ten years ago, the parent company participated in an international carbon market called the Clean Development Mechanism (CDM), selling carbon offsets from some of its low-carbon power generation projects to companies in Europe. Around six years ago when the national emissions accounting guidelines were established and Beijing's pilot carbon market started, the company's CDM team reassembled and quickly designed an emissions reporting protocol for the plants that were to be regulated by the pilot carbon market. They gathered production data from across their subsidiaries, including the plant in Beijing, and established an electronic system for annual reporting. They report this plant's data to the Beijing DRC, which collects annual emissions data from all facilities within Beijing covered by the pilot carbon market. It took some time for the parent company and the DRC to establish a regular, clear reporting process, but they've already had 6 years of practice.

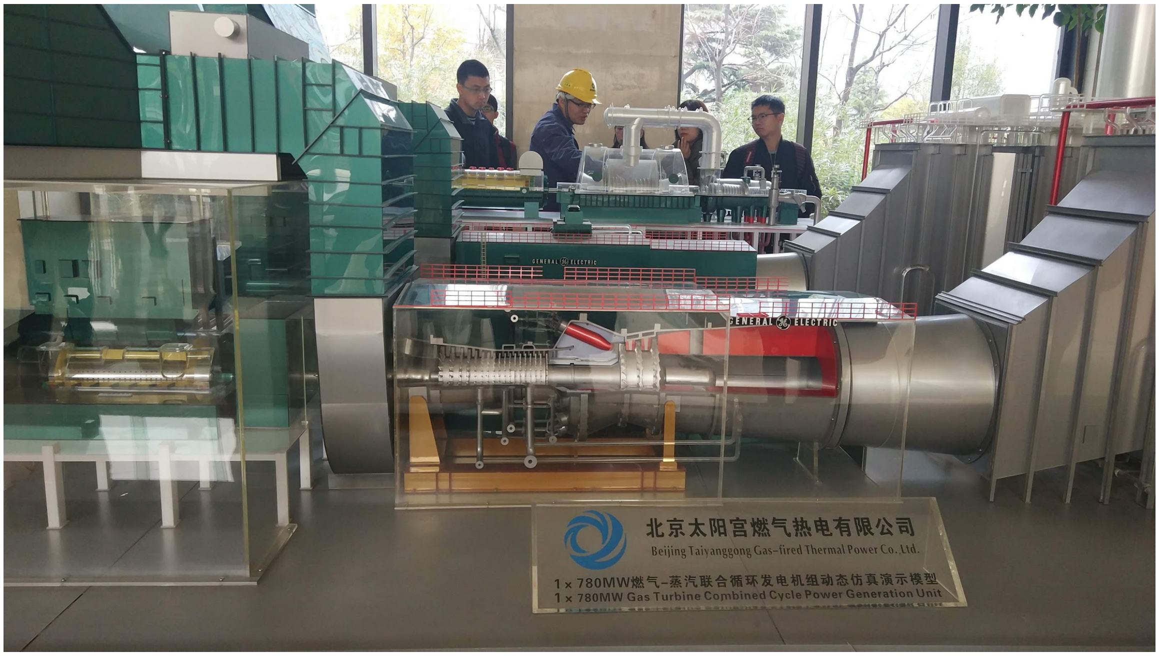


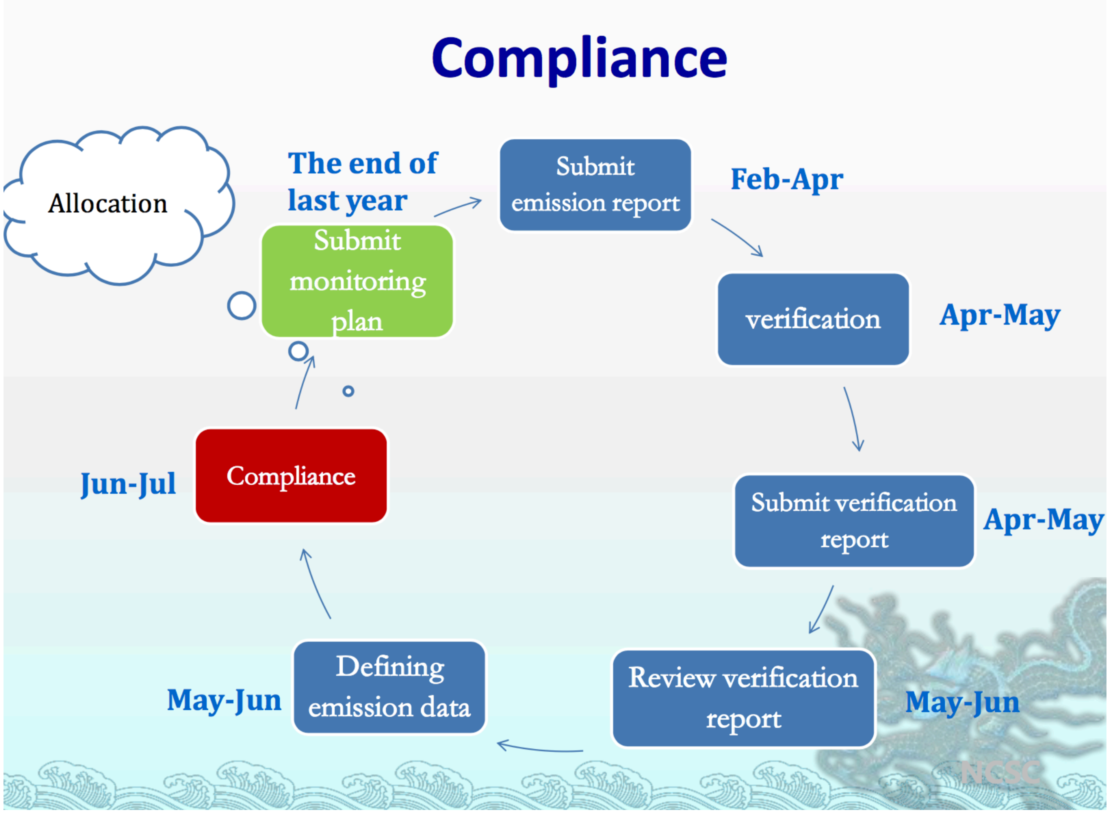
Figure 9: Educational diorama and study tour, Taiyanggong natural gas power plant, Beijing (photo from October 2018, author's own)

Now consider a coal plant in Inner Mongolia. Isolated on the fringes of small city Xilinhot, the plant is above the threshold for inclusion in the national carbon market, but had never accounted for or reported its emissions before the NDRC guidelines were released. The plant managers kept track of their fuel purchases and reported their energy data to local officials, but had never worked with the emissions staff at the Inner Mongolia DRC before. Their parent company is a local generation company with several plants. The parent company manages to report the plant's emissions the first year that it is required, but the next year they hire a consultant that they heard about from their industry group. The consultant helps them prepare a better report for the next year, leading to large discrepancies from the previous year. Later, their emissions reports are verified by two separate third-party verifiers, per NDRC's newest guidelines. These third-party verifiers arrive in teams at the parent company's offices in Ulaanbaatar and cross-check production data and financial data for the plant under review. These third-party verifiers are new companies recently created to take advantage of the sudden and massive need for emissions verification services. It is their first field trip to the province, and the two firms produce different estimates of the Xilinhot plant's emissions for the verification reports.

Figure 10: Coal plant in Inner Mongolia (September 2018, photo credit: Xi Wang)

For the Inner Mongolia plant, multiple 'data points' are collected for a single firm's emissions, all of which are a function of the experience, expertise, and processes conducted by several separate entities, making the actual quality of the data unclear. For the Beijing plant, emissions estimates eventually collapse into a predictable pattern as the local government and the parent company navigate new reporting requirements over a period of years. In fact, once the NDRC's 2016 guidelines were announced, Inner Mongolia and Xinjiang had to re-report and verify their 2013-2015 emissions accounts due to poor data quality and even missing information (Tang et al. 2018). These regional disparities in data quality are further explored in the next section.

Although two verification bodies are required to independently check emissions reporting for each plant, it is not uncommon for these estimates to diverge. The massive heterogeneity in location, experience, company structure, and so on create major challenges in generating a single, "accurate" emissions estimate for each regulated plant. "Making things the same" for the construction of emissions inventories is no small feat, including making different types of greenhouse gases commensurable (MacKenzie 2009). This heterogeneity – the multiple estimates of a single firm's emissions – is deliberately obscured by the compliance cycle set up by the NDRC. The compliance cycle is summarized in Figure 11 below, from a PowerPoint presentation by an official from the carbon markets team at the NDRC (Shuang n.d.).



Compliance

Allocation

The end of last year

Submit monitoring plan

Submit emission report

Feb-Apr

verification

Apr-May

Submit verification report

Apr-May

Review verification report

May-Jun

Defining emission data

May-Jun

Compliance

Jun-Jul

Figure 11: Emissions Reporting Compliance Cycle Schematic

Compliance refers to covered entities following the prior steps on time (i.e., submitting monitoring plans, emissions reports, and verification reports). For covered entities actively engaging in carbon trading (that is, those in the pilot carbon markets), each firm's allocated carbon allowances must also match its emissions. Thus far, the compliance rate (i.e., percent of firms that have complied) is the only metric used to assess the MRV process. Non-compliant firms may be fined or receive a warning (警告) from provincial authorities. Most pilot carbon market areas regularly achieve over 99% compliance rates. Tianjin had the lowest compliance rate at 96.5% in 2014 (see Table 5) (Shuang). Many stakeholders also concede that Tianjin is one of the poorer-performing pilots, but the difference in actual compliance rates hardly reveals this concern. The metric is so aggregated as to obscure underlying heterogeneity in the MRV process.

Table 5: Compliance Rates of China's Pilot Carbon Markets, 2014 and 2015

Pilot Area	Compliance Rate 2014	Compliance Rate 2015
Beijing	97.1%	100%
Tianjin	96.5%	99.1%
Shanghai	100%	100%
Guangdong	99%	100%
Shenzhen	99.4%	99.6%
Hubei	NA	100%
Chongqing	NA	NA

BAD DATA, RESTRICTED DATA

What heterogeneity is being obscured? In this section, I discuss the ways in which some kinds of data are 'better' or 'worse' than others in terms of meeting national and international standards for carbon market emissions accounting and MRV. I propose thinking of variation in emissions data along two axes, data quality and data quantity. Emissions data quality, that is, the extent to which a firm's report of its emissions matches its actual emissions, varies based on the sector, location, and company type for a given plant. Data quantity refers to the number of estimates for a given firm's emissions – this could be over time, by different reporters who regularly audit a plant's emissions, or having the data available in multiple forms and places. A given plant could fall anywhere along these two axes (i.e. low data quality but high quantity, low quantity but high quality, etc.). However, standardization of emissions data refers to the push towards high data quantity and quality (Figure 12). In this section, I discuss the ways in which sector, location, and company type affect data variation.

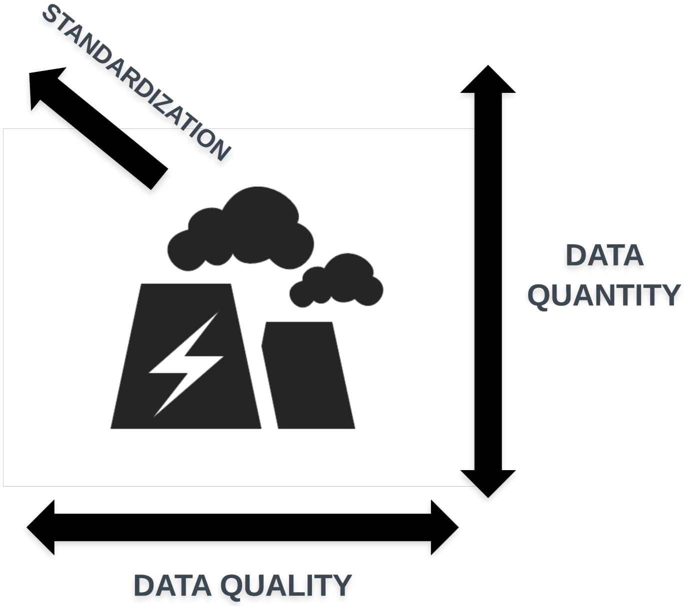


Figure 12: Schematic of Variation in Emissions Data

As discussed in the introduction to this chapter, China's national carbon market was originally planned to cover 14 sectors, but now it only covers one, the power sector. This narrowing of scope is due to the fact that the power sector, for various reasons, currently has the most complete and verifiable emissions data. Why? Electric power plants can precisely meter their output, which can be used to back-calculate CO_2 emissions using an assumed emissions factor or a laboratory-measured calorific content of the fuel a plant is using. Other industries, like the cement industry, face challenges in measuring emissions from electricity used on-site as well as process GHG emissions from the industrial processes themselves (e.g. calcination in cement production, or electrolysis in aluminum production). Not only does the power sector generally have more and better quality data on firm-level carbon dioxide emissions, it is also the sector with the most pilot-based experience (see Table 6 below). In addition, some industries have relatively well-organized industry groups that help their members estimate emissions. For example, the China Metallurgical Industry Planning and Research Institute (an industry group for the metals industry) has spent many years keeping track of China's carbon market policy developments, even working with the World Steel Association, a global industry group, to provide an emissions calculation tool to their members. The China Electricity Council represents over 100 electricity enterprises, including State Grid and generation and planning companies, and has several carbon market staff.

Table 6: Sectors Covered by Carbon Market Pilots

Pilot Area	Sectors Covered

Beijing	Electricity, heating, cement, petrochemicals, public buildings
Chongqing	Electricity, cement, chemicals, iron and steel, metallurgy
Guangdong	Electricity, cement, petrochemicals, iron and steel, public services
Hubei	Electricity, heating, cement, chemicals and petrochemicals, iron and steel, metallurgy, automobile equipment, medical buildings, food processing, papermaking
Shanghai	Electricity, chemicals and petrochemicals, iron and steel, metallurgy, building materials, papermaking, textiles, aviation, public buildings, railway stations
Shenzhen	Electricity, buildings, manufacturing, water supply
Tianjin	Electricity, heating, chemicals and petrochemicals, iron and steel, oil and gas exploration

Differences in data quality and quantity by sector are also related to historical tendencies of certain sectors to be more centralized and proximal to national and global resources, compared to others that may be decentralized and disorganized. The power generation sector, for example, is mostly controlled by five major state-owned companies, while some other sectors consist mostly of small, private companies. These intertwined technological and political characteristics influence the ability to account for emissions sector by sector. However, one carbon market consultant provided a more cynical explanation for this sectoral variation in data quality: sectors are being phased in one-by-one so that the national government doesn't have to admit the data is wrong all at the same time.

Given the aforementioned variation in data by sector, why is it that the pilots have been regulating multiple sectors, while the national carbon market had to start with just the power sector? First, the local DRCs managing the pilot carbon markets have closer links to the industries in their jurisdictions than the national government does to enterprises around the country ("the mountains are high and the emperor is far away", as the Chinese adage goes). Meanwhile, non-pilot regions are proving more difficult to gather data from than those areas already participating in carbon markets. Particular regions of China, notably the northwest "interior" and far northeast, are explained as having less capacity to participate in the emissions accounting and MRV processes. These discrepancies may also be framed around equity. As one academic put it, "I know it should in theory, but will a ton of carbon emitted in Qinghai really be priced the same as a ton of carbon emitted in the East?”, referring to the variation in burden of mitigation between poor and rich areas of China.

