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Gearing carbon trading towards environmental co-benefits in China: Measurement model and policy implications

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ABSTRACT

Given the local effects of co-pollutant emissions, the trading of carbon dioxide emissions between facilities to meet global objectives may improve or worsen local air quality and public health. To gear carbon trading toward maximum environmental co-benefits, a quantitative model based on facility-level carbon dioxide emissions, air pollution dispersion and concentration-response functions is proposed and applied to the Beijing-Tianjin-Hebei region to quantify potential changes of local public health caused by carbon dioxide transactions. The results show that the polluters with the highest Population Health Damage Intensity (PHDI) are medium-sized facilities, because larger facilities either employ more effective pollutant control technologies or are located farther away from densely populated areas. Using this modeling framework, key facilities, sectors and regions can be identified for maximizing the environmental co-benefits from introduction of carbon market and avoiding undesirable environmental damage.

1. Introduction

Carbon markets are important instrument of climate change mitigation, and covered 11% of global energy-related emissions in 2014 (IPCC, 2014; IEA, 2015). The Chinese government has adopted the carbon market as one of its important policies and has rapidly developed it during the last five years (NDRC, 2011; Zhang et al., 2014; Jotzo and Löschel, 2014; NDRC, 2014a,b), with plans to culminate in a nationwide carbon market in 2017 (NDRC, 2016). Unlike developed countries that are focusing mostly on climate change mitigation, China faces the dual challenges of striving to reduce carbon emissions and improve local environmental quality simultaneously. This reflects China's coal-dominated energy mix with substantial share of coal-fired facilities (Wang et al., 2014; Cai and Zhang, 2014). Air pollution has been a major threat to public health in China, resulting in an estimated 1.2 million premature deaths and 25 million disability-adjusted life-years (DALY) lost in 2010 (Yang et al., 2013a).

Carbon markets are designed to reduce the climate mitigation cost. In China, CO_2 emissions often are accompanied by large amounts of other pollutants known as co-pollutants. While the climate effects of CO_2 emissions are global, the environmental effects of co-pollutants are local. In specific localities, CO_2 emission credit transactions between facilities may either improve or worsen air quality, with consequent positive or negative effects on public health. Consider an extreme example: two facilities, A and B, have similar annual CO_2 emissions. They are located, respectively, in an urban area where one million people are affected by co-pollutant emissions and in a desert area with no one living within the range of effects of its pollution. If A buys one ton of CO_2 emissions credit from B in order to expand its use of fossil fuels, the million people living nearby will suffer more co-pollutant emissions than if A's carbon emissions had been capped at the previous level. However, no one will get any air quality co-benefits by virtue of the corresponding reduction of emissions from B. In this context, the total benefit to population health and welfare associated with the carbon transaction is negative. On the other

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hand, the opposite transaction would benefit the people affected by this two-facility carbon trading system.

Unfortunately, the evaluation and assessment of pollution-related health effects of carbon trading have not been fully considered in the pilot emissions trading schemes (ETS) in China (Zhang et al., 2014; Jotzo and Löschel, 2014). They are not even mentioned in the country's ETS strategy document (see NDRC, 2014a,b). Measuring the spatial disparities in environmental co-benefits during carbon trading can be an important step in moving China's ETS forward. If designed with potential synergies in mind, carbon markets can bring about substantial improvements in local environmental health along with the transaction of carbon emissions.

The purpose of this paper is to propose a method to measure and evaluate the environmental effects of carbon reduction from industrial facilities in China using a quantitative model, and to discuss policy options to improve the environmental benefits of carbon markets in China. Section 2 provides an overview of the environmental effects of reducing CO_2 emissions. Sections 3 and 4, respectively, describe the methods and then use the carbon trading system of the Jing-Jin-Ji region (Beijing-Tianjin-Hebei) as a case study to identify the most important sectors and regions in terms of potential environmental co-benefits. Section 5 proposes policy options for remodeling the ETS of the Jing-Jin-Ji region to obtain CO_2 emission reductions with the highest level of environmental co-benefits.

2. Literature review

Mitigation policies related to CO_2 emissions generally have positive effects on air quality and public health via reduced emissions of co-pollutants such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and total suspended particles (TSP) (Haines et al., 2010; Harlan and Ruddell, 2011; Nemet et al., 2010; West et al., 2013). Climate policy instruments that mitigate air pollution, improve air quality and provide public health benefits will be favored and accepted by public. For developing countries with serious air pollution problems, the potential for improving air quality and health will be especially large (Markandya et al., 2009; Nemet et al., 2010; West et al., 2013). These air quality co-benefits mean substantial cost savings which can be obtained by reducing CO_2 emissions. In an international review of studies, Bell et al. (2008) argued that measured co-benefits are likely to be underestimated in some cases because a number of important unquantified health and economic results exist. Many studies on the magnitude of air quality co-benefits associated with climate change policy have concluded that these co-benefits are likely to be significant in China (Aunan et al., 2006; Aunan et al., 2004; Mao et al., 2013; Yang et al., 2013b; Haines et al., 2010).

