Efficiency, Environment, Price: Regional Modeling of China's Power Sector

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Over the next 15 years, China's energy concerns will be dominated by the need to sustain 6 to 10 percent annual demand growth, while raising standards for human and ecological health. To reconcile and achieve these objectives will require deeper understanding of the complex linkages between economic activity, energy resources, and the environment. We propose the use of empirical GE models to elucidate energy-economy-environment interactions and inform more economically and socially effective polices.

Because of its fundamental economic importance, rapid expansion, and slow capital turnover, the power sector will be a salient component of China's medium-term growth experience. Even conservative growth estimates imply that, over the next fifteen years, China must add generation that exceeds Europe's entire installed capacity (850-900GW against 780GW for the 2004 EU). Changes in electricity prices have pervasive upstream (e.g., primary energy prices) and downstream (industry structure, consumption patterns, etc.) linkage effects, and technology choice ultimately determines patterns of resource use. In terms of technology adoption, fuel sources, and emission characteristics, investment decisions made now in China's electricity sector will have economic and environmental implications lasting 30 to 50 years.

While macroeconomic trends can influence the electricity sector through overall growth and investment patterns, equally important are feedbacks from electricity policies to the rest of the economy. The sector is a highly regulated one and, and polices toward prices, investment, and technology can exert complex influences on the rest of the economy. Furthermore, energy and electricity markets in China exhibit significant segmentation. Although many of the country's regional electricity grids have limited interconnection, China has not established a grid at the national level and is unlikely to have one serving up to half of GDP over the period under consideration. For the medium term, electricity sector markets will remain region specific, and policies need to take account of underlying heterogeneity in resource availability and service requirements.

Within regional electricity grids, three interrelated areas have not received adequate empirical attention: energy efficiency, environmental policy, and energy markets. Each of these is well suited to policy simulation modeling.

Energy Efficiency
- Comparing the costs and dynamic benefits from demand-side improvements in energy efficiency

Environmental Policy
- Measuring the economy-wide costs and potential emissions reductions of regulatory approaches to greenhouse gas mitigation.

Energy Markets
- Measuring the effects of institutional changes on electricity and fuel prices, as well as the economy-wide effects of changing prices along the electricity supply chain.

Energy Efficiency

- ***Background.*** As part of the 11th Five-Year Plan, the State Council established an objective of reducing energy intensity by 20 percent by 2010. As a significant proportion of China's final energy consumption, electricity end-use is an obvious candidate for efficiency improvements.
- ***Opportunity.*** While loose efficiency targets have been outlined for specific industries, a more thorough analysis of the costs and economy-wide gains from energy efficiency programs, particularly at a provincial level, has yet to be undertaken.
- ***Approach.*** Measuring the costs and gains from efficiency is well suited to general equilibrium analysis because of its complex linkage and feedback effects. Producers pass along costs and savings to consumers, whose reduced or increased consumption levels slow or spur demand for other goods and services, with corresponding reductions or increases in production and energy use. Provincial-level and regional CGE models offer a powerful tool for analyzing the effects of different levels of investment in energy efficiency.

Environmental Policy

- ***Background.*** As the human health and productivity costs of air pollution become more apparent in China, controlling emissions from power plants has become a higher priority. The scale of new generation capacity, as well as very high levels of reliance on coal-fired generation in some regions, poses important challenges to medium-term objectives for controlling emissions through pollution fees or feed-in tariffs.
- ***Opportunity.*** Regional SO_2 and NO_x cap and trade schemes could play an important role in encouraging further emissions reductions and lowering compliance costs, but their economic viability remains largely unstudied.
- ***Approach.*** By identifying dynamic cost thresholds, a general equilibrium approach to analyzing the economics of cap and trade schemes can offer essential insights about emissions trading. In particular, grid-level modeling can show how trading schemes might work across provinces with different resource endowments, achieving aggregate cost savings from trading. Simulation work is also an ideal context for experimentation with the complex incentive properties of cap and trade, including rights allocation, revenue recycling, banking, safety values, etc.