However, it’s not just the interior provinces that are seen as have lower data quality. One researcher expressed his skepticism regarding the quality of all emissions data from outside of Beijing. Another told of a richer province’s officials mistrusting emissions data from a province they saw as less developed. Even in the richer province, though, not all enterprises have finished reporting their emissions data. An empirical research paper compared self-reported emissions with third-party verifier reports for regulated firms in the Beijing and Hubei pilot carbon markets, finding no evidence of deliberate misreporting. The findings indicated that Beijing firms were learning how to report their data better over time. Tellingly, however, the authors wrote that, “Although the Hubei ETS required firms to submit self-reported emissions, a significant number of firms did not submit them due to inattention, weak internal capacity or limited enforcement by the local government,” leading to a sample size of 63 firms for Hubei compared to Beijing’s 403 (Zhang et al. 2019).

The type of company that owns a regulated firm can also play a role in data quality and quantity. Large state-owned enterprises often have experienced staff – and strong political will – to manage emissions accounting and MRV. However, there are still many small firms that lack expertise, experience, and motivation to do proper and regular emissions accounting. These differences are discussed more in the capacity building section later in this chapter. Some carbon market stakeholders are optimistic about the progress of emissions accounting. At a small meeting with national and provincial officials, external consultants, and a few others, a representative of a regulated company admitted that their company had been noncompliant because they had reported their emissions incorrectly. This was not intentional – rather, they simply hadn’t known how. The company had to pay a fee, but also felt positively about learning how to do the emissions accounting properly afterwards. A consultant described the trusting, tolerant atmosphere in the room as a remarkable sign of progress.

Innocent mistakes and good intentions aside, the ideal carbon market relies on game-theoretic cooperation of all regulated entities in reporting their emissions, so that the national regulator can use complete information to allocate emissions allowances each compliance period. If allocations of carbon allowances are made based on incorrect data, the overall cap on emissions could be weak, leading to low prices and sluggish demand that do little to drive emissions reduction (something the EU ETS has especially struggled with). Provincial officials worry about the national carbon market because data quality could be so poor as to “tank the market”, scrapping years of effort on the part of local governments to develop emissions accounting processes and cultivate goodwill with the national government and regulated companies. For many stakeholders, data quality entirely out of their control is the most concerning challenge for the national carbon market.

These concerns about data quality go hand-in-hand with extremely strict control of emissions data. Even among the carbon markets personnel at the NCSC, only a small subset of staff can see the emissions accounts. Consultants, NGOs, and other external stakeholders have never seen national emissions inventories or actual emissions data. One NGO representative lamented that this lack of information, especially on accuracy of the emissions data or performance of the data collection process, prevented advocacy groups from even formulating a stance on China's carbon market. The NCSC has contracted select teams at academic institutions and consultancies to use the official emissions accounts to help formulate aspects of the carbon market design, but this only increases the insider/outsider dimension of data access. "The data is very secure – it must be protected," said one of these academics. The extreme "security" around emissions data seems at odds with the need for complete information for a perfect market, but is in fact a logical response on the part of national policymakers dealing with incredible variation as well as the need to consolidate authority. This variation in data quantity, and the links between access, authority, and expertise, are further explored in the next section, "From Data to Decision-Making".

THE WILD WEST OF VERIFICATION

These variations in data quality and quantity, as well as the national government's requirement for two separate third-party verifiers to verify each emissions report, have created a sudden and large demand for verification services. For the pilots, the local authority selects authorized verifiers, and in the early stages of carbon trading, even pays them for verification services. Eventually, the national government will also select authorized verifiers for the national carbon market – a tremendous opportunity for any company that receives authorization. Third-party auditing and verification of emissions is a fraught business that has faced challenges in the past, and is highly dependent on regulatory structure (Duflo et al. 2013).

The institutions providing verification services for China's carbon market vary a lot as well. They range from established consultancies with a high-profile brand, like SinoCarbon, to hundreds of small, newly established companies and services. SinoCarbon is an authorized verifier for all of the pilots – in fact, they helped the national government come up with the MRV guidelines, and are well trusted for their expertise. While there are also small carbon and emissions-specialized companies that have emerged to help companies prepare for verification, many verifiers are new to the carbon market. Some are pre-existing independent companies like energy auditors who saw the "gap" and "huge demand" for verification from thousands of facilities suddenly needing to verify their emissions. One consultant who helps train stakeholders on emissions accounting claims that a lot of the verifiers are "bad quality". "It's dangerous if these verifiers do a bad job. The companies might provide honest, accurate data, and then the verifiers provide bad data, and this will lead to mistakes in the allocation process and harm the future ETS." This cements the need for capacity building trainings like the ones their organization provides.

Some regulated firms are not self-reporting at all, and are simply letting third-party verifiers do the work of the "initial" emissions reporting. This leads to a semantic paradox – is "verification" even verification without the first step of self-reporting? When I asked one researcher why some companies weren't self-reporting, they replied, "Maybe they didn't want to. They didn't want to spend any energy on it." Meanwhile, as discussed earlier, it is not uncommon for a company's self-reported emissions and the verifier's reported emissions to diverge. "The training level of people at different verification companies may differ, or they may think about things differently," the researcher explained.

Would emissions accounting be more trustworthy with the help of technology? China has invested heavily in Continuous Emissions Monitoring Systems (CEMS) for air pollution emissions. The China National Environmental Monitoring Centre even publishes real-time air pollution data by city on their website.[10] CEMS encompasses a range of technologies, but refers specifically to monitoring technologies at the plant level that directly measure emissions. The promise of CEMS is that it can deliver the complete information necessary for a 'perfect' market, rendering emissions reporting transparent by objectively recording plant-level emissions, and bypassing the other main approaches to estimating a plant's CO_2 emissions, namely mass balance, which requires calculation of the difference in carbon entering and exiting the plant in feedstock and products to estimate the CO_2 emissions.

However, CEMS technology has not delivered on its promise in China. One study found that key regions in China facing new, stringent sulfur dioxide regulations reported CEMS data with a larger decrease in sulfur dioxide emissions than could be corroborated from NASA satellite data, which the researchers called "suggestive of misreporting" (Karplus et al. 2018). Even with purportedly accurate and objective technologies, CEMS data still must be reported by companies to local authorities, and are thus subject to interpretation by those doing the reporting. In MEE audits, local EPBs have been caught forging meeting notes, destroying computer records, and giving companies advance notice of inspections (Xie 2019).

There has been some dialogue about using CEMS to monitor carbon dioxide emissions for China's carbon market, since it is already used to monitor sulfur dioxide emissions from power plants in many parts of China. CEMS could be an alternative to the unruly third-party verifiers currently used for CO_2 emissions accounting and their calculation-based mass balance approach. However, to fulfill the promise of technological omnipotence, many aspects of the reporting system would need to be standardized and enforced. As one consultant put it, "There would need to be significant checks on the CEMS system, and an institutionalization of these checks, to prevent manipulation. CEMS could reduce the number of third party verifiers that are needed, which is good and efficient. However, any CEMS system would still need 'human' interaction." Even if misreporting could be eliminated, technology can be used to thwart technology. CEMS was used for carbon accounting for CDM-era projects, but there were anecdotes of factories implementing CEMS systems and later re-configuring the measurement devices to falsify data. More recently, MEE inspections in Shanxi and Ningxia provinces found instances of air pollution monitoring machines being sprayed with water to alter readings, with one EPB chief going so far as to pay someone to block surveillance footage of the act. In Henan province, a sealed CEMS system was interfered with using a wireless mouse (Xie 2019). Thus, even a measurement device is subject to technological

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[10] http://www.cnemc.cn/

manipulation. Still, the consultant was enthusiastic about even more cutting edge technologies, like blockchain, that could solve the current imperfections of measurement and reporting technology if ever brought into use.

After an original timeline for launching the national carbon market in 2017, the recent reframing of its launch as a 'foundation building' exercise speaks to the heterogeneity of the emissions accounting and MRV process, which has fallen short of national policymakers' ambitions. Many fear that "bad data" could "tank the whole market", meaning that the carbon market as a whole could be ineffective as a policy instrument and unimpressive to an international audience. Like many kinds of data in China, emissions data is managed closely by national authorities. An entire market for third-party verification has emerged alongside – or within – the carbon market, with the goal of promoting standardization of the quantity and quality of emissions reports. However, for now, these verifiers often end up increasing data quantity but not quality. In addition, due to the risks of misreporting, technology is not yet able to deliver the data transparency needed for a 'perfect' market. This datascape, filled with fear, skepticism, ambition, and opportunism on the part of various actors, reveals the incredible heterogeneity of emissions data in China in comparison to the global vision of standard emissions reporting protocols.

Mackenzie (2009) lays out how the IPCC's authority in establishing the metric of "Global Warming Potential" for various greenhouse gases has been an essential part of making emissions commensurable and thus tradable in the CDM and the EU ETS. Although China's national carbon market only regulates one gas – carbon dioxide – it faces a similarly momentous task in establishing a consistent, standardized, and authoritative structure for emissions accounting across many industries, regions, and layers of government. This process of 'state simplification' and legibility, a la James Scott, is also a story of the state (as expressed by the NCSC, formerly in the NDRC and now under the MEE) attempting to tame a wild, heterogeneous landscape of industries and enterprises that were previously very far from the emperor. Since emissions data is so correlated with production and energy, other major management loci for the Chinese government, the state sees the extraction of this data as worth major investment – such as the government paying for all verification services in the early stages of emissions accounting. In fact, the standardization of emissions accounting and MRV is an incredible process of making the Chinese state's subjects far more knowable by incorporating them into a regular, standardized routine of revealing their innermost workings.

FROM DATA TO DECISIONS: MODELS, MODELERS, AND EXPERTISE

Amidst the arduous collection of emissions data and attempts to standardize the process, how do China's policymakers then take this information to decide how the national carbon market will work? To what extent does emissions data inform policy decisions, or are there other considerations guiding China's carbon market designers? By carbon market design, I am referring to the details that vary across carbon markets. The basic principle of cap-and-trade stands, but the way the cap is set (an absolute or intensity-based cap, for example), the number of sectors covered, the threshold for inclusion, and the method for allocating permits are all aspects of the design that policymakers must decide.

"Science-based policymaking" and "evidence-based policymaking" have become buzzwords for public policy around the world, indicating the desire to incorporate objective and scientific information into policy decisions. However, a rich body of literature on the interface of science and policy also reveals the highly subjective nature of public policy in spite of such aspirations, while also identifying a wide range of other factors besides scientific evidence that shape policy design and outcomes. China's carbon market lies somewhere between "evidence-based policymaking" and "policy-based evidence making", with a wide range of experts and elites, each with their own sets of skills and motivations, shaping the key design parameters of the national market.

Since Mao's death and the onset of Reform and Opening Up, Chinese elite policymaking has been dominated by a technocratic order of leaders, Red Engineers who have consolidated not only power but also a technocratic management philosophy (Andreas 2009). Despite the incredible concentration of trained engineers among China's current elite policymakers, technical knowledge alone is far from enough for these policymakers to achieve their goals. Among these elites, factions are critical for advancing political ambition, suggesting that promotion of officials depends not on achievement of policy goals but rather factional ties and even educational pedigree (Shih et al. 2012). Expertise and connections are deeply intertwined. This network of connections and expertise has ossified into bureaucratic structures, a key determinant of policy outcomes (Lieberthal and Oksenberg 1988).

In this section, I contextualize the space between expert research and policy in the making of China's carbon market. The section overall shows how people form and deploy technical expertise in the carbon market policymaking process. This exploration of expertise is a critical prelude to the subsequent discussion on capacity building. I begin with a survey of the computational models used in research related to China's carbon market, since models are a frequently used to simulate the effects of a policy. I show that while models are often separate from the carbon market policymaking, they are a critical tool that is generative of expertise and authority. Next, the section explores the technical lives of experts and their aspirations. This discussion opens up a new, ethnographic space to think about how carbon market policymakers make decisions – a space that adds dimension to traditional political economic constructions of policymaking. I draw inspiration from the rich ethnographic STS literature on scientists and experts, such as Joseph Masco's study of nuclear scientists and their technoaesthetic engagement with their work (Masco 2013). I focus on how China's expert policy modelers engage with their tools and the knowledge they produce.

MODEL IDENTITIES

I take computational models as a focal point for understanding how experts inform policy in the context of China's carbon market. Models are a useful policy tool. They can help policymakers predict the effects of their policies, and simulate different versions of policy design. Models create simplified representations of carbon markets in order to elaborate potential scenarios and aid decision-making. This necessary simplification in fact parallels the China's efforts towards creating a standardized carbon market.

Many carbon market experts build their cachet and professional identities around computational models. Lü is one such expert turned policy commentator. One hot summer day in 2017, I go to visit Lü, who is a researcher at the Chinese Academy of Sciences. Cool and silent, this CAS building is a welcome respite from the Beijing streets. Lü is extremely knowledgeable about technical details of China's carbon market and how to represent them in computational models. He is one of several government modelers who use CGE models to study energy policies at CAS and the NDRC's various think tanks. They publish academic papers and also write up their research for government officials in the form of policy briefs or discussion drafts (讲话稿). Lü takes pride in his fluency in the programming languages underlying his model, and subsequently looks down on point-and-click software overlays that make models usable by a broader audience. Referring to the highly technical yet tedious work of writing and checking code and parsing data, he says that he usually provides the "hard labor" (劳动) for his modeling collaborations, because it's what he enjoys.

Though sometimes competitive with the other research groups at CAS, Lü has a remarkably diverse network of collaborators and co-authors across other research institutes and universities. He believes that CGE models are highly useful because they are one of the only tools that can track value flows in an economy, which he does when he models carbon taxes or carbon markets that recycle the revenue from the policy to some other sector or group (see Chapter 3).

However, it is not only professors and government researchers engaging in carbon market modeling. Zheng is a government researcher who also moonlights as a private consultant for energy modeling. When we first met, he proposed a street intersection. I assumed I would meet him there and then go to his government office building, perhaps one cold and imposing like CAS. Instead, his office was actually in a small residential apartment converted into a shabby, single-room office with several men typing away at computers. We all crammed around a small folding table to chat. Some of them had their own individual consultancies, though all worked at other places for their primary job. They ranged in age from one fresh-faced recent graduate to middle-aged, seasoned modelers, but all shared an enthusiasm for the model they jointly developed. The proximity of their makeshift office to the government building where Zheng worked revealed their main client. The 'moonlighting' feel to the venture spoke to the nascence and uncertainty of consulting-type modeling in a field crowded with credentialed academic researchers. Yet, their combined expertise was formidable, and their business was good. "Relationships are important for funding," explained Zheng, "and we have good long-term relationships." We talked for several hours, and I eventually had to plead exhaustion, as their ability to talk shop for hours was remarkable.

Researchers like Lü and Zheng publish prolifically in academic journals. An abundance of academic papers model China's carbon market, with various methodological approaches (see Chapter 3). Some provide policy recommendations, while others are meant to advance the methodology or theory. These models and their makers work on the periphery of the carbon market. Modeling the carbon market can be a profitable exercise. In the near term, modelers can attract clients or research grants to simulate various policies such as the carbon market. In the long term, models can make reputations and careers.

