

Final Technical Report
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Our research program has involved data collection and analysis, modeling building, and the presentation of results. The data collection and analysis work was done in collaboration with our colleagues at the National Bureau of Statistics (NBS) in China. Each summer, we hosted on average four researchers from NBS for 3 months to work with us on the data analysis component of the research. Each summer our NBS colleagues would bring an updated data set of firm-level economic, R&D, and energy data that allowed us to explore the impacts of technological change on firm-level energy consumption. This grant also funded a number of graduate and undergraduate students to work on different elements of the analysis.

This research has produced three published articles, one article under submission and a number of works-in-progress summarized below. In addition to these papers, the results from this research have been presented at a number of conferences and seminars listed below.

Papers:

- Fisher-Vanden, K., G. Jefferson, H. Liu, and Q. Tao, 2004, "What is Driving China's Decline in Energy Intensity?" *Resource and Energy Economics*, 26, March, pp. 77-97.

Abstract: While energy intensity in China has fallen almost continuously since the onset of economic reform in the late 1970s, beginning in 1996 the data show a striking decline in China's absolute level of energy use. Most of this decline can be accounted for by falling coal consumption in the industrial sector. In order to investigate this energy puzzle, this paper employs a unique set of panel data for approximately 2,500 of China's most energy intensive large and medium-sized industrial enterprises during 1997-99. Rising relative energy prices, research and development expenditures, and ownership reform in the enterprise sector, as well as shifts in China's industrial structure, emerge as the principal drivers of China's declining energy intensity and use.

- Fisher-Vanden, K., Jefferson, G., Ma, J., Xu, J., 2005, "Technology Development and Energy Productivity in China," forthcoming, *Energy Economics*.

Abstract: Understanding the range of impacts of technological innovation and diffusion in a large carbon-intensive country like China is important for understanding the future trajectory of global carbon emissions. In this paper, we utilize a uniquely rich data set of Chinese firm characteristics and technological innovation activities to identify the key determinants of rising energy productivity within China's industrial sector. We find rising relative energy prices, research

and development expenditures, and ownership reform in the enterprise sector, as well as shifts in China's industrial structure, as the principal drivers of China's declining energy intensity and use over the period 1997-1999. We also find large differences in factor-bias between technology produced internally and technology imported from abroad. Technology tends to reflect the resource scarcities of the country supplying the technology. Whether internal or imported, however, we find technology development to exhibit an energy-saving bias. We also find that the firm's in-house technology development activities are important for creating the absorptive capacity required for the successful diffusion of imported technology.

- Fisher-Vanden, K., and M.S. Ho. 2005. "How Do Market Reforms Affect China's Responsiveness to Environmental Policy." *Journal of Development Economics*, in press.

Abstract: A large percentage of total investment in China is allocated by the central government at below-market interest rates in pursuit of non-economic objectives. This has resulted in low rates of return and a high number of non-performing loans, threatening the future health of the Chinese economy. As a result, reform of capital markets is a high priority of the Chinese government. At the same time, the country is implementing various environmental policies to deal with serious pollution issues. In this paper we ask how reforms of the capital market will affect the functioning of a carbon tax. This allows us to assess how China's willingness to join global efforts to reduce carbon emissions is influenced by China's current efforts to reduce investment subsidies. We compare the costs of a carbon tax in a reformed economy with the costs of a carbon tax in the current subsidized economy. We find that in the subsidized economy the tax-interaction effect dampens the effect of a carbon tax resulting in smaller reductions in emissions than what would result in a reformed economy. Importantly, we also find that the effect on economic welfare from a carbon tax is lower in the subsidized economy; in fact, for lower levels of reductions, the carbon tax is actually welfare improving. These results have important implications for an economy undergoing economic transition. The carbon tax rate required to achieve a certain level of emission reductions will be higher in an economy with capital subsidies. However, the welfare implications of the tax indicate that the current system with capital subsidies is highly distorting implying that there is a high efficiency cost for the non-economic objectives the government is pursuing by maintaining this system of subsidies.

- Fisher-Vanden, K., and G. Jefferson, 2005, "Technology Diversity and Development: Evidence from China's Industrial Enterprises." Submitted to *European Economic Review*.

