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The national and international impacts of coal-to-gas switching in the Chinese power sector☆

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ABSTRACT

We evaluate the national and international impacts—on energy consumption and production, trade, and economic activity—of Chinese coal-to-gas switching in the electric power sector. We find that assumptions about growth rates in electricity generation from renewables are the key determinant in evaluating the economic consequences for coal-to-gas switching in China. The ability to supplement natural gas generation with renewables leads to smaller reductions in Chinese and global economic activity than the alternatives.

1. Introduction

Air pollution in China's major eastern metropolitan areas has reached dangerous levels—much of it due to coal.[1] This has led authorities to "declare war" on smog, and the Chinese government anticipates boosting natural gas consumption in place of coal as a response. Yet coal is China's most important energy commodity, accounting for the majority of energy consumption. China also plays a pivotal role in the global coal market—it produces and consumes almost as much coal as the rest of the world combined.[2] Such levels of coal production raise economic activity; at the same time the large amount of consumption contributes to elevated air pollution.

As one step in combating this pollution, the Chinese central government announced the Action Plan for Air Pollution Prevention and Control in September 2013,[3] followed by an even more stringent Action Plan for Upgrading and Rebuilding Coal-fired Power Generating Units to Conserve Energy and Reduce Pollution.[4] The Plan bans construction of new on-site use coal-fired power plants, and permitting of new grid-serving coal-fired power plants that are not combined heat and power generators in the most smog-affected regions (Beijing-Tianjin-Hebei, and the Yangtze and Pearl River Deltas). These regions account for nearly a third of China's installed coal-fired power capacity[5] and generation.[6] The Plan also sets strict efficiency and emission standards for existing as well as new coal power plants. The government hopes to stimulate development of coal power in the inner-West of the country, and transmit the electricity through national high-voltage transmission lines. Because such infrastructure takes time to build,

☆ The analysis and conclusions expressed here are those of the authors and not necessarily those of the U.S. Energy Information Administration or CSIRO.

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[1] Coal is a major source for direct emissions of particulate matter (PM) such as PM2.5 and PM10 in China, as well as other pollutants such as SO2 and NOx which can further interact chemically to generate secondary PMs (Wang et al., 2011).

[2] See http://www.eia.gov/todayinenergy/detail.cfm?id=16271.

[3] Source: "Air Pollution Prevention and Control Action Plan". State Council Document Number 37 [in Chinese] (Central Government of the People's Republic of China, 12 September 2013); www.gov.cn.

[4] See http://english.mep.gov.cn/News_service/infocus/201409/t20140928_289668.htm.

[5] Source: http://www.greenpeace.org/china/zh/news/releases/climate-energy/2013/12/coal-power-issue/.

[6] Source: http://finance.sina.com.cn/money/future/futuresroll/20130923/102016822004.shtml.

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and existing water shortages in Western China impose challenges for coal-fired generation, the Plan is likely to slow growth in Chinese coal power generation.

Lurking in the background is natural gas, which generates only 2% of Chinese electricity.[7] Because natural gas has greater potential than other alternatives to displace coal at a large scale in the near-to-medium term,[8] the Action Plan provides policy incentives for coal to gas switching in the Eastern coal-restricted regions. This could lead to substantial changes in some Eastern regions—and a meaningful shift from coal to natural gas in the power sector will lead to major changes in the nation's energy markets. The sheer size of the Chinese energy sector means that such a shift will also affect international energy markets.

There have been many papers which consider China's power sector, but most have a different focus than ours. They tend to either center on market structure (Xu and Chen, 2006; Du et al., 2009; Ngan, 2010), the energy portfolio of power generation (Wang, 2007), or the potential for renewables (Cherni and Kentish, 2007; Ma and He, 2008). Others which explicitly consider coal-to-gas switching are centered on how this can improve air quality or reduce carbon emissions (Mao et al., 2005; Skeer and Wang, 2006; Delarue and D'haeseleer, 2007; Jiang et al., 2008; Sheehan et al., 2014).

In this paper we evaluate the national and international impacts—on consumption, prices, and economic activity—of Chinese coal-to-gas switching in the electric power sector. We also address uncertainties surrounding this policy issue by testing alternative assumptions about the development of renewable energies. Our primary conclusion is that the ability to supplement natural gas generation with renewables[9] leads to smaller reductions in Chinese and global economic activity than the alternatives.

2. Policy background

Coal dominates both total primary energy consumption and production in China: in 2012 it accounted for almost 66% of China's total primary energy consumption, and over 77% of total primary energy production (Fig. 1). Coal's share of consumption and production has hovered above 70% on average since 1980.