CGE models are emblematic of efforts to use structural computational models to estimate the potential effects of a carbon market. They are very commonly used to study economic, environmental, and energy policies. The same model can be applied to several different types of policies with minimal adjustment. While some researchers use CGE models primarily for economic research, especially on taxes and trade, recently, CGE models have been increasingly applied to energy and environmental policy. In light of the "empirical revolution", which has popularized econometric methods (Angrist and Pischke 2010), CGE models are not in use in most academic economics departments. However, they do enjoy popularity in applied departments as well as in private sector consulting firms, development banks, government agencies, and other non-academic institutions. One student told me that CGE models are especially popular in China: "Econometrics is too simple. A CGE model can help you win a bigger grant from the Department of Education or such places." In fact, CGE models are descended from the early Soviet planning tool of input-output tables (see Chapter 2). Their popularity in China speaks to a continuity of the planned economy in quantitative tools. Ironically, even though the planned economy has seemingly been put to rest, the tools of the past are being use to build, study, and analyze the market economy.

However, CGE models are not the only kind of computational models used to assess climate and energy policy effects. CGE models are often classified as "top-down" models because they do not have a detailed or technology-based representation of the energy sector, but rather trace effects from aggregated production and consumption data down towards sectors of interest. In contrast, "bottom-up" energy models, sometimes called engineering models, take individual firms or technologies as the unit of analysis and model their effects upwards towards aggregated impacts. However, they tend to lack detailed consideration of economic factors. Some research groups attempt to merge these models, though in practice this is often using the output of one model as the input to another model. For example, the electricity demand predicted by a CGE model could be used to calibrate an engineering model of the electricity sector.

Bottom-up models are a large, diverse class of models. For researchers with an engineering background, they may be more intuitive or attractive. Certainly such models are in heavy rotation at the government think tanks that provide supporting research for the carbon market. One PhD student who studied the carbon market bemoaned his choice to invest his time in learning CGE models, since he felt that his classmates had selected more popular (and more publishable) optimization-based bottom-up models. There is a lack of pedagogy around structural computational modeling, and most students arduously teach themselves. The code and software for models are passed around student-to-student within a research group on USB sticks.

Research groups that model the carbon market are primarily defined around their creation, management, and use of a model. These models may also spur collaboration between research groups in China and abroad. For example, the MIT EPPA CGE model has been adapted to the Chinese economy, and re-named C-GEM or C-REM (depending on the spatial scope of the model), although the majority of the code and the fundamentals of the theory remain the same. Researchers at Tsinghua use C-GEM and C-REM to simulate a variety of energy and environmental policies in China, while those at MIT, sometimes separately and sometimes together with Chinese colleagues, apply the EPPA model to a range of research questions. A similar process has worked for other modeling groups across China.

Typically, the adaptation of these models to the Chinese context is done by students, research staff, or professors from a Chinese institution doing research exchanges at a university abroad, where a model already exists and is being used. "We have learned and imported many techniques from foreigners," said one Tsinghua professor. The State Information Council, a think tank of the NDRC that also has several researchers using CGE models to assess energy policy, uses a CGE model that is based on a CGE model at Monash University in Australia. The lineage of a Chinese model can be traced by following the trail of research exchanges, and models are proliferating as alumni and friendships move across schools. Modelers find comrades and research partners through the work of building and expanding models, and the model comes to shape their professional networks and identities.

The complexity of a model makes it a useful object around which to exchange funding and expertise. Complexity, to an extent, opens up a wider range of analytical techniques and applications. The model is the foundation of international collaborations, the glue of research groups and nascent consultancies, and the technology for which funding is raised. Publications and conference opportunities are churned out from model clusters, not to mention livelihoods, in the case of consultant-modelers like Zheng.

However, the complexity of models also makes them difficult to apply directly to the carbon market design process. If emissions monitoring technologies and reporting software are the beginning of the data pipeline, models are an endpoint in the infrastructure of the carbon market, where data ends up in highly simplified and stylized formats to assist with abstract thought exercises. In the next section, I show how the incomplete, distributed, heterogeneous nature of the firm-level emissions datascape (explored in the previous section) determines the analytical techniques used to manage it. Models and modelers are moved to the periphery, and provide indirect input to the carbon market design process by cementing individual and group reputations.

MAKING EXPERTISE, MAKING POLICY

Data and models are often put forth as objective quantitative tools to aid the design of policy; at the same time, these quantitative tools are constructed within a complex, heterogeneous sociopolitical system. They directly and indirectly enable the generation of expertise. Modeling work, though not directly used to inform policy, helps define research groups and their expert capacity. For China's carbon markets, policymakers have systematically outsourced expertise and cultivated networks of experts, both at the national level and for pilot carbon markets. This expertise on the carbon market is primarily consolidated and exchanged through a high-level steering committee for the national carbon market, convened by the MEE. It is made up of government officials, industry group representatives, some consultants, and many academics.

Besides assisting with the steering committee, local academics and government affiliated researchers like Lü also provide direct analysis for the national government. Name-brand consulting companies, especially international ones, are too expensive and may not understand the Chinese context. "Within China, what brand is better than Tsinghua? Who is better than Professor X, Y, or Z?" Lü asks, mentioning well-regarded professors who are involved in the carbon market design process. "A no-name private company couldn't compete with them." While some international consultancies and agencies are involved in China's national carbon market process, they tend to be called upon as experts for capacity building rather than direct policymaking.

Professor Wu is one of the oft-contracted experts for carbon-market related work for the national government. She has a staggering range of projects. Grants from the National Natural Science Foundation serve as stable funding that give her flexibility in her research, while she is currently working with several different national government ministries on short-term projects. She also consults with the local government on their pilot carbon market and other carbon dioxide emissions-related research. "We have a very good relationship with the local government. This helps with better policy and planning because we have data and experience within this region," said Professor Wu. The sheer number and variety of government grants her research has received reveals the importance of long-term connections and trust between the government and the experts they hire.

Despite this hodgepodge of projects, Professor Wu saw a very clear delineation between her academic research and research for government audiences ("the policy design track"). As she explained to me, government research is conducted through two channels: the first by doing the research and then working to communicate it to the relevant officials, and the second through government solicitation. The latter is more common; indeed, for some professors, it is the ultimate goal that motivates pursuing the first channel. The boundaries around government research are also very clear when it comes to accessing data. "The NDRC gave us data on the emissions trading system, but we are explicitly not allowed to use it for publications. We are only allowed to use it to do projects for them," she said. In fact, one of her collaborators wants to use the data to do several different kinds of analysis, but each analysis requires a separate approval process even though it would use the same data.

The government is not deploying complex models like CGE models in the carbon market design process. "There are many papers on the Chinese ETS allowance allocation scheme, but this is just academic research. They're never going to accept the theoretical approach in my paper – it's for publications only," said another professor who had helped with the design of one of the pilot carbon markets. In part, this is because of the inability of the model to simulate reality. Data underpinning many models is outdated and lacks detail. Boundaries may differ – for example, the iron and steel sector as represented in a model is may be defined differently that for the proposed carbon market. The model necessarily simplifies these highly detailed disaggregations of firm-level detail, and this makes it less useful for the policy process. “In China, the policymakers don’t directly use models. They converge many studies and look at results from many researchers. We didn’t use any complicated sort of model (我们没有用什么复杂的模型),” said Professor Wu, who explained her process of choosing an emissions intensity benchmark for covered power plants: “We just looked at the data and found the average.”

The outsourcing of expertise – and the entrustment of methodological approaches – to a cultivated group of academics is a necessary move on the part of the overextended NCSC. People explain this overextension in several ways. First, there simply aren’t enough staffers to go around (I hear estimates of 70 people total in the NCSC with around 20 working on carbon markets). Hiring more staff is nearly impossible, because creating a new agency job requires an individual application to the State Council for every position. Nor can the NCSC take on students or interns to help them, as academics can. A second and somewhat related explanation is the lack of complete technical knowhow on the part of the NCSC staff. Some say they have too many engineers, others say they have too many economists; either way, the NCSC staff are driven to solicit specific expertise from their expert networks.

Some of the called-upon experts take pride in their work helping with the carbon markets. A professor in Shenzhen claimed that the Shenzhen pilot’s success (it was the first pilot to launch) was because academic economists like her were so involved in the design of the system relative to other pilots. Others dread the work – one young professor in Guangdong complained about the endless reports for the local government, many of which he felt demanded impossible predictions about how the carbon market would perform in the future. Interestingly, Professor Wu, though proficient with modeling and quantitative analysis, sees herself as a policy design expert, and rarely publishes in academic journals. The high-profile work is left to her more senior colleagues, who both publish more and are more visibly involved in the public sphere of the national carbon market, from the steering committees to frequent appearances to give talks. Experts vary in their relationship with their expertise, as the next section further unpacks.

Winning at Life?

Modelers can build coveted careers based on their expertise. The community is tight-knit and hyper-aware of each other. Students, who maintain and expand models, look up to their professors, the progenitors of each lab group’s model. One professor was one of the first scholars in China to begin using CGE models. His wife also has a PhD, which, according to his student, means they were allowed to have two children, circumventing the one-child policy (which was more strict at the time). The wife’s second pregnancy turned out to be twins. “They have three kids in the city. He’s really 人生赢家 (winning at life),” says his student, practically green with envy. Another expert is rumored to have China’s energy system model in his head: “Whenever he gives a speech or says a statistic about energy, researchers around China will re-calibrate their models to his number.”

But what is life really like for these winning experts? One NCSC official who has reality-defying abilities to appear at climate and energy policy events around the world confesses that in the 20 or so years that he's been working, he has almost never traveled for fun. He began as an energy modeler, but has since shifted to policy work that relies more on meetings, speeches, and reports. I ask him what he is doing for the upcoming national holiday, and he says he will be finishing reports. "We often have little notice before having to write a report or provide some technical information. And we have to write a report about everything we do, every event we attended. I miss my college years, that was a break, a relatively relaxed time." The universal downside of being in-demand for one's expertise is have little time to oneself.

Indeed, juxtaposed with these expert "winners at life" are the shifting ambitions of their would-be successors. In their early years, energy and environment students express the desire to go to academic and government research positions, like their mentors. Yet each of these destinations has its unique challenges that eventually become insurmountable for those seeking them. These days, academic jobs in Beijing are nearly impossible to get for those with PhDs from Chinese universities, says every student I meet. Chinese universities prefer to hire professors with foreign degrees. While the professors on the carbon market advisory committees supervise and graduate many students each year, few of their students even attempt to follow in their footsteps. When I first meet a researcher named Wang, she has been working abroad as a post-doc for several years. She contributes to several projects related to China's national carbon market. Pensive, focused, and straightforward, she has held the goal of becoming a professor at Tsinghua for the several years I have known her. Because she did her PhD at a Chinese university, she feels it will be difficult for her to get an academic position. She sees her extended post-doc abroad as penance for those PhD years wasted in China. But her heart is set on becoming a professor in China. "In China, there are not many ways to influence the government. For an ordinary citizen, perhaps one way is to become a professor."

"Working at the Energy Research Institute is my dream job," a PhD student named Cong told me when I first met him. "People from my program are probably the most qualified people to go there and work on the carbon market," he said confidently. As a government institution (事业单位), the Energy Research Institute think tank has a somewhat different hiring path than other positions at the NDRC, which are civil servant positions (公务人员) managed by the State Council. The civil service exam, necessary to become a civil servant, is frequently mentioned as a major barrier for going into government jobs. "If 100 people take the exam, maybe only one will be selected. The content isn't even related to our subject of study," says Cong. Government jobs have also become less appealing following Xi Jinping's corruption crackdown. As Wang tells me, "Some of my friends from back home work for the provincial government. But now, after the campaign, they have to pay out-of-pocket for any work-related expenses, like cabs and meals, making it a financial hardship. The reimbursement process has a lot of red tape, it's very difficult. They're not corrupt, but they could become corrupted. Even officials in Beijing face these kinds of policies. So though I want to influence the government, I didn't necessarily want to work for the government."

Given these obstacles, many graduating students from energy and environment programs in China end up going to finance and consulting companies. Some go to great lengths to conceal this intent to 'defect' from their advisors in their final years, hiding the fact that they are traveling to take accounting exams or do job interviews. “We just want to make money, buy a house in Beijing, and enjoy the benefits of a higher salary.” For many graduating students, obtaining a Beijing residence permit (*hukou*) as quickly as possible is necessary to stay in Beijing. Many students have found romantic partners at other universities and want to make a life in Beijing together rather than returning to separate hometowns. SOEs and private companies can arrange Beijing *hukous* much faster than government jobs. Yet the defection away from energy models and towards financial models is also a testament to these young professionals’ expertise and skills. Financial models require many of the same skillsets as academic energy and environmental modeling, including data management, fluency with programming languages, and understanding of the mathematics behind optimization and other modeling methods. Hard skills trump soft idealism in determining the course of these budding experts’ careers.

More than a year later, I check back in with Wang. She is now an assistant professor at Tsinghua – her exact goal. “I had to have a lot of patience. It’s a long story,” she says. I ask her if she still wants to work with the government. “After my years of trying to get tenure, I will. It’s the motivation for seeking this very job. But it will happen naturally after the tenure process.” I also check back in with Cong, the student who wanted to work for the government think tank. He is now at an oil company, a major Chinese SOE. “It’s not related to environmental protection at all,” he says wryly. He feels overqualified and underpaid. But, he has a Beijing hukou, a Beijing apartment, and a Beijing girlfriend. To many other students, he’s winning at life.

Facing pushes from their line of work and pulls towards other types of jobs, the budding energy policy experts at many Chinese institutions may cycle out of the area they were trained in. Those who remain have a chance to “win at life” and cement their identities as the top experts. Policymakers often leverage these experts in efforts to standardize the making of the carbon market through capacity building, the topic of the next section.

CAPACITY BUILDING: THE MARKET OF THE MARKET

In the carbon market’s state of perceived delay, capacity building keeps aspirations alive by focusing on the future that is yet to come. Capacity building activities make the process of becoming productive for the actors involved. I argue that capacity building is, in fact, the sustaining force of the carbon market itself. Prior literature has identified excessive state intervention as both the source of problems and the lifeline for China’s carbon market. However, capacity building for the carbon market has become an ongoing, self-sustaining process in China that has eventually come to shape even the national government’s vision of China’s carbon market as a policy that must be neoliberally productive.

International aid and development programs frequently frame their work as “capacity building” or “capacity development”. Various trends in the 1980s and 1990s helped form the concept of capacity building: social movements in Latin America, increasing critique of the development industry, a new focus on people, diversity, and rights in “human-centered development”, and the formalization of institutions as units for development (Sagar 2000) (Eade 1997). Capacity building is often described as a process or approach that can span multiple levels from the individual to the institutional. Oxfam calls capacity building an “approach to development” guided by a long list of principles and caveats (Eade 1997). The United Nations Development Programme defines capacity development as a five-step process “through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time” (UNDP 2009). Capacity building is now officially enshrined as a Sustainable Development Goal for the 2030 Agenda for Sustainable Development, with the target to “enhance international support for implementing effective and targeted capacity-building in developing countries to support national plans to implement all the sustainable development goals” (United Nations 2019).

