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A comparative assessment of economic-incentive and command-and-control instruments for air pollution and CO_2 control in China's iron and steel sector

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ABSTRACT

China's iron and steel sector is faced with increasing pressure to control both local air pollutants and CO_2 simultaneously. Additional policy instruments are needed to co-control these emissions in this sector. This study quantitatively evaluates and compares two categories of emission reduction instruments, namely the economic-incentive (EI) instrument of a carbon tax, and the command-and-control (CAC) instrument of mandatory application of end-of-pipe emission control measures for CO_2, SO_2 and NO_x. The comparative evaluation tool is an integrated assessment model, which combines a top-down computable general equilibrium sub-model and a bottom-up technology-based sub-model through a soft-linkage. The simulation results indicate that the carbon tax can co-control multiple pollutants, but the emission reduction rates are limited under the tax rates examined in this study. In comparison, the CAC instruments are found to have excellent effects on controlling different pollutants separately, but not jointly. Such results indicate that no single EI or CAC instrument is overwhelmingly superior. The environmental and economic effectiveness of an instrument highly depends on its specific attributes, and cannot be predicted by the general policy category. These findings highlight the necessity of clearer identification of policy target priorities, and detail-oriented and integrated policy-making among different governmental departments.

1. Introduction

Alongside its rapid economic growth of the past decades, China has been faced with considerable environmental constraints. One of the most urgent issues is the enormous consumption of fossil energy and the emissions of local air pollutants and carbon dioxide (CO_2). In this study, local air pollutants refer to substances such as sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particle matters (PM). Among all the economic sectors in China, the iron and steel sector is one of the largest emitters, responsible for 9.2% of the country's total industrial CO_2 emissions, 7% of the SO_2 emissions and 15% of the PM emissions (China Iron and Steel Association, 2009a). China's 12th Five-Year (2011–2015) Plan aims to reduce 8% of the total SO_2 emissions, 10% of the total NO_x emissions and 17% of the CO_2 intensity, imposing significant pressure on the iron and steel sector to reduce emissions.

Faced with this situation, the environmental authorities are considering two strategic options. One is sticking to the already long used command-and-control (CAC) instruments that require mandatory application of end-of-pipe (EOP) pollution control technologies. The other is implementing economic-incentive (EI) instruments such as a carbon tax. In China, many governmental research institutes have proposed that the country should implement a carbon tax during the 12th Five-Year Plan period to mitigate CO_2 emissions (CRIFS, 2009; Energy Research Institute, 2010), something which is being seriously considered by the government.

Although CAC environmental regulations are still prevalent in the world (Harrington and Morgenstern, 2004; UNEP, 2004; Kolstad, 2011; Bakam and Balana, 2012; Böcher, 2012) and in China, there has been growing interest in EI options. In fact, the question of which type of instrument would be preferable has been at the core of debates within China for years.

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On the effectiveness of the two categories of policy instruments, existing literature either involves only one of the two, namely either CAC regulations (He and Lei, 2010) or EI policies (Cao and Ho, 2008; Rive, 2010; Groosman and Muller, 2011; Mao and Yang, 2012; Muller, 2012), or focuses only on their effects on controlling one single pollutant but does not examine their effects on co-controlling multiple pollutants (Kolstad, 1986; Ruth and Amato, 2002; Malcolm and Zhang, 2006; Pizer and Burtraw, 2006; Tietenberg, 2006; Fischer and Newell, 2008; Bird and Chapman, 2011; Palmer and Paul, 2011; Schmidt and Leduc, 2011; Prasad and Munch, 2012). This study aims to fill this knowledge gap by conducting a quantitative assessment and comparison of the co-control effects of the EI and CAC instruments in the context of the iron and steel sector in China.

Concerning the evaluation tools for 'economy-energy-environment' (3E) policy instruments, various structural models have been developed, including top-down models such as Computable General Equilibrium (CGE) models, and bottom-up models such as Market Allocation (MARKAL) models. Top-down models commonly emphasise policy impacts on economic indicators, such as supply/demand scale and market prices. In contrast, bottom-up models often focus on policy impacts on technology composition. However, 3E policy instruments may first change both the scale and technologies of production, and then influence pollutant emissions. Therefore, there have been ongoing efforts to merge the two types of models for 3E policy evaluations (Böhringer and Rutherford, 2005; Rivers, 2011). This study also aims to make a methodological contribution by constructing an integrated assessment model (IAM) that combines a top-down model and a bottom-up model for the policy assessment.

