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Technology advance and the carbon dioxide emission in China – Empirical research based on the rebound effect

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ABSTRACT

At present, technology advance is the greatest contributor to the carbon dioxide mitigation. However, the real effect of technology advance on mitigation is worth further studying due to the existence of rebound effect (RE). A key issue is how to quantify the relationship between technology advance and carbon dioxide emission accurately. This paper figures out a comprehensive and modified framework involving around the RE of carbon emission from the macroeconomic perspective. Using this framework, this paper quantitatively evaluates the relationship between technical change and carbon emission based on the data of 30 provinces in China. It is founded that: (1) the carbon RE is about 10–60% in Chinese provinces; (2) the RE of carbon emission differs among the regions in China; (3) carbon reduction and environment issues should be solved step by step regionally in China. (4) According to our results, a reasonable control on total energy consumption and fossil-energy pricing adjustment, should be taken as the supplementary policy in China; at the same time, carbon financing, carbon trading and other aspects of institutional innovation should be taken into account at the appropriate time.

1. Introduction

According to *BP Statistical Review of World Energy*, the total carbon dioxide emissions increased by approximately 5.4 times, from 1429.2 million tons (Mt) to 9208.1 Mt, during the year 1978 and year 2012 in China. At the same time, the total increase amount of global carbon dioxide emissions in 2012 is 723.2 million tons, while China's incremental contribution is 548.4 million tons, which accounts for 75.8% of the total global increment. To successfully meet the global carbon dioxide mitigation goal, the carbon dioxide mitigation in China deserves attention of the international community.

At the same time, the reduction of carbon emissions is also imperative to China's own interests. First, there would be a huge impact on China's economy if concepts such as ‘carbon credits and carbon trading’ become widespread around the world. Second, China will face a new round of trade protectionism if the United States and European countries impose a ‘carbon tariff’ on the pretext of climate issues; China's exports — especially high energy-consuming products — are bound to be traumatized if this happens. Third, the speculation regarding ‘carbon labels’ has also added tremendous external pressure to Chinese enterprises.

For the above reasons, the Chinese government has made some plans and efforts to reduce carbon emissions. The latest target is the carbon dioxide emissions per unit GDP (carbon emission intensity) in China will be reduced by 60–65% compared to the 2005 amount by 2030. The change of mitigation targets in China from energy intensity to carbon emission intensity during these years directly embodies the strategic transformation of China's energy policy. To achieve this target, it's necessary to promote researches on carbon mitigations from various aspects, such as economy and technology.

Carbon emission intensity was an important indicator when we talk about “low carbon development”. In 2012, China's carbon emissions intensity was 1119.2 kg / USD, which is approximately 4.74 times of Japan, 4.67 times of Germany and the European Union, 3 times of the US, and 2.3 times of the global average. Therefore, China has a huge potential in terms of carbon emissions from a marginal perspective.

There are two methods to achieve the carbon reduction, one is technology advance, and the other is energy structure optimization. A consensus is that the positive effect of energy structure optimization on carbon intensity decrease is certain (Li and Lin, 2016). However, the way to achieve the energy structure optimization is complicated in the real world, which is not the key point in our paper. The technology

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advance is what we mean to focus.

Technology advance is also an important way to improve carbon emission efficiency and achieve emission reduction targets. However, it might be not true that technical progress always contributes to the reduction of energy consumption and carbon dioxide emissions. Because technological progress may not always towards energy saving or carbon reduction for technological progress may cause using more fossil energy (which will lead to more emission) to replace labour force and capital investment in the production activities. This concept is so-called Rebound Effect (RE). The size of the rebound effect will directly affect the final results of carbon dioxide mitigation.

From the government point of view, the effect of technological progress in carbon dioxide emission reduction is worse than expected due to the RE; the prediction of carbon dioxide reduction may also be biased in the environmental assessment. Therefore, the RE is an unavoidable topic considering the important role of technological progress in carbon dioxide emissions.

2. Literature review

The fact that technology advance is the main driving factor of carbon emission reduction has been proved by numerous researches from different perspectives.

Some papers take this topic as a comprehensive system, and simulate multiple influences. Nordhaus (2002) and Popp (2004) applied integrated assessment model (extended DICE model) to analysis the impact of technology advance on carbon reduction. The results proved the doubtless effect of technology advance. The other studies took this topic under the theoretical framework of economic growth. Ang (2009) attempted to explore the determinates of CO2 emissions in China. Using an analytical framework that combines the environmental literature with modern endogenous growth theories, the results indicated that CO2 in China are negatively related to research intensity, technology transfer and the absorptive capacity of the economy to assimilate foreign technology. Brännlund et al. (2007) and Mizobuchi (2008) applied Almost Ideal Demand model (AID model) to investigate the effect of technology advance on carbon emission in Swedish and Netherlands, and estimated the rebound effect (RE) of carbon emission, respectively. Wei and Yang (2010) focused on the contribution of technological progress to the reduction of carbon dioxide emissions by combining an endogenous growth theory and environmental pollution models, and they confirmed the significant contribution introduced by technical progress to China's carbon dioxide emissions. They also demonstrated that there are obvious regional differences of the impacts of technological progress on carbon dioxide emissions in China. The paper confirmed the core relationship between technological progress and carbon dioxide emission reduction. There are also come studies based on the input-output model (Input Output, IO) (Okushima and Tamura, 2010); and Computable General Equilibrium Model (CGE) (Manne and Richels, 2004; Timilsina and Shrestha, 2006), these literatures agreed that technological progress is the main factor and driving force of carbon dioxide mitigation.

