Final Technical Report

“Factors Influencing Energy Use and Carbon Emissions in China”

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Factors Influencing Energy Use and Carbon Emissions in China

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Project overview

This research project was designed to fill a critical void in our understanding of the state of energy research and innovation in China. It seeks to provide a comprehensive review and accounting of the various elements of the Chinese government and non-governmental sectors (commercial, university, research institutes) that are engaged in energy-related R&D and various aspects of energy innovation, including specific programs and projects designed to promote renewable energy innovation and energy conservation.

The project provides an interrelated descriptive, statistical, and econometric account of China's overall energy innovation activities and capabilities, spanning the full economy with a particular focus on the dynamic industrial sector.

This project proceeded along the following three interrelated tracks.

- The first provided the policy and institutional context of the various organizations in China, their policy objectives, R&D budgets, and innovation output that relate to energy.
- The second employed statistical sources provided by the National Bureau of Statistics in China (NBS), China's Ministry of Science and Technology (MOST), and the National Energy Administration to model, estimate, and analyze the sources and energy-saving biases of R&D and energy innovation across 5 energy types and 37 industrial sectors.
- The third followed on the first two parts of the research by looking in depth at the core of China's energy research institutes and basic energy research capabilities using an extremely detailed data set from MOST spanning China's key energy research institutes

A critical component of this research project was the active research collaboration between researchers at Brandeis University, Penn State University, the National Bureau of Statistics in China (NBS), and China's Ministry of Science and Technology (MOST). Given the proprietary nature of the data used in this work, our access to these data was only possible through our long-standing relationship with colleagues at NBS and MOST. Over the period of this grant, there were multiple research exchanges where researchers from NBS and MOST visited Brandeis and Penn State to collaborate on research projects, and Fisher-Vanden, Jefferson and their graduate students visited NSB and MOST. As access to these data became limited over time, restricting our colleagues at NBS and MOST to bring the data to the U.S., we were able to arrange to have Brandeis and Penn State graduate students work at NBS and MOST for extended periods in order to carry out the research with our NSB and MOST colleagues.

This project has generated three publications, nine working papers (under preparation for journal submission), one master thesis (Guanze He—Penn State University), and two doctoral dissertations (Sarah Le Tang—Brandeis University and Yong Hu—Penn State University). Paper citations and abstracts are provided below. In addition, this work has been presented in multiple seminars, workshops, and conferences. This project culminated with a workshop in October 2016 in Beijing, China, where the papers generated by this project were presented. (Agenda attached).

Papers and Publications

Energy Prices and Investment in Energy Efficiency: Evidence from Chinese Industry 1997-2004

Dissertation chapter: Sarah Le Tang with Gary Jefferson

This paper investigates the role of energy prices in reducing energy intensity in Chinese industry. For the short run, the paper estimates contemporaneous energy price elasticities; for the long run, the paper examines in the impact of energy prices on energy-saving investment. A central purpose of the paper is to identify those subsets of China's industrial firms that are the largest energy consumers and likely to be the most price responsive. Analyzing a unique panel data set which reports firm-level energy consumption and price, the paper shows three stylized facts: (i) real energy prices, which are regulated by government, are typically lowest for state-owned enterprises (SOEs), followed by domestic non-SOEs, and highest for foreign-funded firms; (ii) In descending order of energy intensity, the six most energy-intensive industries are electricity and power generation, petroleum processing and coking, coal mining, chemical products, nonmetal products (cement), and nonferrous metal products (iron and steel). Also these six industries face relatively lower energy prices than the rest of mining and manufacturing industries. (iii) In the short run, SOEs tend to be somewhat less responsiveness than their domestic non-SOE counterparts and foreign-funded firms. However, over the long-run, SOEs tend to be more responsive to rising energy prices by investing in new energy-efficient capital; the same price-investment channels are less robust for non-SOEs or foreign-funded firms. Last, in a DSGE model with a combination of putty-clay and putty-putty investment, the share of output produced by putty-clay investment is estimated through indirect inference. An economy with 69.8% of output produced by putty-clay investment is able to reproduce the energy price elasticities observed from the actual data; it also shows that the 3.1% decline in energy intensity in response to a 10% increase in energy price can be decomposed into a 1.1% drop in output and a 4.2% drop in energy consumption.

