Energy for Sustainable Development 39 (2017) 101–114

Contents lists available at ScienceDirect

Energy for Sustainable Development

The role of government in industrial energy conservation in China: Lessons from the iron and steel industry

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ARTICLE INFO

Article history:
Received 2 January 2017
Revised 3 May 2017
Accepted 11 May 2017
Available online xxxx

Keywords:
Energy efficiency
Energy intensity
Institutional reform
The iron and steel industry
China

ABSTRACT

This paper tracks the energy use and changes to China's energy-efficiency regulatory framework governing the iron and steel industry for the last thirty years. The detailed institutional analysis identifies both abating and augmenting effects of the regulatory framework changes on the energy intensity changes. The paper then assesses the impacts of various other factors on the energy intensity of China's iron and steel industry by using time-series data on the sector level. The quantitative analysis shows that technology progress, specifically the production process transition from high-energy intensive open-hearth furnace (OHF) to more energy efficient basic-oxygen furnace (BOF), is the biggest contributor to energy intensity reductions in China's iron and steel industry in the last thirty years, even after controlling for regulatory change and policy incentives. The ownership reform resulting from changes in the regulatory framework change contributed to energy intensity reductions in China's iron and steel industry, while fast market expansion resulting from market liberalization and regulation decentralization served as a principal barrier for energy efficiency improvements. Government policies, represented by financial subsidies from governments, correspond with energy intensity reductions in key large and medium sized enterprises, but interestingly, seem to be ineffective at producing energy intensity reductions for the industry as a whole. As other research indicated, rising coal prices also contributed to energy intensity reductions in China's iron and steel industry. Finally, the paper concludes that, to further incentivize energy intensity reductions, the Chinese government should consider correcting the negative impacts of the regulatory framework change, as well as transferring production processes to the highly energy efficient electric-arc furnace (EAF) and extending policy regulations to wider enterprise groups.

Introduction

Since the introduction of market reforms in 1978, China's energy consumption has increased rapidly, driven by an average 10% annual economic growth rate. In 2009, China became the largest energy consumer in the world, surpassing the United States (IEA, 2010) and has retained that ranking ever since. In 2012, energy consumption in China amounted to almost 3.6 billion tons of coal equivalent (tce), and the number is expected to continuously increase to support accelerated industrialization and urbanization in the coming decades. To curb extensive consumption of energy and achieve the sustainable development of the economy, China continues to strengthen its efforts in energy conservation and emissions reduction (Wang and Chen, 2010). Different from developed countries, the industrial sector is the most important end-use sector in China, and is responsible for 70% of primary energy use and 80% of associated carbon dioxide emissions. Five energy-intensive industrial subsectors account for the bulk of industrial energy consumption and related carbon dioxide emissions: iron and steel, chemicals, petroleum refining, pulp and paper, and cement. Clearly it is important for both China and the world to better understand China's energy use in various industrial sectors and the factors behind it. This paper on the iron and steel industry aims to contribute to this improved understanding.

China's iron and steel industry has achieved impressive progress in the past three decades. China has become the largest steel producer in the world since passing Japan in 1996 and the largest steel consumer in the world since 2001. In 2015, China produced 804 million tons (Mt) of crude steel (Fig. 1) and consumed 704 Mt., accounting for almost 49.5% of world steel production and 43.2% of global steel consumption (World Steel Association, 2016). In 2013, the Iron and Steel sector consumed 624.9 million tce and released 16.2% of total CO_2 emissions in China in 2013 (Xu and Lin, 2016). In 2014, the iron and steel industry alone accounted for around 16.3% of energy consumption in China. Since 1980, the energy efficiency of China's entire iron and steel

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http://dx.doi.org/10.1016/j.esd.2017.05.003
0973-0826/

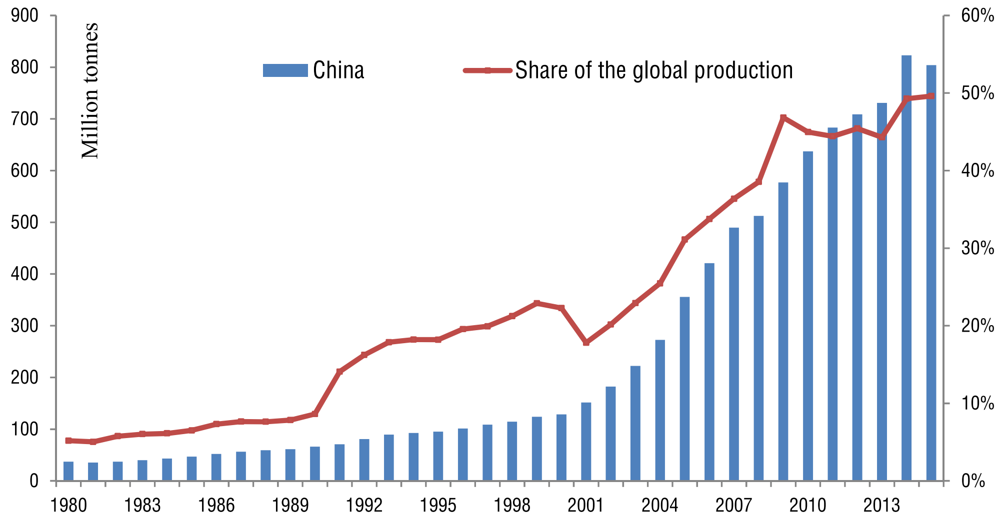

Fig. 1. Crude steel production in China and its share of the world from 1980 to 2015 (Unit: million tons).
Data source: World Steel Association.