2. Methods and data

2.1. Integrated assessment model

2.1.1. Integration framework

Fig. 1 illustrates the integration framework of the IAM in this study. A top-down CGE sub-model and the bottom-up part of the CIMS (Canadian Integrated Modelling System) sub-model are integrated through a soft linkage. Simulations are conducted in each sub-model separately. The primary policy shocks are imposed on the CGE sub-model, and the key elements of steel production and energy prices from the CGE simulation results are fed into the CIMS sub-model as exogenous parameters.

2.1.2. CGE Sub-model

In this study, a single-region, twelve-sector, recursive dynamic CGE model is developed independently, to conduct macroeconomic simulations. Following the general equilibrium theory, this model describes a large open economy, keeping most of the standard neoclassical assumptions. The recursive dynamic process is driven by the growth of labour and the accumulation of capital as described by the Solow model. The carbon tax is modelled as an input tax on energy prices. The CAC-EOP instruments are modelled as mandatory extra input of the EOP technologies for iron production, and the EOP technologies are supplied by the environmental industry, which is included in the service sector. A detailed description of the model was provided by the study of Liu and Mao (2011).

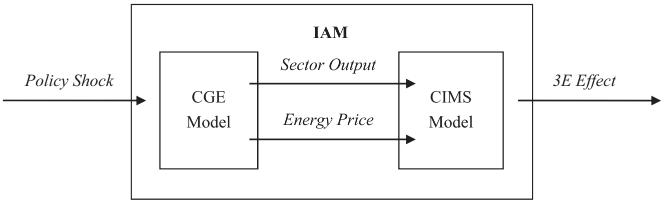

Fig. 1. The soft linkage between the CGE and CIMS sub-models.

This model adopts many standard assumptions of neoclassical models, such as perfect competition and constant returns to scale. The two assumptions actually reflect the recent characteristics of the iron and steel industry of China. Unlike in other parts of the world where this industry is dominated by a few large 'players', the iron and steel industry of China remains highly fragmented and competitive (National Development and Reform Commission of China, 2009; Tang, 2010). In 2007, the top four iron and steel firms merely accounted for 19.3% of the total output of China's iron and steel industry; in comparison, the counterpart shares in the EU, the US and Japan are respectively 90.73%, 52.90% and 74.77%. Meanwhile, firm-level econometric studies have found evidence of constant returns to scale in China's iron and steel industry (Song and Liu, 2012).

2.1.3. CIMS sub-model

The CIMS sub-model in this research refers to the bottom-up part that describes technology substitution. The technology substitution starts with calculating the demand for extra technology investment caused by the phasing out of old equipment and the growth of production scale, both of which are measured by the amount of iron and steel products. Different technologies compete with each other to meet the extra demand based on Life Cycle Cost (LCC) comparison. Basically, a technology with relatively lower LCC takes a larger share of the extra demand. The mathematical expression of the CIMS model was provided by the study of Jaccard and Nyboer (2003).

Although originally developed in Canada, the CIMS model describes a universal mechanism of technology competition and choice-making process applicable all over the world. This model has been widely applied in Canada, the US, Australia and China, and the parameters are adjusted using the specific data from the case study countries (Rivers and Jaccard, 2005; Murphy and Rivers, 2007). For the last ten years, this model has been adapted for major production sectors in China, such as the iron and steel, power generation and transportation sectors (Tu, 2004; Tu and Jaccard, 2007; Xing, 2007; Liu, 2008; Mao and Yang, 2012).

The CIMS sub-model in this study includes 37 production technologies in 6 different stages of iron and steel production, which is presented in the appendix. A calibration test within the model is conducted to ensure that the difference between the simulated and the actual energy consumption in the base year is less than 5%.

2.1.4. Air pollution equivalent index

The evaluation and comparison of emission control instruments take into account the co-control effects of reducing multiple kinds of pollutant emissions. An air pollution equivalent index (AP_{EQ}) (Mao and Zeng, 2013) is introduced to measure the aggregated scale of different pollutant emissions, which is calculated through the following equation:

$$AP_{EQ} = \sum_i [W(i) \cdot E(i)] \tag{1}$$

$E(i)$ denotes the emission volume of the pollutant i, whilst $W(i)$ denotes the weight of the pollutant, which is calculated by dividing the price of the pollutant by the price of SO_2:

$$W(i) = \frac{\text{Price}(i)}{\text{Price}(SO_2)} \tag{2}$$