On the contrary, based on some studies, the effect of technology advance on energy saving and carbon emission reduction is uncertain because of the existence of rebound effect (RE). RE theoretically started from the Khazzoom-Brookes (KB) hypothesis, “energy efficiency improvements that, on the broadest considerations, are economically justified at the micro-level, lead to higher levels of energy consumption at the macro-level”. The existence of RE, make the impact of technology advance complicated. “If the rebound effect is sufficiently large it may undermine the rationale for policy measures to encourage energy efficiency.”(Sorrell and Dimitropoulos, 2008).

Based on KB hypothesis, many scholars have conducted lots of researches on the rebound effect (RE). At the very beginning, RE researches ignored long-term and macroscopical influence (Besen and Johnson, 1982; Lovins, 1988). After that, the definition of RE was advancing along two directions – one based on the macro-economic level (Saunders, 2000a, 2000b; Berkhout et al., 2000; Safarzynska, 2012) and the others were under the framework of micro-economics (Binswanger, 2001; Sorrell and Dimitropoulos, 2008).

From aspects of research contents, the researches on rebound effect (RE) can be mainly divided into twofold: 1. Researches on the mechanism of RE. The typical literatures including Greening et al. (2000), Birol and Keppler (2000), Schipper and Grubb (2000), Sorrell (2007), Brookes (2004), Wei (2007), Van den Bergh (2011), According to these researches, mechanism of RE can be divided into three forms: direct RE (including substitution effect and income effect), indirect RE and RE at the economic-system level. These researches also measured the RE with different production and cost functions, and found out different results with different functions. Some recent studies advocated the distinguishments among different technological progress (Lin and Du, 2015; Du and Lin, 2015). 2. Based on the theoretical researches mentioned above, more studies are focus on the empirical researches (Schipper and Grubb, 2000; Bentzen, 2004; Saunders, 2013; Antal and van den Bergh, 2014; Glomsrød and Wei, 2005; Grepperud and Rasmussen, 2004; Hanley et al., 2006; Washida, 2006; Wei, 2010; Otto et al., 2008; Turner and Hanley, 2011; Druckman et al., 2011; Freire-González, 2011; Chitnis et al., 2013; Murray, 2013). All these studies confirmed the existence of RE at the macro-level, micro-level, industrial level and in the residential sector, respectively.

Studies on the rebound effect (RE) in China started late and mainly focused on the RE at the macro-economic level and in the residential sector. Most researches estimated the rebound effect of the macro-economy in China by Neoclassical model (Zhou and Lin (2007), Wang and Zhou (2008), Liu and Liu (2008), Guo (2010), Xie and Zhang (2013), Liu and Lin (2016)). The results of these studies showed that the macrolevel of China's energy RE were concentrated at 30~80% based on technological progress estimates. The results were relatively high compared to foreign research results. Studies based on the CGE model also existed. (Zha and Zhou (2010)). In recent years, researches on the RE of household sector and traffic sector also appeared in large numbers (Ouyang et al. (2010), Wang et al. (2012); Lin and Liu (2013), Lin et al. (2013), Lin and Liu (2015)).

Studies of the rebound effect (RE) on carbon emission are scare, especially in China. Brännlund et al. (2007) found that the energy efficiency improvement in the consumption of Swiss residents has a rebound effect on carbon dioxide (CO2), sulphur dioxide (SO2) and nitrogen oxide (NOx) emissions; Druckman et al. (2011) used the idea of the rebound effect to study the carbon dioxide emissions of UK residents. Yang (2013) attempted to study the carbon dioxide emissions of the residents department and calculate the value of the rebound effect quantitatively. However, the studies are mainly confined to the daily life of these residents and didn’t show an advance in theory. The studies on the RE of carbon dioxide emissions from the macrolevel are even less in the academic circles, and a better research method is lacking. Zha et al. (2013) estimated the rebound effect of China's carbon dioxide emissions using the CGE model.

All the existent researches about rebound effect (RE) on carbon emission are based on the energy consumption, however, they didn’t draw the concept logically. Theoretically speaking, the relationship between technology advance and carbon reduction will first reflect in the reduction of fossil-fuel consumption and the increase of carbon emission efficiency, which has been mentioned in the literatures (Brännlund et al. (2007), Yang (2013), Zha et al. (2013)). At the same time, technology advance at the macro-economic level will encourage economic growth, which leads to more carbon emission. And this is so-called Rebound Effect (RE) of carbon emission. The mechanism will be expanded in Section 3 of this paper. The thing we should notice is the impact of energy consumption structure, which will also influence the carbon reduction besides technology advance. To analyse the impact of technological progress on carbon reduction, we should first get rid of