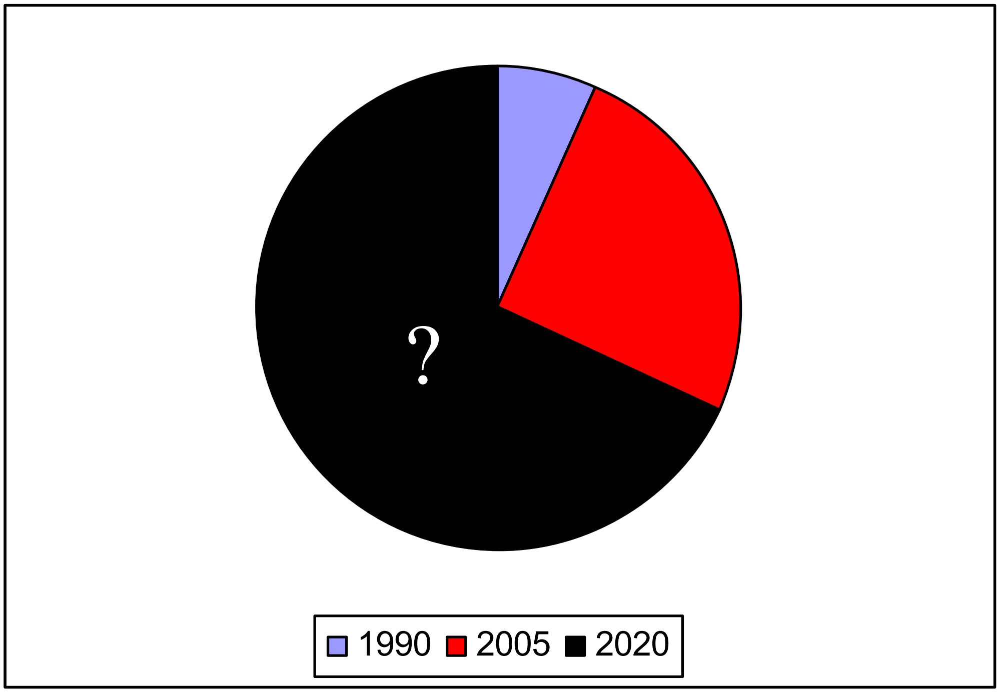
Energy Markets

- ***Background.*** China's electricity sector began a process of deregulation in 2002 with the ultimate aim of creating a competitive electricity industry. Although electricity prices are still set by the NDRC, there is considerable interest within China in liberalizing electricity prices, including competitive bidding systems like those used in Europe and the U.S.
- ***Opportunity.*** Despite their importance to overall sector development, as well as the interplay among efficiency, environmental policy, and electricity price regimes, there is still a lack of understanding of how institutional changes affecting electricity prices

in China might be transmitted through regional grids, particularly those with high fossil fuel dependence.

- ***Approach.*** General equilibrium modeling is ideally suited to tracing price interactions, and it can shed important light on the energy supply chain that links fuel prices, electricity prices, and government, business, and household income and expenditure. In both regulated and unregulated price regimes, regional CGE models can identify impacts of changes in efficiency and environmental policy on prices and economic structure at all levels.

Figure 1. China's Installed Generation Capacity, 1990, 2005, and estimated 2020



Sources: 1990 to 2004 installed capacity data are from www.eia.doe.gov; 2004 data are from China Electric Power Statistical Yearbook; 2005 data are from various online estimates.

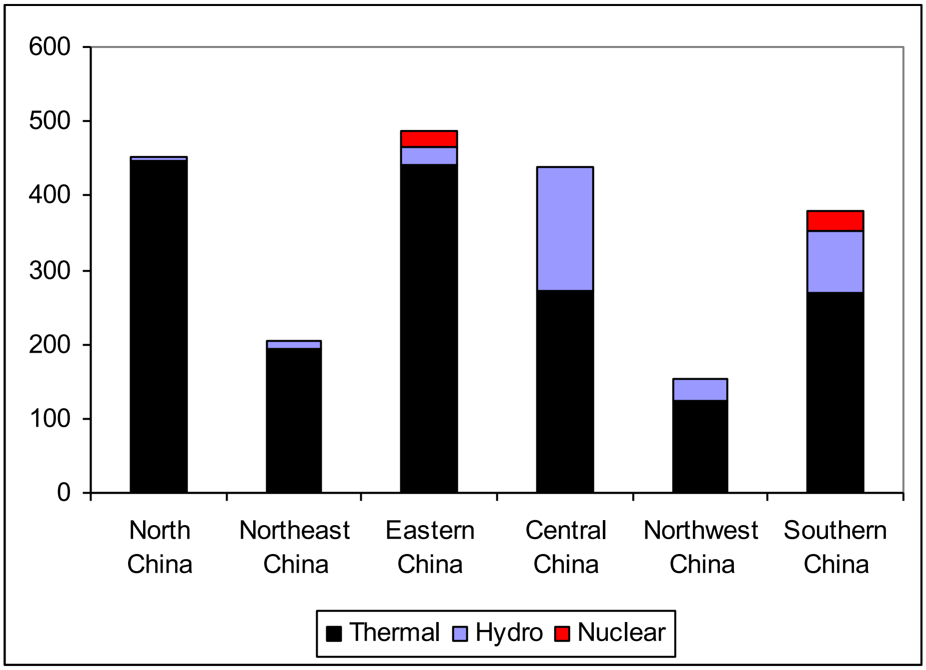
China's installed capacity in 1990 was 138 GW; by 2005 it had reached 510 GW. The black area represents 870 GW, or annual demand growth of 8, 7, and 6 percent between 2005-2009, 2010-2014, and 2015-2020, respectively.

