Dynamic Integrated Assessment of Air Pollution Regulation and Adaptation in Power Sector: An Case Study in Chongqing City

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Abstract

One of the main challenges to reduce GHG and air pollution is the fact that China relies on coal to meet energy demand having the electric power sector as the main contributor. A potential route could be to combine policy options that include regulations and carbon tax schemes to promote technology innovation. However the uncertainties regarding the effect of such policies remains a challenge for policy makers. To address this challenge we proposed scenarios to forecast not only GRP growth and energy source trends and its associated emissions but also technology adoption. The study applied a dynamic input output model and selected Chongqing city as a case study. The results show that the integrated policies will balance GRP growth, total energy consumption and the adoption of cleaner technologies, which in turn will impact GHG and air pollution emissions. The study also shows that the introduction of carbon tax should not be limited to the electric power sector. A diversification of power generation technologies and the shifting towards cleaner natural gas based power generation is also demonstrated. The findings of this study provide a strong platform for policy makers to identify the optimum mechanisms to benefit the society and the environment.

Keywords: carbon tax, subsidy, environmental regulation, air pollution, GHG emissions, technology innovation, energy conservation

1. Introduction

Coal ranks second only to oil as the world's leading energy source and is the world's main fuel for the generation of electrical power. Because of the rapid energy demand growth to fuel its economic development China overtook the USA as the largest emitter of CO2 in 2007 accounting for 21.7% of the global emission (UNSTAT, 2010). Power generation in China relies on coal accounting for 79% of supply and the electricity sector is responsible for more than 44% of the total CO2 emissions (Baron et al., 2012). Coal-based power generation is also associated with air pollution and health damage (Kanada et al., 2013). Many studies already suggest that the cost of environmental degradation has had a dramatic impact on the Chinese economy reaching 230 billion USD in 2012 equivalent to 3.5% of its total GDP (CAEP, 2012).

The decrease in the quality of the environment has caused public anger in many parts of China. Chongqing, an Acid Rain Control Zone designated by the Chinese Central Government, is one of the most affected cities in this regard. Technology development and innovation could play a key role in not only reducing GHG but also air pollutant emissions by promoting renewable and cleaner fossil fuels (Liu and Liang, 2013).

Promoting electricity technology innovation and attaching a price to carbon dioxide emissions have both been suggested as ways of reducing power sector's environmental impact. One potential route for emission reduction is to introduce policy options that apply carbon taxes, which could be used to subsidize power technology innovation. Such a policy would have impacts not only in the whole regional macroeconomic but also on many aspects of the power sector, including demand, power generation energy source composition, air quality and climate change. Therefore, its impacts need to be considered holistically, taking into account likely interaction and feedback effects. In this paper, we apply a model of the expanded input output system, a Dual Nonlinear Integrated Model (DNIM), to assess the demand and emissions response from the following application of such a power sector policy. The study demonstrates that the introduction of carbon tax has no obvious impact for promotion of technological innovation, economic growth and energy conservation. The results also show that government subsidy support for technology innovation is an effective way for regional sustainable development. The technology innovations and their cost reduction in the energy sector alone will reduce both air pollutants and energy to a certain extent. In this regard we must also promote innovation in other economic sectors. Another important finding is the fact that the strict government regulations will actually curb air emissions and energy consumption.

The rest of this paper is organized as follows: section 2 describes the approach used in this paper to estimate the impact of policies; Section 3 presents the methodology. Results and discussion are illustrated in section 4. Finally, section 5 highlights the conclusion and policy implication.

2. Methodology

A novel dynamic I/O model, developed by Zhou et al. (2016) regarding the thermal electricity sectors, was used in this study in order to evaluate the proposed policy. Our hypothesis was that when fossil fuel is utilized under mandatory air pollution reduction, the introduction of advanced fossil fuel energy technology and its resulting reductions in cost resulting from the implementation of a carbon tax and a subsidy could be beneficial in terms of economic growth, energy efficiency, and the reduction of GHG emissions and air pollutants. In this study, the model was applied in order to evaluate these polices in isolation, as well as in combination. This section explains how the proposed policy and the associated key assumptions were incorporated into our model.

