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Incorporating energy rebound effect in technological advancement and green building construction: A case study of China

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ABSTRACT

Energy conservation and emission reduction issues in the construction phase of buildings are increasingly important to meet the challenges of sustainable building. Technological advancement is considered as one of the essential driving forces for green and sustainable construction. But, it is not as effective as expected because the anticipated energy conservation from efficiency improvement would be partially or even totally offset if energy rebound effect exists. This paper fills the research gap by quantitatively investigating the impacts of technological advancement on energy consumption in China's building construction industry by incorporating direct rebound effect. First, technological advancement rate in terms of energy efficiency is measured by constructing an energy-environmental non-radial directional distance function (ENNDF), which provides a strong support for the Porter hypothesis. Second, by incorporating asymmetric energy price decomposition into a framework of translog cost function, it is estimated that 21.8% energy savings from energy efficiency improvement in China's construction industry are offset due to rebound effect. Based on the measured results of technological advancement rate and rebound effect, further counterfactual analyses find that technological advancement contributes 27.11 million tons of standard coal equivalent (Mtce) of energy conservation for the construction industry over the period 2003–2012, and 7.57 Mtce of energy would have been saved in the sector if there were no rebound effect. Empirical findings in this paper reveal that technological innovation as well as energy pricing reforms, tax policies and other environmental regulations should be further implemented to achieve effective energy conservation for green building construction.

1. Introduction

Sustainable development cannot be achieved considering only technological advancement. Along with it, social, economic, cultural and environmental issues must also be considered in a balanced approach for ensuring successful sustainability [1].A lot of literatures have made effort to study progress and innovation of alternative technologies for greener building construction [2,3]. But, as Khazzoom indicated early in the 1980, potential target energy efficiency effects of technological advancement may be overestimated due to "rebound effect" [4–6].

Energy efficiency improvement caused by technological advancement would reduce effective price of energy services, and thus the original expected energy conservation would be mitigated. "Rebound effect" is defined as energy consumption increase in response to decrease in the price of energy services induced by technological advancement [5]. Fig. 1 presents a more accurately considered effect of technological advancement on energy consumption. On the one hand, as expected, technological advancement leads to energy efficiency improvement and results in less energy consumption. But on the other hand, the anticipated energy conservation tends to be partially or even totally offset if energy rebound effect (RE) exists [7]. For example, a 50% improvement in the energy efficiency of a newly-built building usually cannot lead to a corresponding 50% reduction in energy consumption [8,9].

As shown in Fig. 1, the reason for RE is mainly based on two considerations. Generally from a micro perspective, it is expected that less energy will be required to produce the same amount of product since technological advancement makes equipment more energy efficient. But, at the macro level, the effective price of energy

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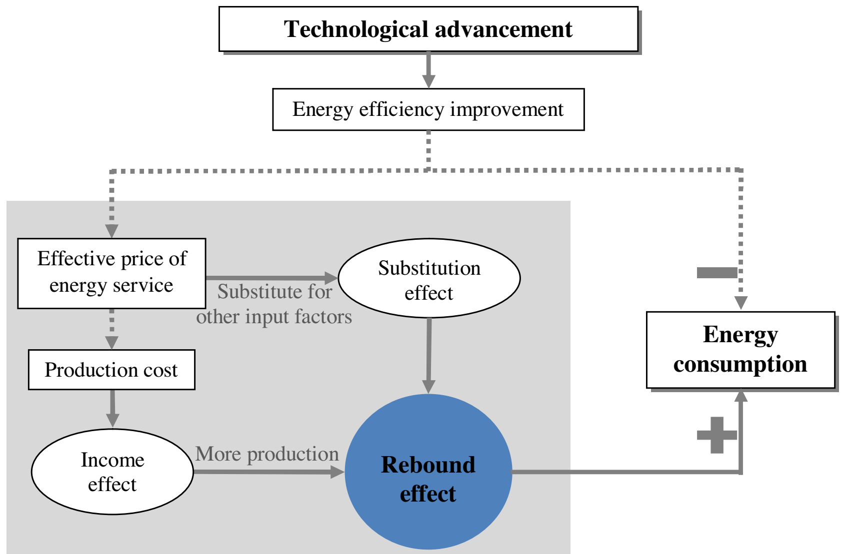

Fig. 1. Impacts of technological advancement on energy consumption in case of direct rebound effect.
Note: The solid lines denote increase effects while the dash lines denote decrease effects.

service decreases due to efficiency improvement and would therefore result in an increase in energy consumption, the amount of which could be large if energy and other input factors are substitutable [5]. More broadly, technological advancement contributes to production cost reduction as well as economic growth promotion, which in turn, increases the demand for more production and thus leads to more energy consumption [10].