sector has significantly improved from 2.04 tce per ton produced in 1980 to 0.845 tce per ton in 2014 (National Bureau of Statistics, 2016). The energy intensity indicator for key large and medium sized iron and steel production enterprises in China also decreased from 1.625 tce per ton in 1980 to 0.572 tce per ton in 2015.[1] There is still a wide energy efficiency gap, however, compared with developed countries (Wei et al., 2007; Guo and Fu, 2010; Hasanbeigi et al., 2014). As China's steel production and consumption are expected to continue to rapidly grow alongside progressive industrialization, urbanization and green development,[2] improving the energy efficiency of China's iron and steel industry is essential for reducing China's overall energy intensity.

Most scholarly papers on energy efficiency use the decomposition method to assess drivers of energy efficiency reduction (Sinton and Levine, 1994; Lin and Polenske, 1995; Galli, 1998; Sinton et al., 1998; Sinton and Fridley, 2000; Zhang, 2003) and they often attribute changes in energy intensity either to structural shifts (Johnson et al., 1997) or technological change (Sinton and Levine, 1994; Zhang, 2003). The decomposition method can unfortunately only reveal limited insights. Other research increasingly attempts to explore the underlying causes behind those factors within sectors, and in particular, within industrial subsectors since they can make the largest contributions to intensity changes (DeCanio, 1998; DeCanio and Watkins, 1998; Sinton et al., 1998). A consensus has emerged that a steady decline of energy intensity can be achieved through technological improvements (Sinton et al., 1998; Fisher-Vanden et al., 2004, 2006, 2016; Sheehan and Sun, 2007; Wei et al., 2007; Ma and Stern, 2008; Rock and Toman, 2015), but it is less clear on what causes the adoption of more efficient technologies. Energy prices, which drive up energy bills for customers, are a crucial motivator for energy intensity reductions (Fisher-Vanden et al., 2004; Hang and Tu, 2007). Some scholars also imply that ownership may be a critical factor determining energy use in China (Fisher-Vanden et al., 2004, 2016; Hang and Tu, 2007; Wei and Liao et al., 2007). Other factors, such as the rate of economic growth, the structure of the economy, the regional locations (Fisher-Vanden et al., 2016) and public financial support have also been found to influence energy use in China (Sinton et al., 1998; Lin, 2007).

Efforts to improve energy efficiency in China from an institutional perspective attract increasing attention. Policies and their implementation are pivotal in energy conservation activities (Sinton et al., 1998). Policy implementation in China is widely believed to be fragmented, and progression is further inhibited by conflict between state departments and between central and local governments (Lieberthal and Oksenberg, 1988; Lema and Ruby, 2007; Sun, 2007). A few papers have already documented these institutional effects in energy governance (Andrews-Speed, 2009; Levine et al., 2009; Zhou et al., 2010) and in technological productivity (Movshuk, 2004). Aden and Sinton (2006) illustrate the role of government policy, implementation, and institutions in augmenting and abating the environmental degradation that can accompany expanded energy usage in typical energy sector. However, few have explored and decompose the effects of institutions on industrial energy efficiency in China, especially in a specific sector.

This paper focuses on China's iron and steel industry and explores how regulatory framework changes, as well as other technological and economic factors, shape energy intensity changes using time series data from 1980 to 2010. The main research questions are: (1) How did China reduce its energy intensity in the iron and steel sector over the last 30 years? (2) How does regulatory reform shape energy intensity reductions in the iron and steel industry? (3) To what extent do regulatory framework changes and other technological and economic factors influence the energy consumption of the iron and steel industry? This paper endeavors to make three contributions to the scholarly literature: First, this paper provides a detailed institutional analysis to identify the conditions under which regulatory framework changes have abating and/or augmenting effects on the energy intensity of China's iron and steel industry. This is innovative because this research is focusing on a specific industrial sector on the energy-demand side, rather than on the energy-supply sectors, such as coal and hydropower (Aden and Sinton, 2006; Andrews-Speed, 2009). Second, the research is the first one to quantify the impacts of policies on the energy intensity changes in China's iron and steel industry. Two of the latest research publications – Rock and Toman (2015) and Fisher-Vanden et al. (2016) – identify the impacts of public policies but have not quantified them. We supplement their research by adding policy instruments as variables. Thirdly, the research can reach more robust conclusion about the role of technology progress and other factors, by controlling institutional changes and policy incentives.

The organization of this paper is as follows. We begin with a brief introduction of energy use in China's iron and steel industry in the Energy

[1] Large and medium sized enterprise refers to a enterprise with the deployment over 300, sale revenues over 300 million and gross assets over 400 million. In 2012, there are 80 key large and medium sized enterprises in China's iron and steel industry, accounting for 54.2% of the total steel production in China in 2016 (Wang, 2017).

[2] Steel is also a crucial material necessary for supporting "green" development, such as the wind power industry, solar PV system, gas turbines, and electric vehicles. For example, 70% of a wind turbine is made of steel and it also requires steel to construct the wind turbines' foundation (World Steel Association, 2012).