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Reducing rebound effect through fossil subsidies reform: A comprehensive evaluation in China

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ABSTRACT

China has committed a sharp reduction in its carbon intensity by 2020 and proposed to take integrated policy package including energy subsidy reform to achieve this goal. While energy efficiency improvement is the key influencing factor for this goal, its effectiveness is significantly determined by rebound effect. Energy subsidy as an economic regulation policy would significantly affect rebound effect. To explore how China's fossil subsidies reform would affect rebound effect, this study conducts a comprehensive evaluation based on a multi-sector computable general equilibrium (CGE) model. Rebound effects at different technological improvement levels are investigated and the impacts of different subsidies reform scenarios on mitigating rebound effects and on the whole economy is analyzed. The results provide significant policy insights: Firstly, rebound effect does exist in China, larger for electricity than for primary energies. Secondly, by removing fossil energy subsides, the rebound effect would be effectively mitigated, and removing all subsides would reduce the rebound effect most, however, it would bring significant negative impacts on the macro economy. Thirdly, an integrated policy with removal of fossil energy subsidies and increment of clean energy subsidies would be more effective, greatly reducing rebound effect and also bring benefits for both economy and environment. Our findings would be critical for China's low-carbon policy making in the future.

1. Introduction

Climate change and carbon mitigation has aroused wide attention in China as it has the top energy consumption and carbon emissions in the world. In the Copenhagen conference, Chinese government made a commitment to reduce its carbon intensity (representing by carbon emissions per unit of gross domestic product) by 40%–45% by the year 2020 compared to the 2005 level. Further in the Thirteenth Five-year Plan for 2016–2020, another carbon emissions mitigation goal is proposed for the peak of carbon emissions beyond 2030. In achieving these goals, there are several pressing and significant challenges: On the one hand, the use of fossil energy has been pointed out as one of the biggest sources of greenhouse gas emissions (IEA, 2009), while at the meantime China is strongly dominated by the consumption of "dirty" coal; On the other hand, as carbon lock-in in the current energy and economic structure is a serious problem for China, low-carbon technologies and innovations should be greatly improved to enhance the energy efficiency and reduce carbon emissions (Karlsson, 2012).

Under this circumstance, China spares no effort in developing its energy related technologies and improving its energy efficiency to reduce energy using as well as to mitigate carbon emissions (Zhou et al., 2010; Hasanbeigi et al., 2013; Levine et al., 2013; Lo, 2014). However, whether energy related technological progress could successfully help reduce final energy using in its full potential is

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strongly determined by the so-called "rebound effect", which referring to the behavioral or other systemic responses to the improved resource utilization efficiency due to new technologies (Greening et al., 2000; Sorrell and Dimitropoulos, 2008; Sorrell et al., 2009; Wei, 2010). In the existence of this "rebound effect", part of the energy savings derived from the new technologies would be offset by the increased energy consumption caused by the much cheaper energies due to the new technologies (Grepperud and Rasmussen, 2004; Barker et al., 2007; Ruzzenenti and Basosi, 2008; Sorrell and Dimitropoulos, 2008; Wei, 2010). As shown in Fig. 1, China's energy efficiency as indicated by energy consumptions per unit of gross domestic product (GDP) has been greatly improved from 1.77 tce/10,000 yuan in the year 1990 to 0.76 tce/10,000 yuan in the year 2014 in the past two decades. Meanwhile, it could also be noted that China's total energy consumption has been continued to increase from 987 million tce in the year 1990–4260 million tce in the year 2014. These two sharply different lines as shown in Fig. 1 well illustrate how rebound effect plays an important role in China.

As for the rebound effect in China, energy subsidies policy makes a contribution to it that cannot be overlooked. As a developing country, China has implemented intensive subsidies for fossil energy to guarantee energy safety and develop modern energy (UNEP, 2008; Li et al., 2011; Liu and Li, 2011). However, fossil subsidies also broaden the harm to the environment and enlarge the rebound effect to a certain extent. The subsidies policy can encourage the energy utilization by lowering the end-use price (Khazzoom, 1980). In this situation, the reform of energy subsidies could be an effective way to mitigate the rebound effect, as well as improving the energy efficiency. At the end, there will be a win-win situation for both budget saving and environmental benefit (Li et al., 2013).