2.1.1 GHG and Air Pollutants Emission

The GHG and air pollutants emissions in this model are defined by the total quantity of energy consumption related emissions i.e. emissions by industries energy consumption and household energy consumption.

$$W^{gas}(t) = \sum_{1}^{4} ED_i^T(t) \bullet EEng_i^{gas} + ED_c^T(t) \bullet EEng_c^{gas} \quad \left(\text{gas} = GHG,\ SO_2,\ NO_x,\ PM_{10},\ PM_{2.5} \right) \quad (4\text{-}7)$$

Where W^{gas} is a vector of 5 elements denoted by the emission amount of the 5 kinds of gases shown above. $EEng_i^{gas}$ and $EEng_c^{gas}$ are gas emission coefficient matrixes that correspond to the energy carriers consumed in i industry and household consumption.

2.1.2 Regional Government Environmental Regulation Constraints

The central and local Chinese governments implement development plans every five years in order to improve the quality of the environment in China. Based on the plan provided by the central government and the environmental situation of Chongqing, the Chongqing government plans to reduce its air pollution emissions by 10% every five years. In this study we used the regulations set by the government and analyzed their impact using integrated evaluation models. We incorporated this regulation into our model by providing a constraint on the amount of emissions in 2015, 2020, and 2025 and keeping the amount of emissions in other years unconstrained, which could be helpful in the optimization of energy utilization and the maximization of economic development.

In addition, the constraints set on SO2 and NOx emissions will indirectly curb PM10, PM2.5, and GHG emissions. This assumption is based on the identified strong synergies between air quality and climate relevant measures that would allow for improvements in the cost-efficiency of air pollution policies Liu et al. (2013).

2.2 Scenario design

The scenarios are constructed to compare the impact by different proposal policy combination. The climate policies in this study are implemented through charge carbon tax on the energy sector's GHG emission from different technology and indirectly impact from government regulation on air pollution emission reduction policies. We propose 7 groups of scenarios to make a comparison between different policy combinations in the table 3-1. The groups are designed based on the different combination of 6 options.

Table 3-1 Policy options

1	2	3	4	5	6
Technology innovation or not Introduce	Technology Cost Reduction	Carbon Tax/Subsidy (70 CNY/Ton)	Carbon Tax/Subsidy (110 CNY/Ton)	Government Target (10% reduction in Five Year Plan)	Proposal Target (5% reduction in Five Year Plan)

The purpose of this paper is to determine whether carbon tax is effective or not for the economic, energy and environment identify the carbon tax level to curb air pollution emission reduction target, GHG, economic development, energy saving energy security through a regional dynamic input output analysis. The study also aims to identify the ideal level of financial support for energy efficient technologies (coming from both government revenues and carbon tax collection).

3. Result analysis

Based on the simulation results, the integrated assessment system can estimate the impact of carbon tax. Simultaneously, we will be able to identify the contributions from different policies through improvement economic develop, environmental preservation and energy saving, which are important indicators to demonstrate the implication of such policies.

Table 4-1: Total amount in each case compare with Baseline

	Case setting	GRP	GHG	SO2	NOx	PM10	PM2.5
Group 1	Baseline	1	1	1	1	1	1
	Base+Re	0.575016	0.671384	0.641571	0.587111	0.665586	0.650282
Group 2	Te_Re	0.771373	0.692694	0.621524	0.588970	0.693332	0.652826
	Te_Re_90%Cost	0.772138	0.692833	0.621674	0.589089	0.693514	0.652984
Group 3	70s	1.002631	1.001045	1.002782	0.996013	1.004236	1.002532
	70s_90%Cost	1.002631	1.001045	1.002782	0.996013	1.004236	1.002532
Group 4	70s_Re	0.773602	0.692436	0.621184	0.58866	0.693185	0.652574
	70s_Re_90%Cost	0.774364	0.692586	0.621343	0.588773	0.693384	0.652740
Group 5	110s	1.003692	1.001286	1.003001	0.996411	1.004583	1.002793
	110s_Re_90%Cost	1.003692	1.001286	1.003001	0.996411	1.004583	1.002793
Group 6	110s_Re	0.774631	0.692406	0.621232	0.588595	0.693393	0.652654
	110s_Re_90%Cost	0.773875	0.692254	0.621069	0.588483	0.693188	0.652484
Group 7	5%Re_90%Cost	0.837590	0.735087	0.665280	0.636008	0.740429	0.697528
	70s_5%Re_Cost90%	0.84206	0.733809	0.663571	0.635778	0.738252	0.695889
	110s_5%Re_Cost90%	0.841698	0.733886	0.663703	0.635817	0.738468	0.696020