China's 1,000 Industrial Enterprise Energy Conservation Program: Preliminary Findings Using a Sample from the Pilot Initiative

Dissertation chapter: Sarah Le Tang with Gary Jefferson, and Karen Fisher-Vanden

This paper is based on a sample of pilot firms in four industries – cement, chemical, iron and steel, and power generation - during 2005-2008. For each industry, the sample also includes a large number of control firms. Two conditions are consistently and robustly associated with reductions in energy intensity. These are (i) increases in energy prices as

shown by robust negative estimates of own price elasticities (although one notable exception appears to arise from measurement errors in the price data) and (ii) the capacity for scale and new output growth to lead to energy efficiency gains at the margin. We explore the impact of various forms of technology development, including R&D, purchased technology, and technology renovation, on energy conservation.

Innovation in Renewable Energy Technology: Evidence from China's Patent Data
Dissertation chapter: Sarah Le Tang with Gary Jefferson
This project intends to investigate and document the patterns in inventions of photo-voltaic and solar power technology in China's firms and research institutes over 2005-2010. Merging three data sources, patent information data from China's State Intellectual Property Office (SIPO), large and medium-size firm data from National Bureau of Statistics (NBS), and research institutes data from Ministry of Science and Technology (MOST), we answer the following questions: Which firms and research institutes are the major patent applicants? What characteristics of firms /research institutes that lead to more collaboration? Will collaboration with research institutes help firms increase their likelihood of patent granting? What is the dynamics in the firm-research institute collaboration?

Electricity Shortages and Firm Productivity: Evidence from China's Industrial Firms
Fisher-Vanden, K., E. Mansur, and Q. Wang, Journal of Development Economics, 114: 172–188, 2015.
Unreliable inputs to production, particularly those that are difficult to store, can significantly limit firms' productivity, leading them to react in a number of ways. This paper uses a panel of 23,000 energy-intensive, Chinese firms from 1999 to 2004 to examine how firms responded to severe power shortages in the early 2000s. Our results suggest that, in response to electricity scarcity, Chinese firms re-optimize among inputs to production by substituting materials for energy (both electric and non-electric sources)—a shift from "make" to "buy" of intermediate inputs to production. While outsourcing can be costly, Chinese firms were able to avoid substantial productivity losses by doing so. As a result of the increase in electricity scarcity from 1999 onward, we find that unit production costs increased by eight percent.

Factor Bias of Foreign Direct Investment Spillovers
Dissertation: Yong Hu with Karen Fisher-Vanden and Gary Jefferson
In this paper, we investigate the factor-bias spillover effect of FDI in China. Specifically, we examine how domestic enterprises guide their technology development direction in response to FDI in their horizontal industry, upstream industry, or downstream industry. Moreover, we will investigate the impact on FDI spillovers, resulting from China's joining of the World Trade Organization in 2001. Our empirical results show that foreign capital invested in upstream industries results in the use of more materials; foreign capital in downstream industries induces the use of more capital, but less labor; and foreign capital in horizontal industries induces saving in capital, but using in materials. Competition from foreign firms in the same industry spurs domestic firms to reduce their production cost by more intensively utilizing their relative factors endowment, which is

capital-scarce, labor- and material-abundant. FDI in upstream industry produces higher quality outputs inducing Chinese firms to outsource more. Benefiting from technology transferred from downstream foreign consumers, local suppliers exhibit technical change with capital-using, labor- and material-saving factor bias.

Region Development and Technology Spillover in China

Dissertation chapter: Yong Hu with Karen Fisher-Vanden and Gary Jefferson

In this paper we use firm-level panel data from Chinese enterprises to examine how regional differences influence the impact of technology spillovers on firms' productivity. This essay contributes to the existing literature in the following aspects: providing regional evidence that vertical channels are more important than horizontal channels to generate positive spillovers; providing empirical evidence on how regional differences, including geographical endowments, economic factors, and government policies, affect within-region and outside-region spillovers; providing empirical evidence to support the fact that China's "Grand Western Development Program" helped to reduce the economic disparity between the Western region and Coastal region. We find within-region spillover effects improve the productivity of firms in the Eastern region, which may due to the "Coastal Development Strategies" and the Eastern region's geographical advantages; firms in the Northeastern region receive significant cost-increasing outside-region spillover effects, which is in some extent caused by the low performances of SOEs in the Northeast; firms in the Southwestern region, which has the lowest GDP among five Chinese regions, receive significant cost-saving within-region and outside-region spillover effects, which may be a result of the fact that Coastal region has bigger positive impacts on the Western region after the implementation of "Grand Western Development Program".