Assuming that around 70 percent of China's generation needs (609 GW) continue to be met through coal:

- At current capital costs for coal-fired power plants (~4,000 yuan/kW), 609 GW translates to 2.4 trillion yuan in investment needs
- Annual coal consumption from new generating units would reach nearly 1.3 billion tons by 2020
- Assuming all new plants are equipped with 95 percent efficient FGD units, controlled SO_2 emissions from new generating units (~1.3 million tons) would be equivalent to one-third of uncontrolled 1990 SO_2 emissions from coal-fired power plants (~4 million tons) by 2020
- At roughly 3.7 billion tons, CO_2 emissions from new generating units would be more than 1.5 times total U.S. 2004 emissions

(All calculations assuming a capacity factor of 0.63, a coal heating value of 25.1 GJ/ton, a thermal efficiency of 0.38, a coal carbon content of 0.8, and complete combustion).

Figure 2. Installed Capacity by Type by Region

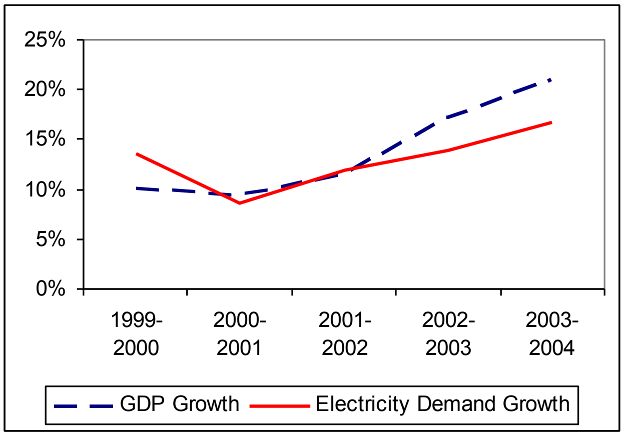


Source: China Electric Power Statistical Yearbook

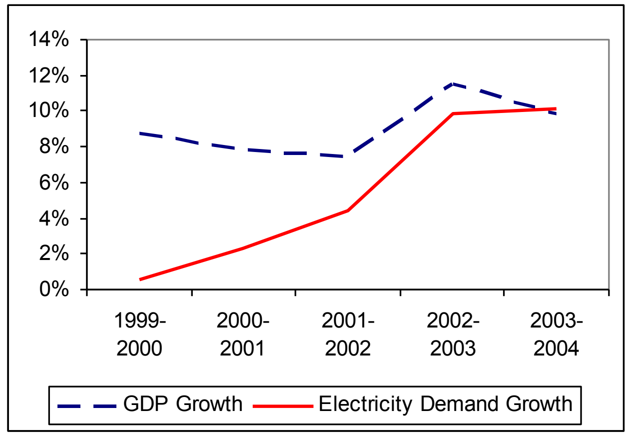
Regional fuel needs for electricity generation vary considerably among grids, as Figure 2 suggests. In north, northeast, eastern, and northwest China, thermal generation capacity dominates, whereas in central and southern China hydropower plays a more significant role. Coal as a percentage of thermal generation varies as well, from nearly 100 percent in the North China Power Grid, to roughly 80 percent in the Southern China Power Grid. Figure 3 on the following page illustrates the heterogeneity in electricity demand elasticities with respect to GDP growth.