Capacity building in practice has been criticized as at odds with capacity building as discourse. “The results-oriented, bureaucratic imperatives of many government and donor agencies effectively nullify the long-term, participatory, and process-oriented approach to capacity building that is promoted in the discourse,” writes Leanne Black in a critical review of the capacity building literature (Black 2003). Capacity building is rarely for the smallholder – it is usually meant for state institutions and market facilitators, even though capacity could be built on any scale. Capacity building is a slippery term, a present participle that captures the essence of an interminable construction process with no clear end in sight. When has capacity been *built*? The term assumes a transfer from those with capacity to those without. In that sense, it is inseparable from the capacity builders’ vision of development.

While not a development program per se, China’s carbon markets involve many institutions that also engage in development work, such as the World Bank and China’s own National Development and Reform Commission (NDRC). The carbon market is a future-oriented policy – on an international stage, China’s leaders proclaim it will bring China’s industry in line with global visions of the climate future, while domestically, the policy is being used to standardize a new approach to clean, green, and marketized industry, The carbon market policy “renders technical” the material and economic processes that produce emissions. Tania Li investigates the deliberate depoliticizing of improvement schemes in Indonesia through their handling as technical problems to be managed by experts (Li 2007). Improvements in any realm can be problematized and rendered technical, from public health to poverty alleviation, land management, and other social engineering schemes. In the process of rendering technical, development institutions morph from infrastructure developers to knowledge gatekeepers (Goldman 2005). Many scholars like Timothy Mitchell and James Scott have explored this technocratic “rule of experts”. Even the modern term “economy” arose from a rendering technical of previously undefined processes of exchange, making possible “new forms of value, new kinds of equivalence, new practices of calculation, new relations between human agency and the nonhuman, and new distinctions between what was real and the forms of its representation” (Mitchell 2002).

Like any market, the carbon market comes to fruition when all its participants adhere to standard accounting processes and begin to exchange the value of molecules of carbon dioxide across time and space. Capacity building problematizes the lack of capacity of various stakeholders, primarily local government and regulated companies, to participate adequately in the carbon market; thus, capacity building is the engine that harmonizes the heterogeneous molecules and viewpoints of the carbon economy.

THE TRAINING IN HAINAN

Here, I introduce two attendees of the same capacity building exercise to show the kinds of experiential, professional, and financial opportunities that can arise for individuals involved with the making of the carbon market.

Yang, a student at a top university in China, took a welcome break from his long days at the computer by flying to a carbon market training in Hainan, a tropical island and popular tourist destination in the South China Sea. The training was part of a larger program providing courses on carbon markets for developing countries. Last year and the year before, similar trainings had been held in Portugal, Thailand, and Belgium. This year, the workshop focused on China's carbon market, with only Chinese trainees.

The two dozen or so attendees came from Chinese universities, potential carbon traders and brokers (清算所), carbon exchanges, firms regulated by the carbon market, NGOs, and banks. Given his monthly stipend of around $900, Yang would not have attended the training on his own. In fact, none of the trainees had to pay to attend. The trainers, who were carbon market experts mostly from Europe, were also compensated for travel and lodging costs, due to funding from the sponsoring European organizations. Sizing up the hotel and meals during the conference, which were a welcome upgrade from the dorm and cafeteria at his university, Yang estimated that sponsors probably had to pay 10,000 yuan (around $1,500) per trainee.

On the first day of the training, Huang, a Chinese national who worked for one of the sponsoring European organizations, posted enthusiastic pictures, emojis, and updates to her WeChat social media account at the start of the conference. Huang believes that her organization, which has a small office in Beijing, has a personalized and therefore highly effective approach to the trainings they run in China. They allow a maximum of 40 people at their trainings, in contrast to the Ministry of Ecology and Environment (MEE), which also runs carbon market trainings throughout China, though for hundreds of people at a time. Huang says that at her organization's trainings, there must be cooperation among the trainees, and they must at least all know each other's names. She says this is the more efficient way to learn. In promoting her organization's trainings, she seeks to clarify and demonstrate their competitive edge, which could attract more funding in the future.

Huang thoroughly documented the training on social media, posting appealing photos from field visits to Hainan Airlines, one of the top airlines in China, and a biogas collection facility that were organized in collaboration with the Hainan government as a part of the training. She also shared daily photos of the lectures and discussions. At the end, she posted a photo of the certificate of participation she received, writing, "mission completed!!!"

For other trainings, Huang's organization targets mainly local government officials, given their critical role in implementing China's carbon market. Next, Huang's organization will run trainings in Zhengzhou and Wuhan (Wuhan is in Hubei province, which hosts one of the pilot carbon markets), and their goal is to eventually run regional trainings in all parts of China. Hers is one of many institutions providing capacity building services for China's carbon market. Huang estimates that there are over 100,000 people involved in China's carbon market, from regulated facilities to verification groups, government officials, and consultants from foreign organizations, like herself.

The Hainan training, labeled as a capacity building exercise, is exemplary of the meta-market of capacity building. A free-flowing cluster of carbon market stakeholders was subsidized to exchange and align knowledge about China's carbon market. The sponsoring organizations, in turn, were funded by larger institutions with an interest in expanding China's carbon market, such as the European Commission (the EU has its own carbon market). Participants in the Hainan training by and large enjoyed the event and the opportunity to visit the beautiful island of Hainan. The organizers of the training also bolstered their reputation and their revenue - with several dozen trainees and trainers costing around $1500 per person, plus administrative overhead, the training organization probably received at least $100,000 for those few days – and this was just one of the many trainings they ran each year.

I further shed light on the capacity building machine by dividing it into separate institutional actors in the following sections, detailing their position, perspectives, and potential opportunities from capacity building. Biedenkopf et al. (2017) identify three main actor groups that they argue are crucial for understanding capacity building as a policy infusion process: external financiers, implementing consultants, and local coordinators. Since different actors can have multiple functions, I instead organize actors by their type of institution. While pedantic, it allows for a more complex, cross-sectional look within these groupings.

NATIONAL AND LOCAL GOVERNMENTS: CAPACITY PYRAMIDS

Given the various bureaucratic and social bottlenecks for entry into the civil service and positions like those at the NCSC, the outsourcing of expertise is inevitable. The national carbon market policymakers have developed their own ways of cultivating networks of experts to fill their own capacity, a process described in the prior section, "From Data to Decisions". How does the national government engage with building the capacity of other actors in the carbon market?

The national government's strategic shift towards capacity building has large costs. First, there is the direct cost of national and local government subsidies for emissions verification services, trainings and workshops for local government officials, and so on. Second, the designation of the first phase of the carbon market as the capacity building phase significantly pushes back the onset of actual carbon trading. National policymakers realized as early as 2017 that national-level trading would not happen on the original timeline laid out by top leaders, but official re-framing of this waiting period as a capacity building phase was not publicized until several years later. Finally, the recent shift in bureaucratic structure has fractured the already fragile capacity of national policymakers and significantly slowed the onset of actual trading. When responsibility for carbon markets was transferred from the NDRC to the MEE, a similar shift had to happen for local governments, with local Environmental Protection Bureaus (EPBs) taking over from the local DRCs. While the NCSC as a unit was transferred to the MEE without any physical relocation of offices or staff, this is not true for the local transfers. While some personnel from the local DRCs moved to the local EPBs, more are new hires. “They have to be trained from scratch. Some capacity was lost,” said one consultant. In addition, although the EPBs are authorized to collect fines and could enhance enforcement of the carbon market policy, local officials who previously managed carbon markets within the DRCs may not be willing to move to the EPBs, since the DRC is a more powerful agency in the governmental hierarchy.

While many consultants I spoke with about this shift described its consequences in terms of waste and loss of capacity, from another angle, this is in fact a massive business opportunity for continued capacity building services. The restructuring has led to an even greater need for capacity building among local government officials. In fact, local government staff have always been the major target of capacity building efforts. They are the ones ultimately responsible for wrangling the regulated firms under their jurisdiction into compliance with the national carbon market. While each of the local governments in the pilot carbon market areas typically has its own network of experts from local universities and even international consultancies, capacity for the national carbon market both within and outside of pilot areas very much still needs to be built.

According to one consultant, over 2,000 people affiliated with local DRCs have already received training. Many of the targeted trainees are directors or deputy directors who can presumably bring the rest of their staff into the fold of the carbon market. NDRC-issued invitations to trainings were necessary and highly effective for producing robust participation and attendance on the part of local governments. An implementer for one of the trainings with NDRC-issued invitations said, “We only had funding for six people from each local bureau to come. But many bureaus self-funded additional people just because they perceived it as very important – an invitation from the central government!” The clear prominence of carbon markets as a national government priority has even led some provinces to vie for participation. Fujian created a voluntary carbon market separate from the official pilots, while Sichuan, Zhejiang, Xinjiang, and Hunan are purportedly actively considering similar systems. Who could resist the opportunity to demonstrate enthusiasm for national strategic policies while also getting paid to it?

For the Shenzhen pilot, proficiency in capacity building was key to marking it as one of the most successful pilots. Shenzhen as a municipality has fewer emissions sources and lower emissions than other pilot carbon market areas. The prospect of ratcheting down emissions in an already relatively low-emissions area may have motivated local policymakers to focus on their comparative advantage of capacity building. Shenzhen stakeholders took pride in their concentration of highly educated workers and their international connections, especially through proximity to Hong Kong. Within a year of announcing the goal to build a pilot carbon market, Shenzhen established a capacity building center (能力建设中心), the first of its kind among the pilots. Various stakeholders in Shenzhen's pilot carbon market were taken to California for a study tour (California has a state-level carbon market that started just before China's pilots). "Tianjin and Chongqing were less successful because they did less capacity building," said one Shenzhen carbon market expert.

The logic of capacity building even creates opportunity for trainees to become trainers. A group of local officials from Shanghai has participated in trainings with one capacity building organization since 2010. Having attended around ten trainings total, including study tours abroad, they are now joining the national-level working groups of experts convened by the NCSC. If they are good students of official capacity building exercises, carbon market policymakers from local governments, especially those who have implemented pilot carbon markets, can easily become capacity builders for their new colleagues following restructuring and their counterparts in areas new to carbon markets. In cynical terms, this recruitment structure mirrors a pyramid scheme in its reliance on continuously seeking out new minds with un-built capacity. While the eventual goal is presumably to have a mature market where regulated companies internalize all this capacity, official restructuring and a strategic shift towards an official capacity building phase for the national carbon market have created at least several more years of booming demand for capacity building on the part of national and local government.

Consultancies: A Numbers Game

Consultancies are the brokers who organize trainings for local governments and regulated companies on the part of the funders – national government and international organizations. Consultancies run trainings themselves as well as arrange for external experts to assist with the trainings. These consultancies, defined by being paid for their capacity building services, vary – from small to large companies, Chinese and international. With the announcement of the first phase of the carbon market as a foundation-building phase, consulting companies have increasingly framed their services as capacity building, now an attractive term for a range of international and domestic funders.

The most high-profile carbon market consultant is SinoCarbon (中创碳投). Founded in 2010, SinoCarbon now has employees in the hundreds and branches in most provinces. SinoCarbon is unique in that is both a consultancy as well as being explicitly involved in the policymaking process, such as the NCSC-convened expert committees, and assisting with the development of the allocation method for the national carbon market. SinoCarbon provides capacity building services through general carbon management trainings and detailed verification trainings. On top of a basic curriculum, these trainings may be tailored by sector or the level of the trainees (i.e. high-level managerial staff, or not). Regulated companies hire SinoCarbon to do personalized trainings, in addition to broader, semi-public trainings associated with national government sponsors. Their slick course materials include textbooks, pamphlets studded with photos and biographies of the high-profile experts they bring in for the trainings, and interactive materials like quizzes and mock trading exercises. "It's the first company firms or pilots will hire to do capacity building or verification," said one expert. SinoCarbon staff claim they have trained over

5,000 people. Part of the appeal of having one's capacity built by SinoCarbon is that SinoCarbon can provide certifications for its trainings – certifications thast are issued by the national government human resources agency (人保部). High-level managers can participate in a carbon management program that leaves them with a prestigious certificate. Unlike most international organizations and consultancies, which focus on local government officials, SinoCarbon's trainees are mostly from regulated firms in China, especially SOEs.

While SinoCarbon stands tallest among the field of consultancies providing capacity building services, these consultancies have a shared vision of what capacity building means. First, the mantra "train the trainers" is echoed by almost every consultancy I have spoken to. Second, capacity builders are very focused on volume and throughput of their trainees. Trainings are handled in traunches and trainees grouped into ever-larger numbers. Consultancies track and regularly put forward the number of people they have trained as markers of their impact and thus importance. While many capacity building groups recognize the importance of quality over quantity in their training, the focus on throughput remains the same, even if with less volume. The standardized vision of the carbon market is designed to be spread ever farther and wider by the logic of China's capacity building consultants.

REGULATED COMPANIES: PUBLIC RECEPTION BENEFITS

Contrary to the dynamics of carbon markets in many other countries, to-be regulated companies in China are often enthusiastic about participating in the carbon market. Larger SOEs are already aware of the national climate and clean energy agenda. Enthusiastic participation can have political rewards - the national government has been picking large SOEs and making positive examples of their contribution to the pilots. "The public reception benefits are large for playing along and even leading," explains one consultant. Participating in the carbon market can be far preferable to shutting down operations, a frequent solution to overcapacity and the need to meet environmental targets in China's past environmental policy. In addition, SOEs profits are unlikely to be affected by the carbon market due to their unique structure, with support coming from the government. With decades of experience with command-and-control environmental policy and pollution levies, regulated companies are familiar with having to "pay to pollute".

More elusive is the idea that these companies could save money by actively participating in the carbon market. The financial aspects of the carbon market are not yet incentives for firm participation, as has been detailed in the literature (Lo and Howes 2013). As discussed in the first section of this chapter, many companies are still getting the hang of MRV. "They wonder why they have to buy carbon, it's so different from just buying tables and chairs," said one carbon market expert. As the MRV process brings companies into a standardized protocol, further capacity building exercises are attempting to teach regulated companies about the financial possibilities of engaging in the market. Yang, the student at the carbon market training in Hainan, had doubts about how effective the training was. Trainees from the power sector struggled to understand the financial opportunities from a carbon market because they could not grasp the concept of buying and selling allowances in a competitive market, given China's tightly regulated power sector. "The carbon market is a burden to them, not an opportunity. They don't want to make money; they just want to not lose money. They don't care about carbon trading at all, they just want to comply," Yang summarized.

Increasingly, regulated companies are re-oriented their structures to meet the carbon market. Companies are increasingly hiring and designating staff to deal with the carbon market. As a representative from the China Electricity Council said, "setting up the carbon market is not a beautiful story. There is concrete work to do every day." The CEC provides technology roadmaps and information on CEMS and MRV to help their member companies "have more choices." While designated staff are increasingly being appointed, usually in financial departments (财务部) or environment and safety departments (环境安全部), a huge range of employees from regulated companies attend capacity building trainings. "Our companies just have huge demand for capacity building and training, from the senior level to the junior level," said a representative from a petrochemicals group.

INTERNATIONAL ORGANIZATIONS: OBJECTIVE EDUCATION

There are roughly two types of international organizations engaged in capacity building for China's carbon markets: international consultancies or NGOs that provide capacity building services, and international financiers, which may channel finance for capacity building through other organizations or may directly provide capacity building services themselves. Biedenkopf et al. 2017 characterized these non-Chinese financiers of capacity building projects for China's carbon market: most financiers are national or subnational governments where there are already operating carbon markets – unsurprisingly, most financiers are European, where the EU ETS is. Some international organizations or research institutes also provide finance for capacity building. The European Union, Germany, and Norway are the largest governmental funders, while the World Bank's Partnership for Market Readiness (PMR) "has the largest single project in financial terms, with a budget of $8 million" (Biedenkopf et al. 2017). The World Bank's PMR is a global effort to prepare countries for carbon markets, and began working in China in the 2000s.