Carbon trading, as one of the important mitigation policies, is likely to have significant impacts on the spatial pattern of CO_2 emissions and co-pollutants emissions. While the warming effects of CO_2 emissions are global, the effects of co-pollutant emissions are local and can be very unequal. The environmental and health effects of CO_2 emissions reduction themselves vary dramatically among locations due to differences in geography, climate and population density (IPCC, 2014; Markandya et al., 2009; Sharon et al., 2009; Smith et al., 2009; GEA, 2012). Spatial differences in co-pollutant emissions add a further dimension of variation to the impacts of carbon trading across locations.

Rao et al. (2013) estimated the extent and distribution of outdoor air pollution exposures associated with climate policies, and confirmed the importance of population exposure and pollution distribution. The Global Energy Assessment (2012), coordinated by the Institute for Applied Systems Analysis, observed that the human exposure risks from particulate matter pollution resulting from energy use are divergent in different cities worldwide. Carbon trading will impact emissions of both CO_2 and co-pollutants at the facility level (IPCC, 2014; Driscoll et al., 2015). The World Bank (2015) concluded that carbon markets could induce carbon leakage, or relocation of carbon-intensive activities, with attendant environment impacts at the facility level. Studies in the United States have shown that the disparities in environmental justice – the extent to which vulnerable populations are disproportionately impacted by environmental harm – can be induced by changes in the spatial pattern of point emission sources (Mohai and Saha, 2006; Pastor et al., 2013; Pollock and Vittas, 1995). Muller (2012) found that the co-pollutant damage per ton CO_2 in the United States varies considerably across source types and locations, and that a large fraction of the welfare improvement from emissions reductions could come from a small percentage of pollution sources.

Most studies focused on the environmental effects of carbon trading in China have been carried out at the macro- or meso-level, and have been based on the average quantitative relationship between co-pollutant and CO_2 emissions with little consideration given to the population exposure (Sun et al., 2014). Beijing ETS policymakers explicitly expect a carbon trading scheme to provide positive effects in air quality by pollutants reduction (BMCDR, 2013), and positive environmental effects have been discussed related to the Guangdong ETS (Cheng et al., 2015) and Shanghai ETS (Zhou, 2015). Spatial variations associated with differences in the relationship between co-pollutant and CO_2 emissions and with differences in population exposure have not been analyzed, however.

The works of Boyce and Pastor (2012, 2013) and Pastor et al. (2013) provide an entry point to explore the spatial differences in the co-benefits of reductions in CO_2 emissions from industrial facilities. These studies used population-weighted measures of co-pollutant damages based on exposure modeling (or, more simply, on the product of co-pollutant emissions multiplied by the number of people living within a 2.5 mile radius of a facility) as a ratio to CO_2 emissions to evaluate the spatial disparities of environmental co-benefits. Taking a similar approach, in this study we develop a comprehensive model that combines facility CO_2 and co-pollutant emissions, facility-specific fate and transport of co-pollutants, and concentration-response functions to measure the potential environmental co-benefits of carbon trading in the Chinese context.

3. Methodology

3.1. Description of the Jing-Jin-Ji region

The Jing-Jin-Ji region is made up of two Municipalities Directly Under the Central Government's control (MDUCG), that is, Beijing and Tianjin, and the province of Hebei (Fig. 1). This region covers 216,760 km^2 and was inhabited by 107.70 million people at the end of 2012 (National Statistics Bureau, 2013). It is emerging as a large regional carbon market, against the background of the Jing-Jin-Ji integration strategy launched by Chinese president Xi Jinping (Encyclopedia, 2015), the inter-regional carbon emissions trading cooperative agreement signed in 2013 (Sina News, 2013), and the integration of the emission units of Chengde City, Hebei Province, into the Beijing ETS in 2014 (He, 2014). The Jing-Jin-Ji region is also one of China's three most important regions needing stricter air pollution controls (the other two are the Yangtze River delta region and the Pearl River delta region), according to the *Air Pollution Control Action Plan* issued by China State Council (2013).

In light of the emerging Jing-Jin-Ji ETS, we use this region as the spatial boundary for our analysis. Because this region suffers from serious smog-related air pollution, an urgent need exists to develop the best methods to measure the environmental impacts