Abstract: A stylized fact of technical change in developing economies is that of Harrod-neutral labor augmenting technical change arising from capital deepening. While in the aggregate this pattern of technical change is widely observed, at the

firm level a variety of channels of technical change and factor biases are possible. Using a large set of firm-level panel data for China's industrial enterprises, this paper identifies three channels of technical change, each associated with a different pattern of factor bias and underlying firm objective. Autonomous, time-dependent capital-using technical change drives the neoclassical growth process. Robustly labor-using and capital- and energy-savings in-house R&D capitalizes on China's comparative advantage, and the purchase of imported technologies, which are comparatively capital using, focuses on new product development. As part of its task, internal R&D adapts imported technology to make it more "appropriate" (i.e. less capital using). These diversified channels of technical change reveal a pattern of developing country technical change that is far more diversified than that suggested by the conventional growth literature.

Works in Progress:

- CGE modeling work: we have begun to modify and use our estimation equations and data to identify processes of technical change within specific industries that can be incorporated into a dynamic recursive computable general equilibrium model of the Chinese economy. We capture technology development in our computable general equilibrium (CGE) model by assigning the relevant industry coefficient estimates to the model's neutral and factor biased productivity terms. Using our CGE model, we compare energy use and carbon emissions in two model scenarios. The first uses the coefficients from regressions where technology development has been restricted to have only a neutral effect on productivity. The second scenario uses coefficients from regressions where technology development has been allowed to exhibit effects that are both neutral and factor biased. The differences between these two scenarios are quite dramatic. In the case where neutral and factor biased effects are incorporated, our simulations show that the energy and carbon intensity of the Chinese economy is approximately 20 percent less than the case where technology development is assumed to have neutral effects only.
- Inducements to technology development: Our previous research suggests that the liberalization of energy prices in China was a significant motivator of the dramatic decline in China's energy intensity during the late 1990s. We also find that domestic technology development seems to be targeting energy efficiency improvements. We have not yet tested the link between these; that is, the extent to which the increase in relative energy prices is responsible for the focus of internal R&D on energy saving technical innovation. Although energy prices seem to be important for inducing demand for R&D and technology transfer, other factors are likely to enter into the decision of firms to deploy resources for in-house R&D or to purchase technology on the market. In addition to the role of changing relative factor prices, we are examining the role of the particular factors in shaping demand for R&D effort and the purchase of technology. In addition to

relative factor prices, we focus on four sets of conditions – market factors, industry factors, firm-specific factors, and public policy.

Presentations:

- “Technological Change in Chinese Industry: Implications for energy use and carbon emissions.” Presentation to the Energy Modeling Forum Workshop on Modeling Technological Change, Washington, DC. June 5-7, 2001.
- “What is Driving China’s Decline in Energy Intensity?” Presentation to the Environmental Studies brownbag lunch, February 21, 2002.
- “What is Driving China’s Decline in Energy Intensity?” Presentation to the Rockefeller Faculty Lunch Seminar series, February 26, 2002.
- “R&D and energy consumption in Chinese industry.” Presentation at the Second World Congress of Environmental and Resource Economists, Monterey, CA (June 2002).
- “What is Driving China’s Decline in Energy Intensity?” Presentation at the Second World Congress of Environmental and Resource Economists, Monterey, CA (June 2002).
- “Technological Innovation and Diffusion in Transition Economies: The Case of China,” Presentation at the Energy Modeling Forum Summer Workshop on Climate Change Impacts and Integrated Assessment, Snowmass, CO (August 2003).
- “What is Driving China’s Decline in Energy Intensity?,” Presentation at the Environmental Studies Colloquium at Middlebury College, Middlebury, VT (November 2003).
- “Modeling Technological Innovation and Diffusion in Transition Economies: The Case of China,” Presentation at the Association of Environmental and Resource Economists Association sessions of the Allied Social Sciences Associations Meetings, San Diego, CA (January 2004).
- “What is Driving China’s Decline in Energy Intensity?,” Presentation at the Center for Energy and Environmental Studies Seminar Series, Boston University, Boston, MA (January 2004).
- “Factor Bias in Technological Innovation and Transfer: Evidence from China’s Industrial Enterprises” Presentation at the Trade, Development and Political Economy Seminar Series, Department of Economics, Syracuse University, Syracuse, NY (March 2004).

- “Factor Bias in Technological Innovation and Transfer: Evidence from China’s Industrial Enterprises” Presentation at the Trade, Development and Political Economy Seminar Series, Department of Economics, Stanford University, Stanford, CA (April 2004).