International consultancies like Ecofys and ICF International have been involved with both the pilots and the national carbon market, often sub-contracted by the aforementioned agencies. One Chinese government official estimates that international organizations have spent several million USD on these carbon market capacity building activities – still much less than the Chinese government's several hundred million.

While domestic institutions are focused on getting the national carbon market off the ground, including the massive costs of verification, international organizations have the resources and distance to think of the bigger picture. A consortium of European governments is trying to build a post-2020 evaluation framework for the carbon market to assess its performance along the way. The European Commission is also "trying to get local stakeholders to have a better sense of long-term road-mapping," says one of their contractors. To achieve these big-picture goals, funding from these organizations comes in massive, multi-year traunches, with multiple phases and many partners, structured around plans and objectives. There are regular donor-implementer meetings where these cooperating groups discuss strategy. “We have to work together to ensure that work isn’t repeated, which would waste money. The NCSC doesn’t play a coordinating role at all, so we have to actively work together,” notes one international consultant. Indeed, there is a remarkable level of coordination and deliberate standardization among China-based international staff. Training materials from previous years are “recycled” to meet the need for “consistency”. “When we train people, it’s not propaganda, but rather an objective education about how to deal with the carbon market.” At an event on EU-China carbon market cooperation, I hear repeatedly that the Europeans do not want to “copy-paste” their experience to China. Yet, while they are not copying and pasting a specific policy design, it is clear that there is an “objective” standard for the carbon market and its management that these myriad capacity building efforts are promoting.

CARBON TRADERS: BRAVING THE MARKET

Limited involvement from the financial sector is widely seen as a barrier to a strong carbon market in China (Lo 2016). However, while opportunities to make money from buying and selling carbon allowances generated by the carbon market may be limited in the near term for would-be carbon traders, there is tremendous economic opportunity in the capacity building meta-market.

Carbon traders include the exchanges that manage allowance transactions (there is an exchange in every pilot carbon market area) as well as other types of organizations, like private consultancies and financial institutions, that are participating in the buying and selling of allowances for financial gain. So far, it has not been uncommon for investment institutions of various sizes in the pilot areas to buy up allowances in the beginning of the compliance period at low prices, then sell them at the end of the compliance period when the price is high. Regulated companies have to take the price at the end of the compliance period because “they have not been brave enough to evade this yet and buy and sell on the market,” says one professor who studies the financial aspects of the carbon market. However, aside from a few niche firms that have experience with carbon trading, the trading itself is not lucrative. The carbon exchanges are supposed to make money from managing these transactions, but most have actually shifted to consulting and capacity building, which are far more lucrative in the near term. Representatives from China’s carbon exchanges give lectures, assist with trainings, and participate in conferences around the country as they try to figure out their role while waiting for more opportunity from the actual trading of carbon.

CONCLUSION

An interpreter whom I befriended at a carbon market event offered her perspective: “Lack of capacity isn’t a problem in China. The carbon market must have been delayed for other reasons. You can just buy capacity. It’s like if a company doesn’t have a printer, it's cheaper to go pay to use one at another company rather than buying a whole printer for yourself." Consulting organizations have generated a market for their printing services, so to speak. Prior literature has described these consulting organizations as competitive with each other, never conflicting outright but nonetheless working to carve out geographical and topical niches for their services (Biedenkopf et al. 2017). At the same time, they "reduce the costs of capacity development by virtue of specialization", more effectively coordinating knowledge and skills transfer while "the tendencies for state domination in this process are declining" (Lo et al. 2018). Competition makes a service more efficient – a healthy neoliberal market.

Local governments and regulated companies, instead of fully managing their own engagement with the carbon market, are simply outsourcing the work to a burgeoning consulting field. International financiers and the national government mostly foot the bill. The national government can make delay productive in the carbon market through capacity building. Thus, there is little incentive for anyone to wean themselves from the capacity building cycle just yet.

Like blind men touching an elephant, external researchers have only a limited view into what kind of beast China's national carbon market will prove to be. In this chapter, I have tried used my insight into quantitative modeling of the carbon market as an entry point to understanding the much broader nature of the carbon market itself. Through carbon market modeling, I saw how expertise was constructed and deployed – from there, I worked backwards, to uncover the fundamental data being gathered to inform the market, and forwards, to understand how expertise was being transferred in the form of capacity building to ever more carbon market trainees. I have reorganized this thought process into a story of how emissions data is collected, how decisions are made about how to regulate these emissions for the carbon market, and then how those decisions are put into standard practice through capacity building. In doing so, I try to move beyond current political economic studies of China's carbon market. While providing illustrative stories that can contribute to the longstanding dialogue on the tensions of centralization and decentralization, state and market in China, I attempt to move beyond diagnosis of an imperfect market, and towards a specific explanation of how Chinese neoliberalism is being enacted through ecological civilization and the carbon market.

China's carbon markets capture the essence of ecological civilization, which insists on uniting economic growth and environmental protection. To operate, China's national carbon market must spread the vision of a carbon commodity, once an invisible byproduct of industrial production. Facing challenges in the onset of trading carbon at the national level, national policymakers have elevated the spreading of this vision (called capacity building) as the first phase of the national carbon market. Data collection must be standardized, experts cultivated, and trainings conducted. This phase is only supposed to last for a few years until the onset of carbon trading at the national level. But, when the carbon market expands to include sectors beyond just electric power, the capacity building engine will inevitably find new fuel. China's neoliberal climate policies are tied to national targets expressed on an international stage. As climate policy is increasingly envisioned as national-level chunks of a global goal, the nature of carbon markets across the world must also become uniform. A global carbon market is a perfect policy for a perfectly uniform commodity, according to economy theory. China faces challenges in making a uniform carbon commodity across its massive domain filled with incredible variety. The story of China’s carbon market is not just one of incompatibility between state and market; rather, it is a bigger story of the taming of heterogeneity to enact a globally-derived national vision by the name of “market”.

PART TWO: THE BELT AND ROAD INITIATIVE

CHAPTER 5: BELTS, ROADS, AND LEAKAGE

THE SCALE OF IMPACT

The Belt and Road Initiative (abbreviated BRI, full name: the Silk Road Economic Belt and the 21st-Century Maritime Silk Road) is often introduced in terms of its scale: one trillion 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 (Ascensão et al. 2018).

This sheer scale has ignited increasing international concern about environmental damage from the Belt and Road Initiative (Horvat and Gong 2019). These environmental concerns can be sorted into several buckets: 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 (Ascensão et al. 2018).

In response, China's leaders have begun to develop and promote the idea of a green Belt and Road. Like the carbon market, the Belt and Road Initiative has been explicitly linked to ecological civilization in China's policy guidances: "Promoting green Belt and Road is an internal need to share the ecological civilization philosophy and achieve sustainable development," according to the Guidance on Promoting Green Belt and Road from 2017 (Belt and Road Portal 2017). While the BRI was not originally tied to environmental goals as the carbon market was, it is now being integrated with the idea of an ecological civilization. At the same summit with President Obama where Xi Jinping announced that China's national carbon market would start in 2017, their joint statement also read: "China will strengthen green and low-carbon policies and regulations with a view to strictly controlling public investment flowing into projects with high pollution and carbon emissions both domestically and internationally."

The sheer scale of China means it is seen as the key actor in many global decision points. Many frame the direction of BRI as a turning point for the global energy system, based on China's decisions on what kinds of energy to fund and how those projects end up operating. "… the Belt and Road Initiative, with its huge volume of investment, is an opportunity we cannot miss to propel our world into a green future and to help countries transition to low-carbon, clean-energy pathways with new infrastructure that is sustainable and equitable," said UN Secretary General António Guterres (UN 2019b).

Although the BRI was first launched in 2013, overseas investment from China is far from a new phenomenon. China provided development aid to countries in Africa during the Mao era. In the mid-1990s, China's State Council began to reform its development aid approach to incorporate economic goals, cooperation, and trade (Yeh and Wharton 2016). In 1999, China officially announced the Going Out policy (走出去战略), which supported domestic companies in investing overseas. For China, the line is thin between official aid and finance coming directly from the government, and commercial arrangements for private actors investing overseas (Bräutigam 2011). The BRI puts a new name, narrative, and institutional structure on an existing process, convenient for broader geopolitical attention. This narrative shift was solidified by the creation of the China Agency for International Development Cooperation (CIDCA) in 2018, one of eight agencies that were created during the 2018 bureaucratic reforms alongside the MEE. CIDCA took on more responsibility for management of the BRI from the Ministry of Commerce.

The high-profile attention to BRI and its potential impacts masks the continuity in China's overseas engagement in infrastructure and development. Why is it that China's overseas investment is increasingly being seen as a channel of environmental impact? In the next section, I discuss several conceptual frameworks that can mechanistically connect investment to environmental impact.

FINANCE AS LEAKAGE

To begin to unpack how to evaluate the environmental impact of BRI and Chinese overseas investment, I propose looking at BRI through the lens of leakage – the movement of pollution, through various channels discussed below, to an unregulated area once regulation occurs, such that total pollution ends up being higher than before regulation. This opens up a range of frameworks and empirical methods that are appropriate for understanding the aggregated effects of Chinese finance.

I identify several areas of the literature that characterize leakage. The first area is the economics literature on trade and the environment. This literature explores the hypothesis that the advent of trade could increase pollution. Trade allows economic gains from specialization, but simple theoretical models illustrate that the impacts of trade on the environment are ambiguous, as channels can be delineated for both positive and negative effects (Copeland and Taylor 2003). Early empirical studies indicated that openness to trade is associated with less growth in pollution intensity within a country, likely because cleaner technologies are used by multi-national companies and for export-oriented production (Birdsall and Wheeler 1993). There is also a large body of literature using multiregional input-output (MRIO) databases to estimate embodied emissions in traded goods, which can be thought of as one avenue of leakage resulting directly from trade (Moran et al. 2018). That is, there is clear evidence from MRIO models that although emissions have decreased in many developed countries over the past two decades, net emissions have gone up because production is moving to poorer countries, which then export products to rich countries. While MRIO databases can help with accounting for emissions by final consumption, they ignore the economy-wide impacts of consumption decisions on prices. Many MRIO studies interpret their results around the assumption that imports *cause* emissions in the exporting country, when in fact this may not be a direct relationship (Jakob and Marschinski 2013). Partial and general equilibrium models directly simulate the movement of production across borders, not just the movement of products.

The second area of leakage literature is the analysis of production and its associated pollution moving across borders in response to regulation – the classic definition of leakage. This is also sometimes known as the pollution haven hypothesis – the idea that firms are attracted to areas with weak environmental regulations. Partial and general equilibrium models are used to simulate leakage as a response to different policy changes, though the choice of model also has theoretical implications – partial equilibrium models will necessarily show that a pollution tax produces a pollution haven effect, while general equilibrium models allow changes in factor prices to moderate cost increases in the taxed sectors, so the leakage effect may not be clear (Karp 2011). The magnitude and direction of these leakage effects depends on several key elasticities, such as the elasticity of fossil fuel supply or the substitution elasticity of factors of production.

Finally, there is some literature on finance and investment as conduits for leakage. The hypothesized mechanism is that a decrease in the returns to capital in one region due to regulation causes firms to invest overseas, where pollution intensity is higher (Siikamaki et al. 2012). This is similar to the prior definition of leakage, but with explicit articulation of international investment flows. Empirical analysis of the pollution haven hypothesis has found that foreign ownership of a firm in a given country is associated with lower levels of energy use (Eskeland and Harrison 2003). Many studies assess the determinants of foreign direct investment (FDI), including weak environmental regulation. Interestingly, a study on the determinants of FDI from China found that ethnically Chinese sources of investment displayed more pollution haven-seeking behavior than non ethnically Chinese sources (Dean et al. 2009). Recent studies are beginning to apply the determinants-of-FDI framework to BRI. One study found that BRI host countries had more favorable exchange rates for the Chinese yuan, displayed more "market openness", and had relatively less infrastructure compared to non-BRI countries (Liu et al. 2017). However, the average differences between BRI and non-BRI countries may disappear as more and more countries sign memorandums of understanding with China regarding the Belt and Road, raising questions about the utility of country-level analysis on the determinants of BRI. And more importantly, how do we move from determinants of inward investment to understanding the impacts of that investment?

The BRI is increasingly being recognized as directed leakage, that is, a strategic effort on the part of China's national government to provide a "soft landing" for domestic infrastructure companies that are facing shrinking markets within China by helping them expand abroad. However, framing of BRI impact is still simplistic, shirking the complex mechanisms that a leakage lens provides.

Much of the media and advocacy discourse on BRI implies that finance directly translates into impact. This narrative was and is embodied in divestment campaigns, which urge entities to withdraw their investments from places or industries associated with a negative impact. From the divestment campaign against apartheid in South Africa in the 1980s to today's fossil fuel divestment campaigns to combat climate change, the implication is that money can be wielded as a tool to lessen an undesirable impact. On the flip side, the investment from BRI is assumed to be causing environmental harms. For example, in a policy brief titled "The Carbon Consequences of China's Overseas Investment in Coal", the author estimated the lifetime CO_2 emissions from 50 coal plants that had received support from Chinese financial institutions, a massive quantity of emissions (Gallagher 2016). However, are these emissions direct "consequences" of this investment? Without Chinese financial support, many of these plants would likely still be built, so it is simplistic to directly attribute their lifetime emissions to one policy initiative. Yet many such analyses assume that the scale of BRI will lead to a similar scale of impact. Consider also a scorecard a consortium of environmental NGOs assigned banks around the world based on the scale of their investment in coal power. Among all banks rate, three Chinese banks received F grades and the lowest rank of "Worst Banks" due to the total amount of their col power financing (Rainforest Action Network 2019).

Is there something more than scale at play in these fears of BRI? If so, how do we assess the impact of specifically Chinese investment? Many of the environmental concerns about BRI arise from perception of BRI as a sudden and new phenomenon, and both its continuity and its relative impact are rarely considered. The empirical evaluations of leakage discussed above provide evidence for the environmental impact of outgoing finance, but for the most part academic research has yet to consider the nature of the investment sources and how this affects environmental impact. A growing number of specific case studies document social and environmental impacts for individual BRI projects, but they cannot shed light on relative or aggregated impacts. In the next chapter, I attempt to compare the relative environmental impacts of Chinese and non-Chinese finance across thousands of individual plants.

CHAPTER 6: EMPIRICAL ANALYSIS OF ENVIRONMENTAL PERFORMANCE OF CHINA'S OVERSEAS COAL PLANTS[11]

INTRODUCTION

China's 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). China frames its own overseas investment and aid as South-South cooperation that respects the sovereignty of host countries and promotes non-interference and mutual benefit (Yeh and Wharton 2016). At the same time, various international media outlets and advocacy organizations have created the narrative of China going overseas with extractive investment projects that have negative social and environmental impact in host countries. China is critiqued for preying on resources, flooding markets with cheap Chinese commodities, and supplanting democracy and human rights with a governance-agnostic development model (Hofman and Ho 2012). These contrasting viewpoints in fact both reinforce the notion that Chinese investment is qualitatively unique (Lee 2014).

