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Environmental externality of coal use in China: Welfare effect and tax regulation

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HIGHLIGHTS

- China's interprovincial embodied CO_2 flows are evaluated in monetary unit.
- A carbon tax complemented with VAT adjustment is proposed and analyzed.
- The carbon tax leads to significant wealth redistribution if not adequately offset.
- Resource-abundant provinces are hit harder from the carbon tax.

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ABSTRACT

This study employs a multi-regional input–output model at the provincial level to evaluate the environmental costs of coal burning in China in 2007, in terms of its damages from climate change externality. According to the results, the contributions of central-west provinces to the national economy are significantly underestimated because the hidden environmental inputs are not reflected by conventional national account. For example, if the externality of CO_2 emission is monetized to be 20 USD/ton (152 RMB/ton), the net external cost introduced by Shanxi in 2007 amounts to nearly 8 billion USD (59 billion RMB), which is equivalent to over one tenth of the annual local output. Our results confirm that developed regions, such as Beijing and Guangdong, shape their low-emission profiles by transferring embodied emission flows to less developed regions. By using a Pigouvian tax to correct for the environmental externality, national consumer price index, producer price index, export price, and gross domestic product deflator will increase by 2.28%, 3.94%, 1.44%, and 1.61%, respectively. To offset the inflationary effect, a complementary measure of reducing domestic value-added tax rate is proposed and analyzed.

1. Introduction

Externalities are one of the most frequently observed causes of market failure, especially when energy and environmental issues are involved. The environmental problems brought about by energy externalities predominantly fall into two major categories. First are market inefficiencies. These occur when the externalities distort incentives leading to a sub-optimal market structure and lost social welfare. For example, when the negative effects of CO_2 emissions are not taken into account, carbon-intensive goods are overproduced, as happens in many industrializing countries [1]. The second major concern is in the distribution of social costs, which tend to fall hardest on the poorest. As richer, more-developed regions outsource pollution intensive heavy industry to poorer, less-developed regions, the social costs of the associated externalities fall most heavily on the latter [2–5].

Both these problems can be corrected through various policies such as direct command-and-control regulations, cap-and-trade systems, or Pigouvian (corrective) taxes. In designing such policies, two important questions need to be addressed. First, how severe is the market distortion caused by the energy externality? Second, how will the costs of any corrective policies be felt by the different

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stakeholders involved? In other words, it is necessary to both assess the welfare loss generated by the energy externality and evaluate acceptable corrective costs.

Hand in hand with China's rapid GDP growth has been a rise in energy use, the majority of which comes from coal. Incomplete and poorly-enforced environmental legislation has meant that this growth has led to increasingly serious environmental challenges. The widespread use of coal has caused a dramatic deterioration in urban air quality, threatening residents' health [6–10]. In addition, the free rider effect has hindered investment in renewable energy which could help to alleviate the environmental pressures [11,12].

Previous analysis has shown that the social costs caused by greenhouse gas emissions from fossil fuel combustion are the main source of energy externalities in China [13]. This has been recognized by the Chinese government which has sought to curb emissions through several policy initiatives. Targets have been set to reduce CO_2 intensity per unit of GDP by 40–45% from 2005 levels by 2020 [14]. The 12th Five-Year Plan (2011–2015) also contained a CO_2 emission intensity reduction goal of 17% [15], and this national target was in turn converted into provincial targets. Energy and environmental policies may be promulgated centrally, but they are implemented by individual provincial governments facing widely different development issues. The conversion of central, national-level policies into appropriately calibrated provincial targets is therefore a key test for policy-makers.

This paper therefore investigates China's most prominent energy externality: the social costs of CO_2 emissions from coal burning. Emission volumes and intensity are calculated at the provincial level to highlight the regional differences in coal consumption. Using a multi-regional input–output model, this study further quantifies the effect of domestic trade (and its embodied emissions) on social welfare. As stated earlier, one way of correcting for externalities is through a Pigouvian tax. The paper therefore presents a comprehensive tax scheme to assess the costs of effective regulation, while a compensatory offset mechanism is used to ensure equitable social outcomes across China's provinces.

In this way, the paper's chief contributions are: (1) the welfare effect of China's inter-provincial embodied CO_2 flows is evaluated on an economic basis in contrast to previous bottom-up assessments; and (2) a tax package consisting of a Pigouvian tax with a value-added tax adjustment is analyzed as a possible solution to correct for the environmental externalities of coal use in China.