Note:

70, 110: carbon tax 70 CNY/Ton and 110 CNY/Ton; S: Subsidy; Re: regulation with SO_2 and NO_x emissions targets of 10% reduction in five years; 5%Re: assumed regulation with SO_2 and NO_x emissions targets of 5% reduction in five years; 90%Cost: 90% reduction in the fix cost of high efficiency electricity technology plant;

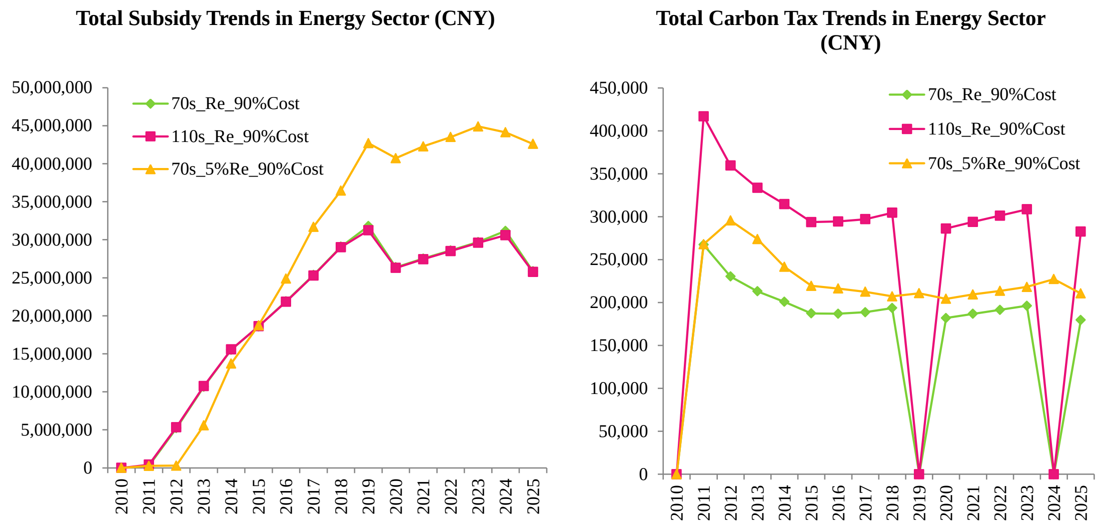

Figure 4-1 Carbon tax and subsidy trends in energy sector

The result in Table 4-1 shows that if there is no environment regulation, the carbon tax and technology cost reduction has no obvious impact on the economic, energy consumption, technology innovation and environment conservation. Government regulation has positive impact on environment conservation and technology innovation. Under the government regulation, the carbon tax 70 CNY/Ton or 110 CNY/Ton has not so much different impact on 3E. But, under the 50% government regulation carbon tax 70 is more effective than 110. Figure 4-1 shows that a variable carbon tax can act as a buffer to meet the government regulations. Therefore, the carbon tax should be adapted to the environmental regulation. Subsidy is the most important way for technology innovation.

4. Discussion and conclusion

We propose 7 scenario groups that range from the current trends (baseline) to the introduction of different carbon tax rates in the power sector and the introduction of high efficient technology and technology cost reduction for regional air emission reduction. These carbon taxes are based on the government carbon tax plan and our own estimates. We constructed a dynamic evaluation model based on an Input-Output (I/O) analysis for the period 2010-2025. The main outcome of this study is perhaps that governments should pay more attention to promote and induce the development of new technology innovations. This way we can eventually not only introduce these technologies but also promote their diffusion that will result in lowering their price. So it's better for government to improve the price of fossil fuel energy to push the low efficient fossil fuel energy and its utilization technology loses competitive. This kind of policy is significant and practical. For one side it can achieve the target of reduce fossil fuel energy consumption another side no need to set the platform for carbon tax and simplify the government institute.

In the long run, as the GHG emission reduction, carbon tax income will become small and its effectiveness becomes weak. Therefore, other climate policy should be considered such as smart grid infrastructure and the use of short-term bridge fuels such as natural gas and shale gas. It would also include a strong signal from government, possibly in the form of a command and control regulation that the fossil fuel era is going to gradually come to an end.

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