Academic studies from the fields of geography, sociology, and area studies have formed a robust literature of case studies of China's projects in other countries, examining social and environmental impact of China's overseas investment case by case. In the economics literature, there are many studies on the determinants of foreign direct investment (FDI), including weak environmental regulation (see Chapter 5). However, the former studies lack aggregated, comparable quantitative information, while the latter studies do not look at the impact of investment on environmental metrics (rather, they tend to investigate the reverse - the impact of environmental characteristics on investment inflows). This chapter aims to address both these shortcomings in the literature. It will provide evidence for the claim of the uniqueness of Chinese involvement, summarizing data on China's overseas projects and comparing them to projects owned, designed, or built by other sources. As the Green Belt and Road becomes an increasing topic of study for research and policy institutions around the world, it is imperative to first establish a baseline understanding of the environmental impacts of China's overseas finance.

This study will compare coal-fired power plants in Asia receiving finance from 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, such as the Natural Resources Defense Council, and academic institutions, such as Boston University, actively track coal plant projects around the world. 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) have revoked development aid for coal power plants in developing countries, although these gaps are readily filled by private capital (Jones et al. 2011). These same groups, as well as environmental advocates, have expressed interest in the Belt and Road Initiative and

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[11] This research was co-authored with Samuel Evans and will be submitted to a journal as an edited version of this chapter.

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. 2018). While the Asian Infrastructure and Investment Bank (which China contributes finance to) has ruled out finance for coal-fired power plants, no Chinese banks have placed any restrictions on coal financing to date or to our knowledge (IEEFA 2019).

The regional focus for this chapter is Asia: Asia is the first and primary 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).

DATA

We obtained 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 China's overseas projects, we also excluded coal plants within China. The final sample size is 4,290 plants. Below, Figure 13 shows a map of the coal plants in this dataset that have latitude and longitude information (n = 2,516).

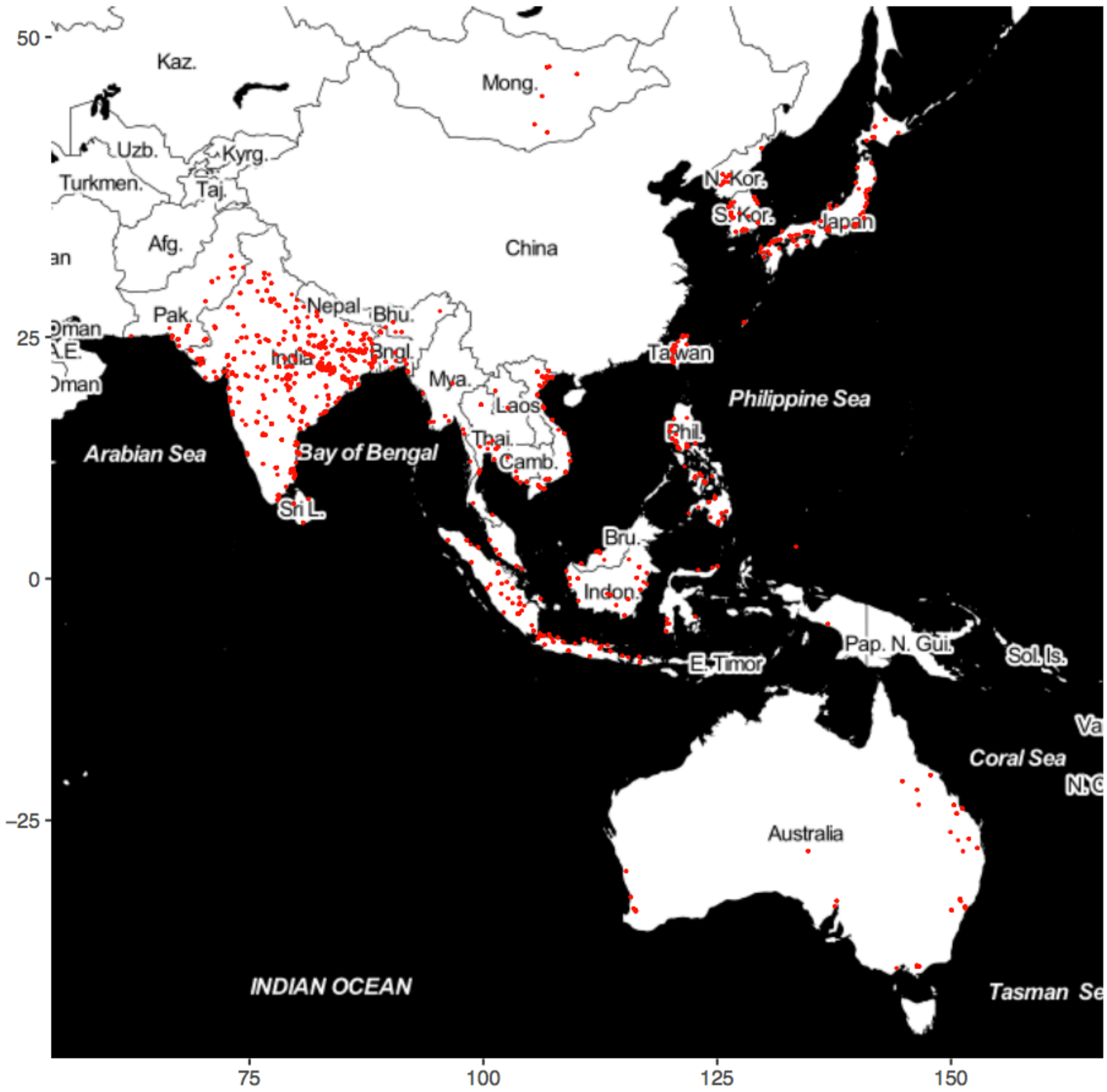

Figure 13: Map of Coal Plants in Asia (excluding China)

We also constructed several key variables. We used the Platts data on parent company (n = 4,260 observations with data on parent company), architect or engineering company[12] (n = 1,778), and construction company (n = 1,733) to identify the country of origin for each of these types of companies. From the maps below (Figure 14), 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 don't reveal the relative sizes of the companies. India clearly has many companies of all types, while China, which tends to consolidate

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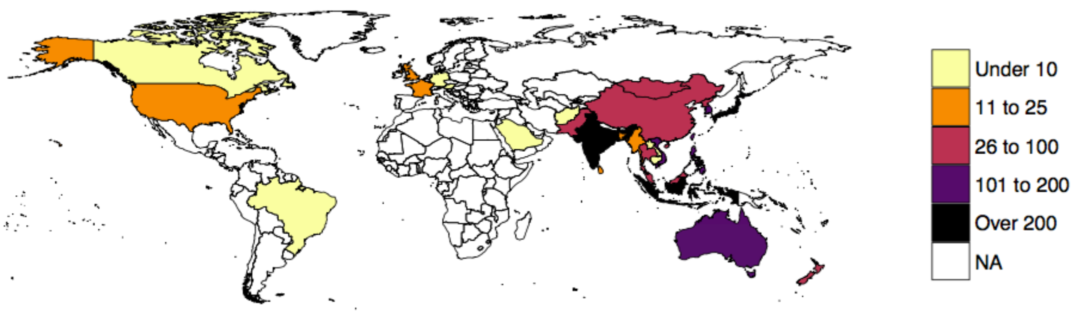
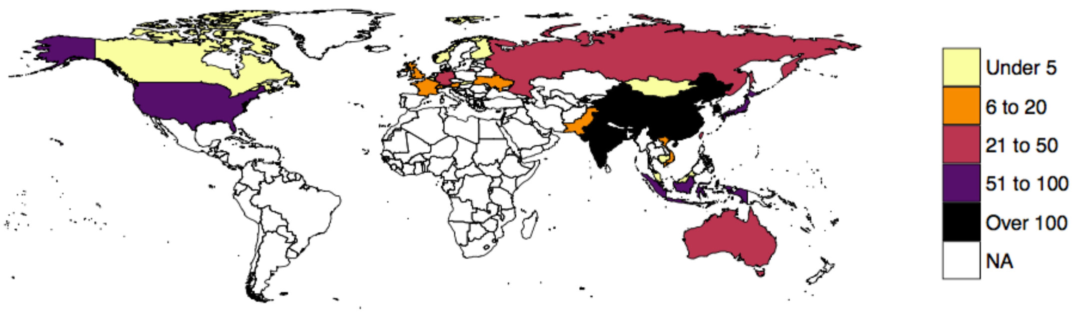
[12] Platts describes these firms as the "primary architect or engineering company", from here on simply referred to as engineering company

resources in large state-owned companies, may have a fewer number of companies but not necessarily a lower market share.

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

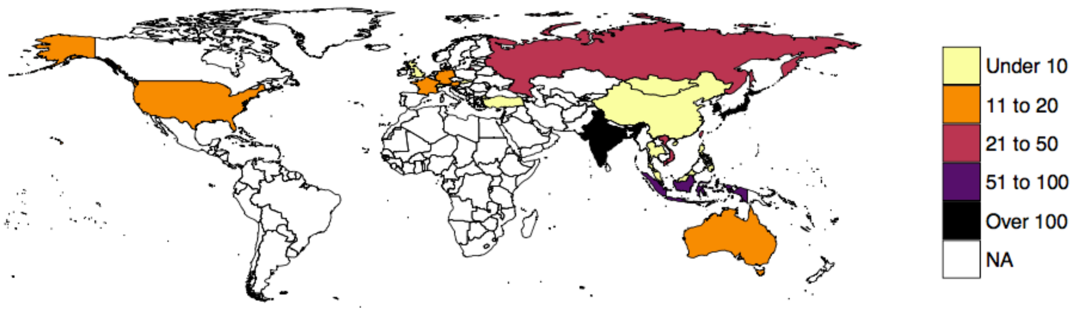


Figure 14: Countries of Origin for Coal Plant Company Types

Each type of company (parent, engineering, and construction) was then coded with a dummy 'treatment' variable for Chinese (D = 1) or non-Chinese (D = 0) ownership. Joint ventures with a Chinese company were coded as Chinese.[13] This dummy variable is a proxy for receiving Chinese finance and thus being connected to management practices, technology choices, or other mechanisms unique to China's overseas finance. Table 7 shows the balance of observations of Chinese and non-Chinese companies by company

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[13] Hong Kong and Taiwanese companies were coded as non-Chinese, although there is some empirical evidence that Sinophone and ethnically Chinese areas may have similar FDI patterns (Dean et al. 2009).

type.

Table 7: Ownership by Company Type

	Parent Company	Engineering Company	Construction Company
Chinese	87	445	396
Non-Chinese	4,173	1,312	1,309

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 CO_2 a plant produces per unit of energy generated (Equation 6). 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 8), 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 SourceWatch. Table 9 shows the assumed penalties for plant age and capacity (SourceWatch 2019a). We also validated this approach by comparing our calculated emissions intensity and EPA-reported emissions data for a sample of coal plants in the United States (see Appendix).

$$Emissions\ Factor\ \left(\frac{tons\ CO_2}{btu}\right) * Heat\ Rate\ \left(\frac{btu}{MWh}\right) = CO_2\ Intensity\ Rate\ \left(\frac{tons\ CO_2}{MWh}\right)$$

(Eq. 6)

Table 8: Assumed Base Heat Rate by Steam Type

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

Table 9: 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. 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 and sulfur dioxide control technology types to assess whether each plant's technology was "best available technology" (BAT) or not. There were 10 different particulate matter control technologies and 16 different sulfur dioxide control technologies across all plants. For each of these types of pollution control technologies, we coded a dummy variable for BAT or non-BAT. To assess if a technology was BAT or not, we used the catalogue of BAT air pollution control technologies based on WEPP data from Purvis et al. 2014. For a list of technology types and their ratings, see the Appendix. Table 10 shows the final balance of observations on control technology classifications by air pollutant.

Table 10: Number of Plants with Best Available Air Pollution Control Technologies

	Particulate Matter	Sulfur Dioxide
Plants with BAT	247	857
Plants with non-BAT	1,565	797

Summary statistics for the final list of variables are provided in Table 11 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 11: Summary Statistics by Company Type

	Chinese Parent Company		Non-Chinese Parent Company	
	N	Mean	N	Mean
Capacity (MW)	87	455.5	4,203	263.7
Year plant was built	49	2016	2,923	1995
Steam pressure (bar)	8	206	1,408	124.2
Steam temperature (°C)	8	554.8	1,395	519.9
Emissions factor (kg CO_2/TJ)	44	97,030	2,304	97,810
Heat rate (btu/kWh)	47	10,320	3,060	11,990

	Chinese Engineering Company		Non-Chinese Engineering Company	
	N	Mean	N	Mean
Capacity (MW)	448	297.4	1,330	266.2
Year plant was built	348	2012	1,154	2003
Steam pressure (bar)	103	181	490	144
Steam temperature (°C)	100	559.5	492	530.1
Emissions factor (kg CO_2/TJ)	265	98,040	798	99,820
Heat rate (btu/kWh)	360	11,110	1,181	11,570

	Chinese Construction Company		Non-Chinese Construction Company	
	N	Mean	N	Mean
Capacity (MW)	339	287.2	1,326	284.9
Year plant was built	241	2012	1,174	2003
Steam pressure (bar)	30	171.5	491	151
Steam temperature (°C)	30	562.6	489	535.4
Emissions factor (kg CO_2/TJ)	181	98,270	792	99,500
Heat rate (btu/kWh)	255	11,250	1,202	11,510

METHODS

A simple comparison of the mean CO_2 emissions intensity for Chinese and non-Chinese plants by company type indicates that Chinese companies have a lower average emissions intensity (Table 12). To explore this intriguing difference further, we control for other variables using ordinary least squares (OLS) and matching regressions.

Table 12: Average Emissions Intensity (tons CO_2/MWh) by Company Type

	Parent Company	Engineering Company	Construction Company
Chinese	1.046	1.156	1.167
Non-Chinese	1.230	1.211	1.202

We analyzed the effect of ownership of each type of company separately for each outcome variable. For assessing CO_2 emissions, we used ordinary least squares (OLS) regression to examine the effect of a Chinese parent, engineering, or construction company on CO_2 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.

Because random assignment of ownership of these companies can't be approximated, we use a matching technique to attempt to isolate variation from country of origin of these companies. In addition, the imbalance in sample size for observations of Chinese and non-Chinese companies indicates a need for matching (see Table 11, summary statistics). For analyzing CO_2 emissions, the Chinese and non-Chinese companies were matched based on the same variables controlled for in the OLS regression: status and electricity type. We use the MatchIt package in R for the matching analyses.

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 matching analysis. 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. Since the outcome variable is binary, we perform a logistic regression, controlling for size, status, fuel type, steam type, country, and electricity type of the plant. We also perform a matching analysis, matching on the same variables as in the logistic regression.

RESULTS

Table 13 presents the results from our analysis of CO_2 emissions intensity (or rate). We show the coefficient for the effect of Chinese ownership, controlling for status and type of coal plant. The OLS and matching specifications both indicate a statistically significant effect similarly large in magnitude for plants with Chinese parent companies - that is, plants with Chinese parent companies have around 10-13% lower emissions intensity. We find that the effect on CO_2 emissions rate is less for a Chinese engineering company, around 3% lower than non-Chinese companies for the OLS specification. The matching coefficient was similar in magnitude by not statistically significant. For a Chinese construction company, emissions rates are 5% lower than non-Chinese companies based on our matching analysis.

