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The implications of China's investment-driven economy on its energy consumption and carbon emissions

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ABSTRACT

In this paper, we aim to fill the research gap by analyzing the relationship between China's domestic investment and energy consumption, as well as related carbon emissions. First, we use an expenditure-approach-based framework to qualitatively examine the effects of China's domestic investment on its energy consumption. Based on this framework, we define and differentiate the investment-driven energy consumption and carbon emissions from that which is driven by other economic activities. Second, we establish an allocation model to quantify China's investment-driven energy consumption and carbon emissions. The results reveal that in 2007, China's domestic investment contributed one third of both its energy consumption and carbon emissions. Further results show that a majority of this investment-driven energy consumption and carbon emissions, namely nine tenths of the total, is attributable to the construction and manufacturing sectors. Finally, we use the construction sector as a case to discuss how to determine the energy-saving and emission-reduction potential of improving investment-driven energy consumption practices.

1. Introduction

In the last five years, the Chinese government has implemented a set of intensity reducing policies (IRP), i.e. policies to reduce either energy consumption or carbon emissions per unit of gross domestic product (GDP) [1]. The IRP have made significant reductions in terms of energy- and carbon-intensities [2,3]. However, the IRP have not sufficiently released the intensive pressures on China's energy-supply security and climate-change mitigation, because the absolute volumes of its energy consumption and carbon emissions continue increasing at a rapid pace due to the fast economic growth [4–6].

Given the context of urbanization and industrialization processes, China's economic growth has long been labelled investment-driven, because the capital formation, which is induced by investment, contributes greatly to the country's GDP and its growth [7]. Such a growth mode presented China's sustainable development with a dilemma: on one hand, it induced a sustained high rate of economic growth, providing a favourable condition for a successful achievement of China's policy goals of energy-intensity reduction. On the other hand, it led to the rapid economic expansion, which further increased the total volume of China's energy consumption and the associated carbon emissions. Furthermore, phenomena, such as the short lifespan of buildings and infrastructure [8–10], and overcapacities in many industrial sectors [11], have been emerging in China's economy, which represents inefficient use of capital, energy, and other resources consumed by corresponding investment activities.

In this paper, we therefore analyze the effects of China's domestic investment on its energy consumption and the associated carbon emissions to gain some insightful conclusions to help the country's leaderships to get rid of the dilemma.

The input–output analysis, a useful analytical framework developed by Leontief [12], has been widely used in analyzing the energy consumption in economic activities [13–16]. Given the Leontief inverse matrix, input–output analysis can be easily used to calculate the total (direct and indirect) energy inputs of a sector, regardless of the length and complexity of production process [17]. The results derived from such studies help to gain critical understandings of the correlation between (global, national or regional) economy and the corresponding energy use.

Among the empirical studies of China, analysts have already studied the effects of many economic activities on energy consumption. For example, Chen and Zhang [18] built up a greenhouse gas (GHG) emission inventory by economic sector in China in 2007, and systematically reveal the GHG emission embodiment in final

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consumption and international trade of the Chinese economy. Su et al. [19] analytically investigated how sector aggregation affects estimates of energy-related carbon dioxide (CO_2) emissions in international trade based on the input–output analytical framework; Liu et al. [20] evaluated the impacts of international trade on energy use and identified the underlying factors that contribute to modifying the energy embodied in exports over years; Chang et al. [21] estimated the embodied energy and environmental impacts of construction projects in China; Liu et al. [22] made a comprehensive evaluation of household indirect energy consumption and impacts of alternative energy policies in China.

Although previous empirical studies have already covered many economic activities in China, such as the residential consumption and the international trade, few analysts have studied systematically the investment effects, i.e., analyzing the implications of China's investment-driven economy on its energy consumption. Particularly, some fundamental questions have not been well addressed yet. These include, for example, what the correlation between investment and its energy consumption is, how to define the investment-related energy needs and then differentiate it from the ones driven by other activities and what connections these different energy needs have, etc.