Coal production also has an important economic component. Value added in coal mining accounted for about 2.1% of real Chinese GDP on average from 1980–2014, and grew steadily to over 3% of real GDP by 2011. The total value of production in coal mining was slightly smaller, averaging 1.5% of real gross output from 1980–2014, rising to over 2% by 2011.[10]

This stands in stark contrast to natural gas. Disaggregated data on value added in natural gas extraction suggests that it accounted for less than 0.1% of real GDP in recent years. The bottom two lines in Fig. 1 show that natural gas's share of total consumption and production in 2012 was 4–5%, and the average shares since 1980 are just above 1%.

From this low starting point Chinese authorities plan for the share of natural gas consumption to rise to around 10% by 2020, much of it at the expense of coal.[11] How might this be accomplished?

Given the wide spread between natural gas and coal prices in China, especially the limited conventional natural gas resources and uncertainties in developing unconventional gas resources, switching from coal to natural gas requires different types of policy intervention. The aforementioned Action Plan for Air Pollution Prevention has spurred a series of polices and guidelines from various levels of government to ensure its implementation. Many of these supporting plans include specific measures to curb coal consumption and increase natural gas use, production, and imports in certain regions. In general, the policies drive switching through direct mandates, indirectly by changing the relative economics between natural gas and coal, or some combination of the two.

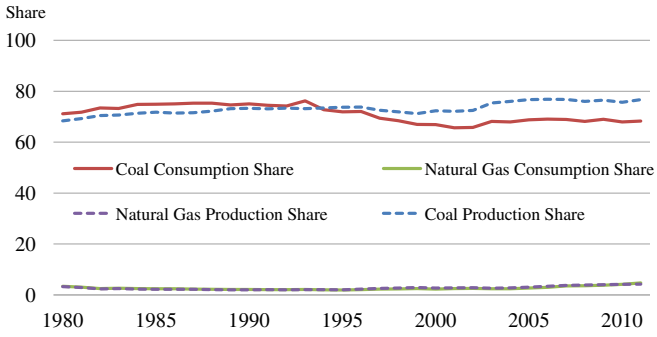

Fig. 1. Chinese coal and natural gas consumption and production as a share of total primary energy consumption and production, 1980–2012.
Source: EIA International Energy Statistics, 2015.

Policies which work through mandates have the potential to directly limit coal supply and demand and directly increase gas supply availability in the near term (and potentially improve the economics of supply in the long-term). For example, the Action Plan for Air Pollution Prevention and Control mandates reduction in coal consumption in three regions: Jing-Jin-Ji (Beijing, Tianjin, and Hebei), the Yangtze River Delta, and the Pearl River Delta. It also bans new coal-fired power plants, among other new projects in heavy industries, in 13 regions (47 cities). As another example, the Work Plan for Enhancing Air Pollution Prevention and Control in the Energy Sector issued by the National Development and Reform Commission (NDRC), the National Energy Administration (NEA), and the Ministry of Environmental Protection (MEP) in March 2014, calls for expediting the development of unconventional natural gas such as coal-bed-methane and shale gas.

Other policies work through economics, increasing the relative cost of using coal or reducing the relative cost of using natural gas. For instance, the air emissions standards issued by the MEP in July 2011 in many cases are more stringent for both new and existing plants than similar standards in the U.S. and Europe. These standards require installation and operation of various types of emission control equipment, which will increase the cost of coal-fired power generation if everything else remains the same. On the other hand, the Natural Gas Utilization Policy, updated by the NDRC in October 2012, aims to allocate natural gas supply to prioritized sectors (including power generation) in some regions. These prioritized sectors do not necessarily pay the highest price for this natural gas supply.

The combination of these policies will lead China to increase natural gas consumption at the expense of coal. In this paper, we focus on the potential impacts of coal-to-gas switching in the Chinese power sector. Before evaluating the impacts of this transition, we turn to the implementation of such switching within our modeling framework.

3. Modeling approach

We simulate coal-to-gas switching using the CSIRO variant of the Global Trade and Environment Model (GTEM-C) developed by Cai et al. (2015). GTEM-C is a hybrid model that combines the top-down macroeconomic representation of a computable general equilibrium (CGE) model with bottom-up details regarding energy production. It is a dynamic extension of the widely-used GTAP CGE model (Hertel, 1997), in that GTEM-C adopts its global trade and economic core from GTAP. The current version of GTEM-C includes 19 sectors[12] in 13 global

[7] Source: http://data.stats.gov.cn/workspace/index?m=hgnd.
[8] Source: http://www.oilobserver.com/tendency/article/1544.
[9] In this paper, renewables exclude hydropower unless otherwise noted.
[10] Source: Oxford Economics Global Industry Database for May 2015.
[11] See http://www.eia.gov/beta/international/analysis.cfm?iso=CHN.

[12] The 19 sectors are coal, oil, gas, petroleum, electricity, petrochemical, iron and steel, nonferrous metals, non-metallic minerals, other mining, manufacturing, water transport, air transport, terrestrial transport, crops, livestock, fishing and forestry, processed food, and services.