Table 13: CO_2 Emissions Results, Coefficient of Chinese Ownership Dummy

	Dependent Variable: log(Emissions Factor * Heat Rate)	
	OLS	**Matching**
Chinese Parent Company	-0.101***	-0.135**

	(0.029)	(0.047)
Chinese Engineering Company	-0.031*	-0.029
	(0.013)	(0.017)
Chinese Construction Company	-0.014	-0.048**
	(0.014)	(0.017)

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

We also examined the interaction effect of steam type and plant ownership, variables which are independent for all types of companies based on a chi square test. We used a dummy variable for subcritical and non-subcritical plants and found that the interaction term was significant for parent companies, indicating that Chinese ownership of parent company has a unique effect on CO_2 emissions intensity for subcritical plants, while CO_2 emissions intensity of supercritical and ultrasupercritical plants are less likely to be affected by Chinese ownership of parent company. This is an interesting interaction effect given the focus of international media and advocates on critiquing China's investments in subcritical coal plants overseas (see e.g. Shearer et al. 2019). Given the difficulty in estimating plant-level CO_2 emissions, these results indicate the need for further analysis of variable interactions while improving data quality.

Table 14 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 engineering companies and construction companies are associated with higher energy efficiency in coal plants, mirroring the direction of results for CO_2 emissions intensity (since higher energy efficiency would tend to be associated with relatively lower emissions intensity). Coal plants with Chinese engineering companies have around 5-6% higher steam temperature than those with non-Chinese engineering companies, and 17-38% higher steam pressure, an effect that is significant across the OLS and matching specifications. Plants with Chinese construction companies have around 4% higher steam temperature than those with non-Chinese construction companies, and 12-14% higher steam pressure, an effect that is significant across specifications. However, the effect of a Chinese parent company is lower in magnitude and not significant across specifications.

Table 14: Energy Efficiency Results, Coefficient of Chinese Ownership Dummy

	Dependent Variable: log(Steam Temperature)	
	OLS	**Matching**
Chinese Parent Company	0.003	-0.063
	(0.037)	(0.040)
Chinese Engineering Company	0.047***	0.060***
	(0.010)	(0.015)
Chinese Construction	0.045***	0.044**

Company	(0.009)	(0.016)
	Dependent Variable: log(Steam Pressure)	
	OLS	**Matching**
Chinese Parent Company	-0.016	0.469
	(0.141)	(0.263)
Chinese Engineering Company	0.168***	0.353***
	(0.034)	(0.066)
Chinese Construction Company	0.121***	0.147*
	(0.035)	(0.063)

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

Table 15 presents the results for the air pollution control technology analysis. Due to the smaller sample sizes, the analysis of air pollution BAT is less robust and has large standard errors. 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. We find that a Chinese parent company means a plant is more likely to have BAT for sulfur dioxide control technologies, while a Chinese engineering company significantly reduces the quality of sulfur dioxide control technologies. These contradictory results need to be further explored. Other coefficients were not significant, and none of the particulate matter coefficients were significant.

Table 15: Air Pollution Control Results, Coefficient of Chinese Ownership Dummy

	Dependent Variable: Particulate Matter BAT Dummy	
	OLS	**Matching**
Chinese Parent Company	-1.613	-0.836
	(1.074)	(0.945)
Chinese Engineering Company	-0.303	-0.074
	(0.455)	(0.384)
Chinese Construction Company	-0.481	-0.434
	(0.492)	(0.422)
	Dependent Variable: Sulfur Dioxide BAT Dummy	
	OLS	**Matching**
Chinese Parent Company	3.338***	1.935**
	(1.207)	(0.859)
Chinese Engineering	-0.666*	0.164

Company	(0.262)	(0.181)
Chinese Construction Company	-0.274 (0.257)	-0.019 (0.194)

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

CONCLUSION AND DISCUSSION

This paper provides the first systematic comparison of Chinese and non-Chinese coal plants outside of China, collecting and analyzing data on environmental performance across three metrics: CO_2 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. We can also see in Figure 15 that there are differences across company portfolios by steam type of coal plant (subcritical, supercritical, and ultra-supercritical). The steam type of the coal plant plays a large role in CO_2 emissions and energy efficiency. Mirroring our findings, some countries, including China, have a relatively cleaner portfolio. There is much more research that can be done with our dataset, exploring the environmental performance coal portfolios of other countries with coal plants in Asia.

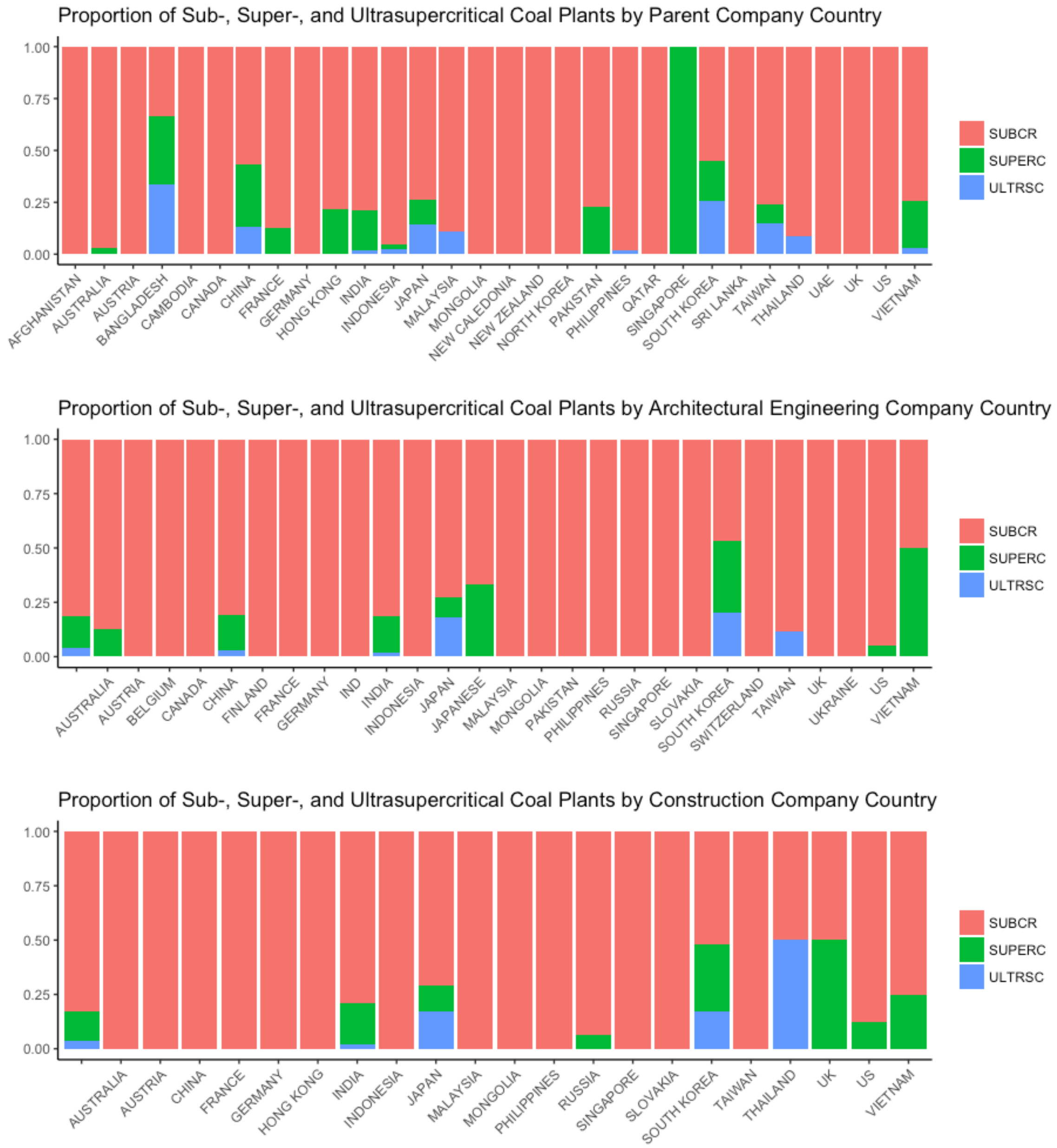

Figure 15: Country of Origin Portfolios by Steam Type

This study has many limitations. The first issue is limited data – for future analysis, we recommend validating the Platts dataset against the Global Coal Plant Tracker and checking the robustness of the results for each dataset. The study also 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, 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 inclusion of the year the plant was built, data on the influx of Chinese involvement at different points in time could open up a new set of analyses. Finally, we hope to improve upon our characterization of Chinese company ownership as proxy for finance, such as by testing the effects of cumulative ownership (i.e. if Chinese ownership of parent, engineering, *and* construction company has a greater effect than ownership of just one of those companies for a given plant).

This analysis provides suggestive evidence that 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. We are not advocating for increased investment in coal. However, for the countries around the world that continue to actively build out coal power, BRI investment could be a comparably better option for low-environmental-impact coal plants. In this analysis, we use parent, engineering, and construction companies as proxies for financial flows, suggesting a potential mechanism through which differential environmental impacts occur (company practices). The next chapter explores mechanisms by which specifically Chinese investment could explain these relative differences in environmental performance of coal plants and infrastructure projects more broadly.

CHAPTER 7: MECHANISMS OF IMPACT

COMPANY ROLES

While the prior chapter shed light on trends across thousands of coal plants in Asia, this chapter returns to case studies to try and understand the mechanisms that might drive our findings – that coal plants in Asia with Chinese parent, engineering, and construction companies are correlated with lower emissions intensity and higher energy efficiency that plants managed by companies from other countries, controlling for plant size, age, and type.

The prior chapter used company involvement as a proxy for finance in order to evaluate the effect of Chinese involvement. The results suggest that the companies that manage, design, and build coal plants are related to relative performance. How might this work in terms of each type of company's role?

Parent companies are hypothesized to mediate external pressures (i.e. from government, activists, and shareholders) and potentially translate these policies into a specific plant's adoption of environmental management practices (Delmas and Toffel 2004). To understand the Chinese companies involved in overseas coal plant development, I briefly profile the Chinese companies involved in the last chapter's analysis. 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 policy institutions, like the China Development Bank, as well as commercial banks, like Bank of China. These companies are directly subject to various guidelines issued by the NDRC and other state agencies. For example, in addition to complying with host country environmental regulations, firms are requested "to undertake environmental impact assessments for their overseas construction and business operations, to apply for environment related permits from the host country… to reduce the emission of pollutants through clean production, and also to actively engage in ecological restoration" (Gallagher and Qi 2018).[14] 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 China's and host country's 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,

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[14] For a full summary of these policies, see Gallagher and Qi 2018.

providing logistics and shipping, equipment, design services, etc. Engineering and construction services are often bundled together in the form of EPC (Engineering, Procurement, Construction) contracts. Though there is no information on this in our dataset, these arrangements may even go further than just engineering and construction, 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 an obvious channel for environmental performance. The China Daily waxed poetic about one such arrangement for a supercritical coal plant in Bangladesh: the China-Bangladesh joint venture company, in a Build-Own-Operate project, "has a professional operation and maintenance team, an efficient management team and a scientific management system, and will spare no effort in ensuring the safe, stable and efficient operation of the units after they become operational… the special coal-unloading terminal makes use of seawater DC cooling and seawater desulfurization technology. Most of the equipment for the project will be made in China" (China Daily 2017).

Given the significant role of different types of companies in directing Chinese finance and its impacts, painting BRI's environmental impact as a function of geopolitical motives, as is often done in the media, is too broad a brushstroke. While some studies attempt to fit the BRI process into political theories, they lack rich empirical evidence. Environmental critics describe BRI host countries as "vulnerable", with already-stressed resources and "underdeveloped" governance. Such portrayals gloss over the complexity of the companies on the ground that are enacting BRI. Although Chinese institutions that operate overseas – like the China Development Bank, argued to be the world's most powerful bank (Sanderson and Forsythe 2012) – are portrayed as monolithic entities, the global integration of China's overseas finance is not an inevitable process that unfolds with full cooperation and coordination of state actors. BRI is not a coherent 'grand strategy' that state capitalists follow in an orderly manner (Jones and Zeng 2019). Rather, Chinese financiers are a diverse group of actors who encounter even more diverse institutions in local government settings (Lu and Schönweger 2017). In some cases, such as the Chinese-funded Kamchay dam in Cambodia, where local energy bureaucrats overrode environmental impact assessments by citing the pressing need for energy supply, the dominance of certain local actors and their goals plays out in the actual implementation of projects, leading to different scales of environmental impact (Hensengerth 2017). Our analysis in Chapter 6 attempted to shed light on the aggregate effects of these dynamics using empirical data.

HYPOTHESIZED MECHANISMS

Besides through company-level choices, there could be other mechanisms through which specifically Chinese finance and management of a plant lead to better environmental performance. In my master's thesis, I found that Chinese-funded and constructed alumina plants in Vietnam had much higher energy intensity than average for the industry, and I identified several mechanisms that might explain why this was the case. Local opponents of the bauxite mines and alumina plants alleged that Chinese managers and workers were unfamiliar with the local geology and brought outdated technologies to Vietnam (Springer 2018). Despite China's claims that their overseas finance is an apolitical boon to developing countries, Chinese finance often comes with several conditions (Nature Editorial 2019). In Vietnam, disgruntled locals complained that the conditions were always the same three things: Chinese currency, Chinese workers, and Chinese equipment. Although in the case of Vietnam's alumina plants I found evidence suggesting these conditions drove worse environmental performance, they could potentially also improve environmental performance if Chinese technology and practices were better than the alternative.

In a systematic review of media articles on coal and BRI published since January 2019 in CoalWire and the RWR Belt and Road Monitor, two aggregators of media and advocacy coverage, I identified several consistent hypotheses for why Chinese-funded plants might perform better or worse than others. Many of these hypothesized channels could exert positive or negative influence on environmental impacts, depending on the local context in each case.

The first hypothesis is that China's tremendous financial resources lead to exceptional conditions regarding project costs. From a negative point of view, excess financial resources disincentivize operators from being efficient. The South China Morning Post cited China Development Bank's bailout of coal-intensive South African utility Eskom, which has faced financial and political struggles, allowing it to continue to "mismanage" power plants now using Chinese technology (Nicholas 2019). As discussed in Chapter 5, the increasing perception that BRI is meant to help China's domestic companies find new markets elsewhere fuels this suspicion that Chinese finance, especially from state policy banks, will spare no expense for projects abroad. On the other hand, China's tremendous financial resources could improve the environmental performance of projects. For example, after China banned the import of F-grade coal, nearby Mongolian coal plants have been stuck with this glut of low-quality coal. Chinese operated plants in Mongolia, however, can afford to source better quality coal (SouthGobi Resources 2019). For the Hwange coal plant, the largest power plant in Zimbabwe, Chinese construction contractors signed an EPC contract with Zimbabwe to upgrade and expand the station (SourceWatch 2019b), potentially enabling state-of-the-art technology with superior environmental performance.