The rest of this paper is organized as follows. Section 2 provides a brief review of previous energy externalities studies. Section 3 introduces the method and data. Section 4 describes how the different levels of coal use across China's provinces, combined with patterns of domestic trade, have led to a skewed distribution in the fallout from coal use's externalities before setting out a possible tax package to reduce the effects of the externalities. The paper concludes with some policy suggestions in Section 5.

2. Literature review

Previous energy externality investigations have largely focused on one of two elements: (a) the direct burning of fossil fuels and (b) thermal power generation, and initially looked primarily at the United States and Europe. The National Research Council [16] estimated that the aggregate damage associated with emissions of SO_2, NO_x, and particulate matter from coal-fired facilities in 2005 was approximately 62 billion USD, or an average of 156 million USD per plant (both in 2007 dollars). Greenstone and Looney [17] found that the total social cost of coal use in the USA was 1.7 times its retail price: over 40% of the costs of coal were not internalized in its price, resulting in its over-consumption. Such results are not unique to North America. In a bottom-up analysis of air pollution from energy use in Central and Eastern European (CEE) Countries, Maca et al. [18] found that although the countries had attempted to regulate emissions through strict command-and-control measures, most of them even had introduced air emission charges and taxes on electricity, the price of coal still failed to fully reflect its social costs. The regulations internalized around 3% (for coal- and lignite-fuelled plants) to 31% (for gas-fuelled power stations) of the externalities.

Lee et al. [19] and Rowe et al. [20] were among the first attempts to employ a comprehensive, bottom-up approach to evaluate the external costs of electricity fuel cycles in the United States. The fuel cycle included three stages: exploration, transportation, and electricity generation. However, the two studies neglected the climate change externality caused by greenhouse gas emissions. The first study of externalities to cover climate change, the ExternE project, was implemented by the European Commission, in conjunction with the United States Department of Energy, Resources for the Future, and the Oak Ridge National Laboratory, to estimate the externality costs of power generation by coal, fuel oil, and natural gas [21]. ExternE showed that the external costs of greenhouse gas emissions contributed a substantial part to the total cost of thermal power generation. In addition, the social costs (externalities) of coal-fired generation (0.02–0.16 USD/kW h) were higher than those of fuel oil or natural gas generations [22].

Jiang et al. [13] estimated the total environmental costs of thermal power generation in China to have increased from 298 billion RMB (36 billion USD, exchange rate in current year is applied here and hereafter) in 1998, to 850 billion RMB (126 billion USD) in 2010 (giving a unit cost of 0.216 RMB/kW h or 0.032 USD/kW h. Even higher environmental costs were calculated by Shi [23]: 0.31 RMB/kW h (0.04 USD/kW h) between 2005 and 2007.

The uneven distribution, transfer, and use of coal across China's provinces have been analyzed in several studies. Understanding the root cause of China's spatial patterns in pollution is important for a country in which environmental policy is determined centrally but implemented locally. In 2006, the inter-provincial coal trade led to Shanxi province, a less-developed but coal-rich province, producing an extra 0.44 billion tons of industrial wastewater, 0.68 billion tons of chemical oxygen demand, 0.02 billion tons of oil solid waste, and 0.03 billion tons of industrial solid [24]. In contrast, the relatively well-developed and coal importing Shandong province reduced the same pollutants by 0.39, 0.48, 0.01, and 0.01 billion tons, respectively. Zhou et al. [25] went further, computing the embodied CO_2 flows in the inter-provincial trade of secondary energy. By importing energy-intensive products, China's eastern coastal provinces have effectively transferred their emissions to the resource-abundant central-west provinces.

It is, however, not only in the trade of energy, but in the trade of all goods and services containing embodied energy, that the externalities of coal use can be displaced between provinces. Further, it is not only the direct producers and consumers of energy that are responsible for the provincial distribution of coal's environmental impact, but all market actors. For example, Wal-Mart is not directly involved in the energy market and may appear to be unconnected to the spatial transfer of energy externalities. However, when the retailer buys goods from a manufacturer in other city, province, or country, and that manufacturer consumed energy to produce the goods bought, a substantial transmission channel is formed for the flow of embodied energy externalities. For this reason, the spatial transfer of energy externalities is more appropriately analyzed using general equilibrium models, so that the transactions of non-energy markets are also considered, revealing the full impact of energy externalities [26,27].

There are two general equilibrium models suitable for the analysis of spatial transfers: Multi-Regional Input–Output (MRIO)