Figure 3. GDP and Electricity Demand Growth Rates, China's Six Electricity Grids[1]

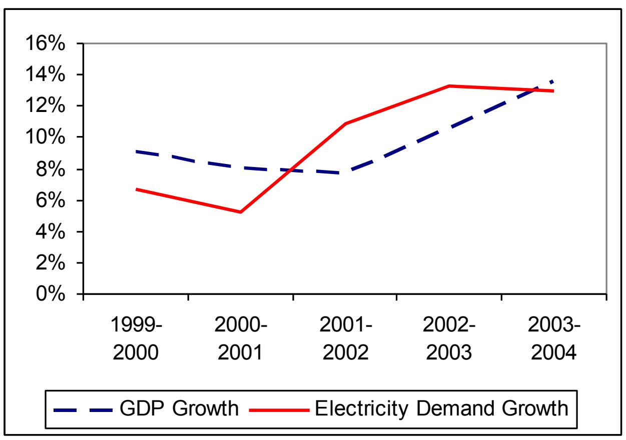
North China Power Grid (华北电网)



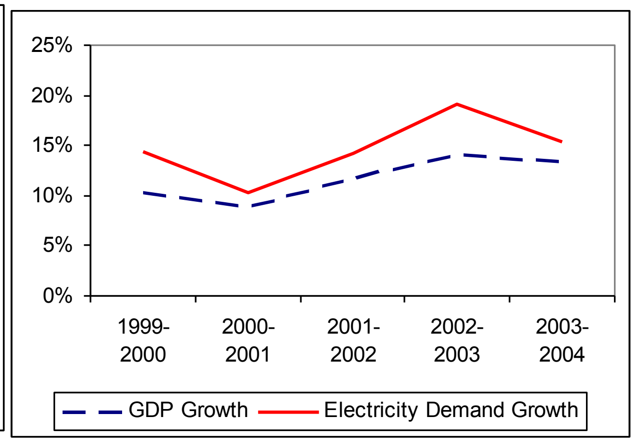
Northeast China Power Grid (东北电网)



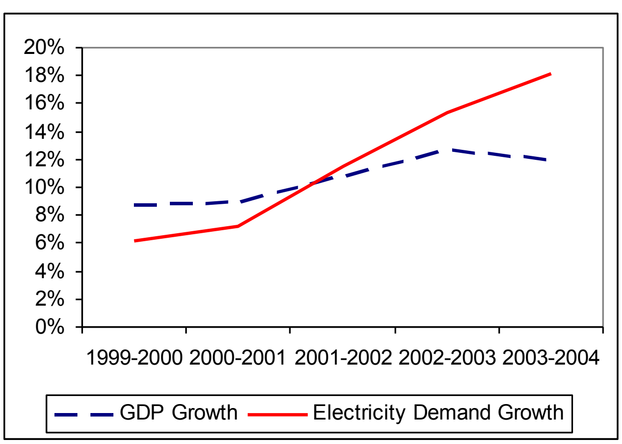
Central China Power Grid (华中电网)



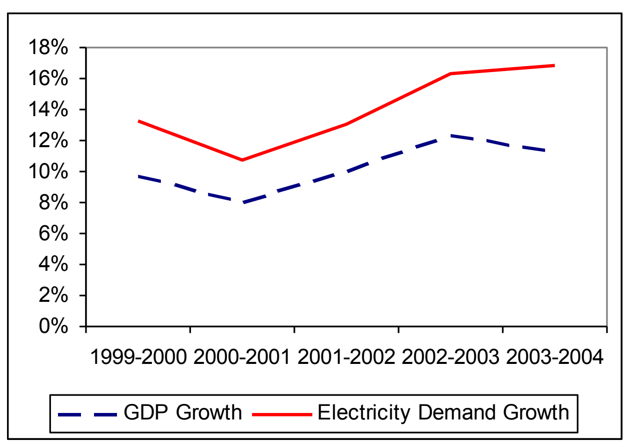
East China Power Grid (华东电网)



Northwest China Power Grid (西北电网)



Southern China Power Grid (南方电网)



[1] Data are from the *China Electric Power Statistical Yearbook*. North China here includes all of Inner Mongolia, while eastern Inner Mongolia is not included in Northeast China. GDP measured in 2000 prices.