FDI Spillovers and Industrial Policy: The Role of Tariffs and Tax Holidays

Du, L., Harrison, A., and G. Jefferson, World Development, Vol 64, December 2014, 366-383.

This paper examines how industrial policy – specifically tariff liberalization and tax subsidies – affects the magnitude and direction of FDI spillovers. We examine these spillover effects across the diverse ownership structure of China's manufacturing sector for 1998 through 2007. We find that tariff reforms, particularly tariff reductions associated with China's WTO ascension, increased the productivity impacts of FDI's backward spillovers. Tax policy – both corporate income and VAT subsidies – has seemingly drawn FDI into strategic industries that spawn significant vertical spillovers. We conclude that liberalization measures during the critical 1998–2007 period on balance served to enhance productivity growth in Chinese industry.

Restructuring China's research institutes: Impacts on China's research orientation and productivity

Renai, J., D. Tortorice and G. Jefferson, Economics of Transition, Volume 24, Issue 1, pages 163–208, January 2016.

Over the past two decades, China's R&D intensity has surged. The institutional arrangements underlying this surge remain unclear. We study the notable restructuring of the country's 5,000 research institutes, begun in 1999. This study first reviews the

evolution of China's research institute sector over the period 1995–2010. Then applying OLS, fixed effects, event study and propensity score analysis to institute level data, we find the restructuring programme has accomplished some of its goals. The converted Science and Technology enterprises shifted towards a more commercial mission, the institutes converted to non-profit research institutes have focused on a more research-oriented mission.

Can China Achieve its Energy Conservation Goal?
Working paper, Gary H. Jefferson, Brandeis University; Li Jing, Anhui University of Technology; Sarah Le Tang, Suffolk University, 2016
Using data from spanning 7 energy types, 40 sectors, and 31 provinces over the period 1995-2014, the paper models and estimates energy demand and CO2 emissions. Using these results the paper evaluates three energy and CO2 emission scenarios over the period 2015-2030. Each of these involves different energy pricing scenarios. Relative to the baseline scenario holding relative prices fixed at their 2014 levels, the most aggressive plausible pricing policy reduces the increase in CO2 emissions by approximately 50 percent by 2030.

Comparing Chinese-U.S. Patent Quality in Photovoltaic Technology: the Role of Domestic and International Research Collaboration.
Gary H. Jefferson, Brandeis University; Samuel Zucker, Brandeis University; 2016
This paper draws on patent data for photovoltaic technologies to investigate the implications of research coordination for the quality of patent outcomes for China and the U.S. The patent date, drawn from the U.S. Patent and Trademark Office (USPTO), enable patent quality to be ordered by applied but not granted; granted; duration in force; and Triadic grant (U.S., E.U. and Japan). Measures of research collaboration consist of the nationalities of the inventors and their listed organizational affiliations (company, university, and or research institute; domestic and/or international). We find a significant but weak association between the measures of diversity of research collaboration for the U.S.; the result is most robust for China, particularly collaborations involving domestic company-university and domestic-international affiliations.

Embodied vs disembodied capital in energy conservation: The case of Chinese industry
Working paper, Sarah Le Tang, 2016
Studies focusing on energy conservation in Chinese industry and elsewhere generally employ methods, including production technologies and energy demand functions, that assume the capacity of energy use in industrial economies to instantaneous adapt to policy incentives to motivate greater energy efficiency in production. In this paper, we explicitly acknowledge the so-called putty-clay nature of a significant portion of investment and the capital stock, that is, various forms of investment in plant and equipment are likely to embody a certain vintage of technology or factor intensities – capital-labor ratios or capital-energy ratios – that once installed afford only limited opportunity to adjust. Given differences in the time structure of price responsiveness, we identify the embodied-disembodied profile of the underlying capital stock across different

industries. The results suggest that energy-price conservation strategies need to account for substantial differences in the structure and pace of adjustment across industries.