Previous researches have shown the importance of RE in the building sector. For example, Haas and Biermayr reveal the existence of RE in buildings, ranging from 20%-30% in Austria [11]. Hens et al. further construct a rebound curve for heating based on the fact that the benefits of direct rebound are much larger in non-insulated than in well-insulated buildings [12]. Bourrelle presents that the rebound effect associated with cost-effective energy efficiency improvement should be quantified and included within the energy/emission balance of zero energy/emission buildings [13]. Wang et al. figure out that 74% (in the long-term) and 72% (in the short-term) of the anticipated electricity savings are offset due to energy rebound effect in China's urban residential buildings. The empirical results also find that the elasticity of energy consumption with respect to price decline is greater than that with respect to the price rise due to rapid economic growth, rise in urban disposable incomes, and electricity price regulation in China [8]. Lin and Liu show the existence of "back-fire" effect[1] in China's rural residential buildings. Moreover, if the rebound effect had been eliminated by implementing effective energy policies, 20% of the electricity consumption in China's residential buildings could be further saved each year [9].

Most of the literatures are focused on energy consumed in buildings while the rebound effect in other phases of the building total life-cycle is rarely discussed. Building construction accounts for 23% of total energy consumption in the whole building life-cycle, while in some low energy consumption buildings the ratio ranges from 40% to 60% [14]. It is indicated that building construction is increasingly important to meet the challenges of energy conservation and climate change [15,16]. Many evidences have proven that green construction, which refers to lower non-renewable energy consumption and environmental impacts without compromising

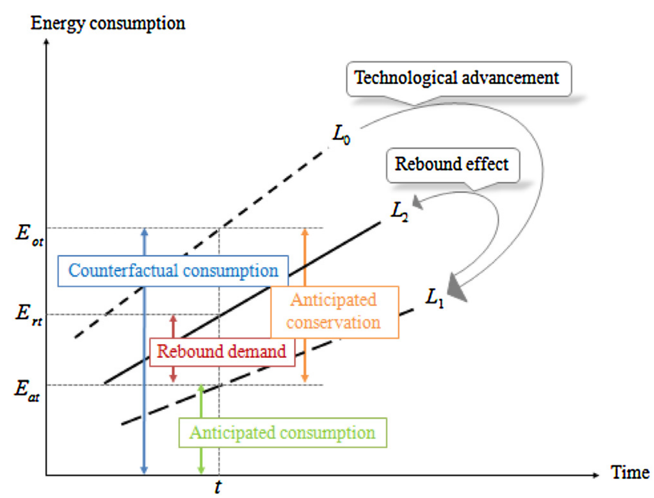

Fig. 2. Theoretical relationship between technological advancement, rebound effect and energy consumption.

the quality and safety of constructions, is gradually given more attention in China [17,18]. However, both the theory and practice of green construction in China have not attracted sufficient attention compared to developed countries. As Zhao et al. indicates, such green and sustainable project is still facing a lot of social problems, from humanistic needs to public attitudes and behaviors [19]. There is a pressing need to steer building construction activities from the existing mindset of ever-increasing growth to a new paradigm of sustainable growth [20].

As Bourrelle points out in his researches, the contributions of green construction to energy conservation and emission reduction are unclear unless effective measures are taken to dampen the rebound effect [13]. A more thorough understanding of the contribution of technological advancement to energy conservation is necessary, especially in the context of strengthening green construction and energy efficiency policies. To our knowledge, this paper is the first to measure the effect of technological advancement on energy consumption for building construction by incorporating direct rebound effect.

Fig. 2 illustrates the basic idea of this paper by linearly depicting real and simulative energy consumption changing trends. Line

[1] "Back-fire" effect happens when energy efficiency improvement results in an increase in energy consumption instead of leading to any energy conservation.