In this paper, we first apply an expenditure-approach-based framework to elaborate the effects of China's domestic investment on its energy consumption, and we define and differentiate the investment-driven (ID) energy consumption and its associated carbon emissions from those driven by other economic activities. Second, we establish an energy input–output model to identify quantitatively China's ID energy consumption and carbon emissions in 2007. Finally, we discuss how to determine energy-saving potentials by improving the utilization of the ID energy consumption.

2. Understanding the implications of investment on energy consumption

2.1. Expenditure-approach-measured GDP and investment

Analysts use the gross domestic product (GDP) to measure the output of an economy (the value of all the final goods and services produced in a country in one period of time (e.g., one year). It can be measured from the production side, the expenditure (final-use) side or the income side [23]. Measuring GDP from the expenditure side, namely the expenditure-approach, involves counting expenditures on goods and services by three groups of economic activities, i.e. final consumption (private and government), investment, and international trade [24].

Among these three activities, investment usually plays the key roles of maintaining and expanding an economy by continuously forming new assets, such as buildings, infrastructure, and various industrial facilities. These newly formed assets, plus those assets formed and accumulated previously, provide the current production capacities (or conditions) of goods and services of various economic sectors. Subsequently, the operations of the current production capacities provide various goods and services to meet the three groups of economic activities in the same time period.

From a statistical perspective, all three groups of economic activities consume goods and services in the same time period, comprising the GDP from the expenditure side. However, investment often sustains across several time periods in order to form new assets. For example, if someone invests to start building a coal power plant in this year, the construction work will last for about three to five years, so that the newly formed power-generation capacity created by the investment will only take effect in the future when the coal power plant is put into use. Therefore, although investment consumes goods and services in the current time period, contrary to the other two groups of economic activities, the new assets that are formed by investments will actually take effect in a future time period.

2.2. The correlation between investment and its energy consumption

Given the understanding above, we propose using an expenditure-approach-based framework, as shown in Fig. 1, to map the correlation between China's economy and its energy use. Currently, the energy system, as one part of the accumulated assets, operates to extract primary energy supplies and convert them into different forms to meet the demand of different economic activities. According to the expenditure approach, the annual energy consumption also can be sorted by the three groups of economic activities, i.e. final-consumption-driven (FCD), export-driven (ED) and investment-driven (ID) categories. Each category of energy consumption includes both direct and indirect energy, i.e., embodied energy [25], consumed by the corresponding economic activities. For example, investment consumes both energy and non-energy goods and services, so that the energy consumed by investment, namely the ID energy consumption, should take the embodied energy of all the goods and services into account.

As described above, although the total energy consumption in the current term is comprised by all three groups of economic activities (FCD, ED, and ID) from a statistical perspective, the ID energy consumption will actually start to take effect in the future when the investment finishes forming the new assets and puts them into use.

Given the proposed framework, the mechanism behind the fast growth of China's annual energy consumption can be interpreted from the perspective of the whole economy.

If we assume that China's final consumption and export both stay at the current scale, then the annual energy consumed by operating the current assets (i.e., the accumulated assets in operation) would be mainly used to meet two purposes. The first one, which is to provide goods and services to meet the demand of the current volumes of the final consumption and export, causes the FCD and ED energy consumption. The second one, which is to meet the investment so as to form new assets to substitute old (or to-be-retired) ones, causes the ID energy consumption.

In this context, the annual energy consumption would remain at a stable level or even decline over time, because the newly formed assets often possess higher energy efficiency compared with the old ones. However, the fact is that China's economy is now experiencing a dynamic development period. The expectations about China's final consumption and export in the future often have significant increases compared with current volumes. The expected increases will require current investment to start building the incremental assets considering the time consumed by construction. This will raise the third purpose of current energy consumption – which is to form new assets in the future to expand the scale of the current ones – and accordingly increase the ID energy consumption.

Therefore, the annual energy consumption will likely show a constant (or even accelerated) increasing trend over time, because the continued volume expansions of the three groups of economic activities drive the growth of the annual energy consumption.

The framework in this paper can also be used to analyze the carbon emissions associated with the energy use of an economy. As with energy consumption, annual carbon emissions can be sorted by the three groups of economic activities, i.e., FCD, ED, and ID categories. Subsequently, the mechanism behind the fast growth of China's annual carbon emissions can be interpreted in the same way as above.