Does ownership matter for energy conservation?: The impact of privatization on energy conservation in China

Working paper, Sarah Le Tang, 2016

This paper investigates the extent to which adjustment costs of investment differ by ownership type within Chinese industry. Controlling for industry, region, and energy price differences to determine if differences in energy intensity and the respective structure of price elasticities are truly ownership related or if, alternatively, other factors, which are correlated with ownership, account for the differences that we often assign to ownership, we find that ownership does matter with respect to patterns of price responsiveness. We also find that SOEs appear to depend more on investment to achieve their price responsiveness, a finding that helps to explain why SOEs tend to take longer to achieve the price adjustments that are achieved in relatively short order by the non-SOEs. A formal modeling analysis of these costs of adjustment, including empirical analysis using a large panel of state and non-state enterprises, confirms these predictions. We estimate the relative difference in costs of adjustment for SOEs and non-SOEs. Given these estimated differences, we compute the relative resource savings – both in energy and investment-related costs of adjustment – associated with ownership reform. Because these energy-savings and costs of adjustment are concentrated within China's most energy and capital-intensive industries, they are not trivial.

Innovation and Energy in Chinese Research Institutes and Enterprises

October 12-13, 2016

Location: Beijing Yulong International Hotel, 4th meeting room
adjoining the Beijing Yulong Hotel
40 Fucheng Road
Beijing, China

Sponsored jointly by the Chinese Academy of Science and Technology for Development (CASTED), Brandeis University, and Pennsylvania State University.

Wednesday: 8:45 – 9:15 refreshments

9:15: Song Weiguo, Xuan Zhaohui, Karen Fisher-Vanden, and Gary Jefferson welcome

9:45: "China Research Institutes: Policy Questions and Research Strategies," Xuan Zhaohui, Song Weiguo, Shi linfen, Cheng Bangwen, Jiang Renai.

- 25 minutes presentation
- 10 minutes discussion

10:30: "China's Research Institutes: Changes in the Incidence and Quality of Patent Production," Jiang Renai, Xuan Zhaohui, Gary H. Jefferson

- 25 minutes presentation
- 10 minutes discussion

11:15: "Innovating by Deploying in Energy Efficient Building Technologies," Zhen LEI, Penn State University

- 25 minutes presentation
- 10 minutes discussion

Lunch: noon – 1:30

1:30: "Sources of Quality Difference in Chinese-US Solar Photovoltaic Patenting," G. Jefferson, Tang Le, Samuel Zucker

- 25 minutes presentation
- 10 minutes discussion

2:15: Electricity shortages and firm productivity: Evidence from China's industrial firms, Karen Fisher-Vanden, Erin Mansur and Juliana Wang

- 25 minutes presentation
- 10 minutes discussion

3:00 – 3:30 general discussion

6:00 dinner

Thursday: 8:45 – 9:15 refreshments

9:15: "Energy and Investment in China's Industrial Firms," Tang Le, Suffolk University. Boston, MA and Gary Jefferson.

- 25 minutes presentation
- 10 minutes discussion

10:00: "Energy and CO2 Emissions in China," G. Jefferson, Li Jing, and Tang Le

- 25 minutes presentation
- 10 minutes discussion

10:45: "Factor Bias of Foreign Direct Investment Spillovers," Yong Hu, K. Fisher-Vanden, G. Jefferson

- 25 minutes presentation
- 10 minutes discussion

11:30 – noon Wrap-up/Final discussion

Lunch: noon – 1:30

Participants:

CASTED:
Xuan Zhaohui
Song Weiguo
Jiang Renai, Xi'an Jiaotong University
Karen Fisher Vanden, Penn State University
Gary H. Jefferson, Brandeis University
Li Jing, Hefei University of Technology
Sam Zucker, Brandeis University
Yong Hu, Zhejiang Gongshang University
Lei Zhen, Penn State University
Shi Linfen, Huazhong S&T University
Cheng Bangwen, Huazhong S&T University.