The rebound effects are hotly debated in both academic and policy field, considering the double-edged sword of technological advancement (Herring and Roy, 2007). On the one hand, the development of technology would help improve energy efficiency and mitigate carbon emissions. On the other hand, the energy prices might be decreased due to the accelerating technological progress and related cost-down, which might stimulate energy using and offset the positive role technological progress plays in energy saving. In this circumstance, energy subsidies reform provides an important socio-economic measure to mitigate the rebound effect, so as to enhance the effectiveness of new technology in energy saving and carbon mitigation. The unprecedented change in China offers a unique opportunity and an ideal laboratory

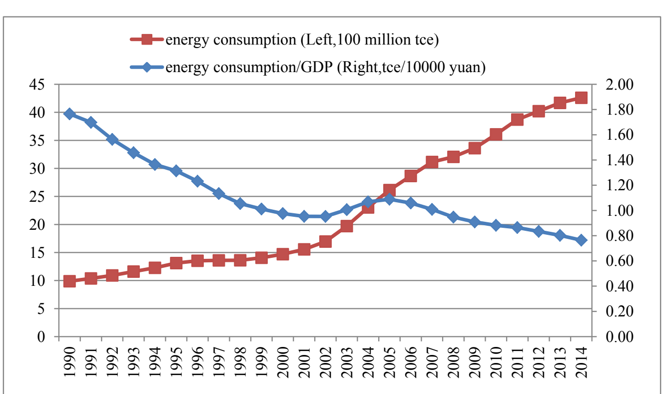

Fig. 1. China's energy consumption and energy efficiency, 1990–2014.
Source: Calculated based on the data in China Statistical Yearbook (2015); GDP is calculated at 2010 constant prices.

to study the relationship between energy policy and rebound effect, which is important to enlighten both China and the world. However, to our best knowledge, very few studies pay attention to this topic in China.

Under this circumstance, this study would like to propose an interesting and significant topic: Whether energy subsidies reform policy will mitigate the rebound effect in China? Several related questions are highlighting: How large are the rebound effects for different improvement in energy efficiency in China? When taking the energy subsidies reform into consideration, how will a better policy design help reduce the rebound effect? What is the best available subsidies reform policy package to address rebound effect? To resolve them, we build a multi-sector CGE model with clean energy for China to investigate the rebound effects and the impacts of different energy subsidies reform policy scenarios on the environment and the economy. Particularly, both removing fossil energy subsidies and increasing clean energy subsidies are taken into consideration as useful policies.

The structure of the study is organized as follows: Section 2 provides a literature review on rebound effects and China's energy subsidy reform. Section 3 presents the methodology and the proposed CGE model. Results and analysis are discussed in Section 4. Section 5 provides policy suggestions and conclusion.

2. Literature review

Beginning with Khazzoom (1980), the rebound effect has been widely discussed and debated in the field of energy policy. In the existing literature, the precise definitions of rebound effect were put forward (Khazzoom, 1980; Gillingham et al., 2016). In general, when rebound effect is considered, it means as energy efficiency makes improvement due to technological change, it would make energy services cheaper and thus promoting its consumption, which might offset the energy saving effect brought by the technological change. Despite some scholars asserted that rebound effect is exaggerated (Gillingham et al., 2016), there are numerous studies suggest that rebound effect is indeed of empirical relevance and can be very significant in both developed and developing areas, such as in the U.S. (Greening et al., 2000; Bentzen, 2004), in the U.K. (Barker et al., 2007), in Germany, in Netherland, in Austria (Haas and Biermayr, 2000), in South Korea, in India (Roy, 2000) and also in China (Ouyang et al., 2010; Wang et al., 2012a,b,c,d; Lin and Liu, 2012).

With regard to the economic transmission mechanism of rebound effect, there are mainly two perspectives: One is a single price effect (Khazzoom, 1980); the other is a multi-effects mechanism, including direct and indirect rebound, transformational effect, secondary fuel use effect and economy-wide effect (Greening et al., 2000). Accordingly, based on the original single-service model in a neo-classical framework raised by Khazzoom (1980), many models and methods have been built to study rebound effect, such as partial equilibrium models (Grepperud and Rasmussen, 2004), general equilibrium models (Bentzen, 2004; Barker et al., 2007; Chan and Gillingham, 2015) and econometric methods (de Haan et al., 2006; Matos and Silva, 2011; Safarzynska, 2012), and specific technologies or policies (Li and Han, 2012; Wang et al., 2012c, 2012d) are simulated regarding rebound effect. From the methodological approaches to estimating rebound effect, household uses (space heating, space cooling, lighting, and others) and personal transport have been most widely discussed (Freire-González, 2011).

However, with immediate concerns, there are still several research gaps that need to be filled.

First of all, most of the existing studies discussed the rebound effect merely from a technological perspective, and failed to