The second hypothesis is that plants receiving Chinese finance are given special treatment due to their political status, which leads to differing environmental performance. A coal plant in Serbia, constructed by a Chinese company and financed by the China ExIm Bank along with the Serbian government, was accused of beginning construction without environmental impact assessments or construction permits (Beyond Coal 2019). Lack of assessments or preparations could lead to higher environmental impact. In Vietnam, an audit of a Chinese-funded coal plant in Binh Thuan province criticized the provincial government and the national ministries of environment, industry and trade for inadequate supervision of the project and lack of proper assessment of environmental impacts due to a desire to please Chinese partners (CoalWire, March 13 edition). However, given increasing international scrutiny of BRI, Chinese plants could potentially be held to higher environmental standards given attention and political sensitivity. The advisor to the Pakistan prime minister on climate change, Malik Amin Aslam, who was critical of the many planned coal plants in Pakistan receiving Chinese funding, said Pakistan will ensure “the strictest possible environmental controls” with monitoring systems “to minimize and control any damages” (Third Pole 2018). In addition, as BRI host countries become more active in guiding BRI investment, they may form more mechanisms for oversight and regulation that affect BRI projects more than other projects. For example, Myanmar has formed a steering committee to manage BRI projects (Xinhua 2018).

The final hypothesis is that Chinese funders are interested in different projects than other funders. Chinese financiers are accused of supporting otherwise unprofitable projects that wouldn’t receive finance for elsewhere, and tend to be less efficient (Beyond Coal 2019). While some accuse China of investing in politically unstable areas, thus supporting pariah regimes, China has defended itself by saying that traditional investors have already saturated the desirable markets. From the perspective of relatively better performance, perhaps Chinese funders can pick the best projects in such areas because they are the only funders, meaning those projects will perform relatively better overall. “For solar and wind or other renewables we can get financing from anywhere,” said the special assistant to Pakistan’s prime minister on the power sector, though “finding international financing for coal had been difficult, with China the only country willing to invest” (Ebrahim 2019).

Although our empirical analysis suggests that Chinese funded coal plants tend to perform better than their counterparts, it is understandable that there is a perception that Chinese projects are worse. The sheer scale of BRI means that Chinese projects receive more attention and scrutiny. For example, a breakdown at a Chinese funded coal plant in Sri Lanka led to officials being inundated with complaints – the plant provided 78% of Sri Lanka’s power supply (Newsfirst 2019). Nevertheless, I believe that the scale of BRI should not be the main indicator of its potential impact. As our earlier analysis attempts to do, there should be apples-to-apples comparison of projects that could receive funding from a variety of sources, including Chinese banks and Chinese companies. As Chapter 5 laid out, China’s overseas investment is not new, nor is its impact simply a function of the amount of money.

Our analysis and this collection of hypotheses are but a first step to understanding the impact of Chinese finance. To assemble a more comprehensive set of hypotheses and gather more empirical evidence regarding any uniqueness of Chinese finance, I recommend a systematic literature review of the many rich case studies in the academic literature on overseas Chinese projects. In addition, other indicators beside environmental impact could be considered, such as social conflict. New methodological tools, such as web scraping, could be used to systematically gather data on incidents of environmental or social conflict for Chinese-funded projects.

The current efforts of advocates, scholars, and NGOs to track and characterize flows of China’s overseas finance are laudable. However, just knowing dollar amounts is not enough; this data should be combined with information on environmental and social performance to inform more detailed analyses of aggregate impacts, adopting frameworks that enable a broader understanding of how finance is connected to impact.

CHAPTER 8: CONCLUSION

The two parts of my dissertation illustrate how two of China's major ecological civilization policies – the national carbon market and the Belt and Road Initiative – are being enacted, and how they are related to economic and environmental impacts both inside and outside of China. Through this research, I have sought to understand the premise of China's ecological civilization concept – that China is uniquely positioned to simultaneously guide economic growth and environmental protection.

In Part 1, I introduced China's carbon market in the context of ongoing economic reform in many sectors of China's economy. I used a computable general equilibrium model to directly simulate structural economic transition in China and its interaction with a national carbon market, looking at effects through 2050. I found evidence that with certain policy designs, China can increase aggregate economic growth while reducing emissions, based on growth in the lower emissions intensity service sector. Given the many necessary simplifications in this modeling analysis, I also sought a qualitative approach to understanding the nature of China's carbon market. Through field visits, interviews, and participant observation, I showed how China's carbon market is a challenging exercise in standardization of carbon management. I began by examining the ways emissions data vary in quality and quantity, and how the emissions monitoring, reporting, and verification process is attempting to standardize emissions data. I showed how expertise is constructed and consolidated with the help of computational models. Finally, I concluded that capacity building is the engine that drives standardization, and that the market for capacity building is lucrative and productive where the national carbon market itself is not, thus encapsulating the neoliberal spirit of an ecological civilization policy.

In Part 2, I aimed to make methodological and conceptual contributions to the understanding of the potential environmental impact of China's Belt and Road Initiative. Since international discourse on BRI often implies that Chinese overseas finance is qualitatively unique, I sought to test this claim using data on coal plants in Asia, the first frontier of BRI. I used regression techniques to examine the relationship between Chinese finance and several indicators of environmental impact. I found that plants owned, managed, or built by Chinese companies tend to have lower emissions rates and higher energy efficiency than those associated with non-Chinese companies. These findings indicate that Chinese ownership of parent, engineering, or construction companies for overseas coal plants can affect the environmental performance of the plants. I sought to identify several hypotheses for how this might occur, such as exceptional conditions due to the scale of finance, or special political treatment of overseas Chinese projects by host governments. Taken together, this part of the dissertation aimed to advance the conversation about the environmental impact of BRI through careful consideration of comparative impact and the mechanisms through which financial involvement could influence relative environmental performance.

This dissertation makes several methodological and topical contributions to the literature. Chapter 3 adds to the small number of studies that explicitly model structural economic transition in China, and frames this analysis as an assessment of the ecological civilization premise. The combination of quantitative and qualitative methods in Part 1 is a novel methodological approach, and one that is necessary for understanding the complex dynamics of carbon markets in China's 'partial reform' economy. In addition, Chapter 4 re-frames the process of carbon market development in China as an issue of standardization rather than marketization, which assumes that China's state-market tension is inefficient, when in fact it has generated its own benefits for many actors involved. In Part 2, my empirical analysis is the first apples-to-apples comparison of environmental performance of Chinese and non-Chinese plants, providing suggestive evidence for an ongoing debate in the policy and advocacy realm about the role of Chinese finance for coal power. In addition, I propose framing the environmental impacts of finance around leakage, which opens up a broader range of empirical methods for analysis.

In fact, leakage is another thread that ties the carbon market and BRI together. As environmental regulations like the national carbon market are adopted within China, the BRI is increasingly recognized as a concerted effort on the part of national policymakers to help domestic companies in regulated sectors find new opportunities abroad. This link is a ripe area for future research. What will the net environmental impact of these policies be, and to what extent will the ecological civilization ethos be applied to BRI projects?

While the results of this dissertation are generally not oriented towards specific policy recommendations, the findings have several theoretical and methodological implications. First, the results from Part 1 suggest that the carbon market is embedded in a broad landscape of social dynamics. Chapter 3 suggests that social spending policies can facilitate structural economic transition and support the goals of the carbon market, while Chapter 4 shows that a diverse network of actors build expertise and livelihoods through engaging with the carbon market. In Part 2, my results indicate that China should not necessarily be considered a coal financing pariah, because of the relatively better environmental performance of Chinese owned, built, and operated plants. These findings could have major implications for how international policy and advocacy organizations engage with BRI. Taken together, both parts of the dissertation illustrate the need for interdisciplinary approaches to the study of complex policies. Any policy on the scale of those covered in this dissertation will take years if not decades to design and enact, and thus will require expansive methodological approaches to be understood.

Ecological civilization is proclaimed by China's leaders to be a uniquely Chinese concept, and it has become a guiding ideology for many of China's policies. In this dissertation, I explore the enactment and implementation of two major ecological civilization policies, shedding light on Chinese policymaking and its economic and environmental impacts from an interdisciplinary perspective. With economic and environmental implications both inside and outside of China, these policies will shape our world for years to come.

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APPENDIX

ABBREVIATIONS

BAT – Best Available Technology
BRI – Belt and Road Initiative
Btu – British thermal unit
CDM – Clean Development Mechanism
CEC – China Electricity Council
CEMS – Continuous Emissions Monitoring Systems
CES – constant elasticity of substitution
CIDCA – China Agency for International Development Cooperation
CGE – computable general equilibrium
CO_2 – carbon dioxide
CO_2e – carbon dioxide equivalents
DRC – Development and Reform Commission
EPA – Environmental Protection Agency
EPB – Environmental Protection Bureau
EPC – engineering, procurement, and construction
ETS – emissions trading system
EU ETS – European Union emissions trading system
FDI – foreign direct investment
GCPT – Global Coal Plant Tracker
GDP – gross domestic product
GHG – greenhouse gas
Gt – gigaton
GTAP – Global Trade Analysis Project
INDC – Intended Nationally Determined Contributions
IPCC – Intergovernmental Panel on Climate Change
kWh – kilowatt hour
MEE – Ministry of Ecology and Environment
MRIO – multi-regional input-output
MRV – monitoring, reporting, and verification
MW – megawatt
MWh – megawatt hour
NCSC – National Center for Climate Change Strategy and International Cooperation
NDRC – National Development and Reform Commission
OECD – Organisation for Economic Co-operation and Development
SAM – social accounting matrix
SOE – state-owned enterprise
TJ – terajoule
UNFCCC – United Nations Framework Convention on Climate Change
WEPP – World Electric Power Plants database

AIR POLLUTION CONTROL TECHNOLOGIES

The tables below list the air pollution control technologies in use in our dataset for the analysis in Chapter 6, based on data from Platts. We also classified these technologies by their BAT and non-BAT status according to Purvis et al. 2014.

Table 16: Particulate Matter Control Technologies

Control Technology	Classification
Baghouse	BAT
Baghouse/Wet ESP	BAT
Combination (usually ESP preceded by multiclones)	BAT
Cold side ESP	BAT
Electrostatic-fabric integrated precipitator	BAT
Electrostatic precipitator (ESP)	Non-BAT
ESP/Baghouse	BAT
Hot side ESP	Non-BAT
Mechanical particulate control device	Non-BAT
Wet particulate scrubber	BAT
Wet ESP	BAT
Water-film venturi particulate scrubber	BAT
Water-film venturi particulate scrubber/ESP	BAT

Table 17: Sulfur Dioxide Control Technologies

Control Technology	Classification
Atmospheric circulating fluidized bed boiler	BAT
Regenerable aqueous amine FGD system	BAT
Circulating bed FGD scrubber	BAT
Circulating dry FGD scrubber	Non-BAT
Compliance fuel (fuel that allows plant to meet applicable air quality standards)	Non-BAT
Semi-dry circulating fluidized bed FGD scrubber	BAT
Coal washing	Non-BAT
First generation wet sulfuric acid FGD system	BAT
Wet limestone bubbling reactor FGD system	BAT
Double alkali FGD scrubber	Non-BAT
Dry FGD scrubber	Non-BAT
Dry lime FGD scrubber, hydrated lime injection	Non-BAT
Flue gas desulfurization (FGD)	BAT
Wet limestone FGD scrubber	BAT

Limestone injection into furnace with calcium oxide activation	Non-BAT
Lime injection	BAT
Magnesium oxide FGD scrubber	BAT
Ammonia or ammonium sulfate FGD scrubber	BAT
Novel integrated desulfurization scrubber (dry lime)	BAT
Pressurized fluidized bed combustor	BAT
Reflux circulating fluidized bed FGD scrubber (semi-dry design)	BAT
Regenerative activated coke technology system	BAT
Spray dry FGD scrubber (typically using lime reagent)	BAT
Spray dry FGD scrubber	BAT
Semi-dry lime FGD system	BAT
Seawater FGD scrubber	BAT
Wet calcium carbonate FGD scrubber	BAT
Wet carbide sludge FGD scrubber	BAT
Wet FGD	BAT
Wet lime FGD scrubber	BAT
Wet limestone FGD scrubber	BAT

EMISSIONS CALCULATION VALIDATION

We checked the method used to calculate plant-level CO_2 emissions rates in Chapter 6 by validating based on actual reported plant-level emissions in U.S. coal plants. Using the EPA FLIGHT tool, we downloaded data on coal plant reported emissions for the most recent reporting year, 2017. We then randomly sampled one operational coal plant from each U.S. state with coal plants in the 2018 GCPT dataset. We compared the calculated emissions rate in the GCPT dataset to the back-calculated emissions rate from the EPA for each sampled plant. We back-calculated emissions rates for each plant by converting EPA annual CO_2 emissions to a rate assuming a capacity factor of 0.525, the official International Energy Agency estimate for global average coal plant capacity factor. The average error was 35%, indicating that our approximation of emissions rate was reasonable but could certainly be improved. We believe that the outliers in Figure XX are plants with very high or very low capacity factors.

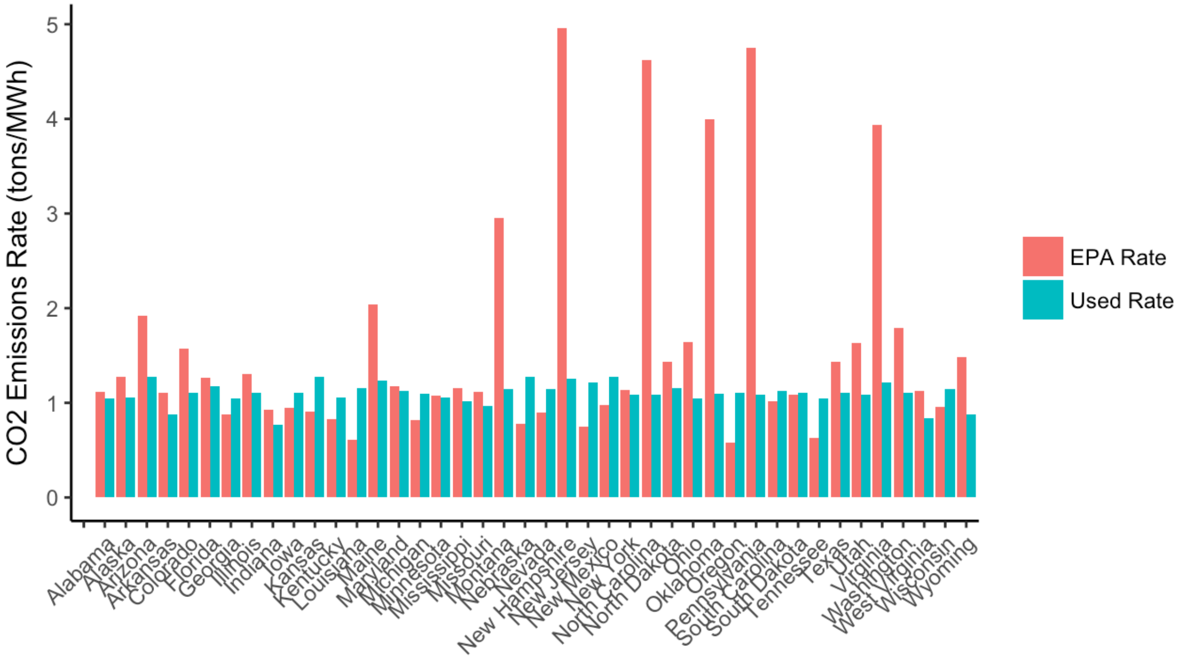

Figure 16: Comparison of Calculated and Reported Emissions Rates