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Understanding marginal abatement cost curves in energy-intensive industries in China: insights from comparison of different models

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Abstract

The Kyoto Protocol inspires the idea of establishing emissions trading scheme, regarding economic-effectiveness as a significant factor to achieve reduction targets and meet obligation. With this trend, marginal abatement cost curves (MACCs) have been used in climate policy analysis under general equilibrium framework, and have been proved a valid device to highlight the superiority of ETS. This paper focuses on the comparison of MACCs at industry level in China, derived by us from CGE, GCAM and TIMES respectively. It's clear that there is no dynamic adjustment process in these models, so we use linear interpolation method to introduce carbon tax to simulate actual situation. Meanwhile, we also take data from potential and cost study into account. To make our work more targeted, we pay close attention to energy-intensive industries with high carbon emissions level such as electricity, cement and steel, which are most likely to be covered in carbon market. The results indicate how MACCs change and illustrate why they change, depending on applied methodology and underlying assumptions. As we ignore the indirect effects, for instance, tax distortions and non-financial costs during above simulation, the emissions abatement cost we achieve by using integral calculus won't be equivalent to real cost. Therefore, it's a wise decision for government department and research institute to be cautious when using MACCs as basis of policy making and academic studies.

Keywords: Climate change; Marginal abatement cost curves; Bottom-up and top-down models; Potential and cost study

1. Introduction

Climate change is threatening the survival of human beings and the stability of our ecological system.

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The United Nations Framework Convention on Climate Change (UNFCCC) proposes that it's important to stabilize the concentration of greenhouse gases under specific level to prevent climate system from dangerous anthropogenic interference. China, one of the largest CO_2 emitting countries, is facing increasing pressure to reduce its carbon emissions and shouldering challenging task to fulfillment its reduction commitment. China has already started the pilot work of Emissions Trading Scheme in five provinces and two cities, intending to find effective method to reduce carbon emissions relying on reasonable market mechanism. Above all preliminary work for ETS, policy makers should firstly take the acceptance of enterprise managers in related industries into account. When considering which industries should be covered in carbon market, there are some fundamental selection criteria, such as energy intensity, carbon emission level, reduction potential and abatement costs. Among all these factors, abatement cost that reveals the influence of ETS on industries directly and provides policy makers with an intuitive cognition of economic effectiveness of market mechanism is gaining its popularity.

The best tool to analyze abatement costs is the MACC, short for marginal abatement cost curve. MACCs represent the relationship between the emissions reduction amount and a carbon price or tax, which indicates the marginal cost for abating one additional unit of carbon dioxide basing on the status quo. Moreover, MACCs are usually applied to heuristically highlight the superiority of ETS. Up to now, there have been numerous studies focusing on marginal abatement cost curves. Ellerman and Decaux [1] derived MACCs from EPPA model developed by MIT to analyze ETS's advantages during the process of meeting emission reduction commitment in Kyoto Protocol and came up with the viewpoint that regional MACCs have strong robustness. Klepper and Peterson [2] declared that the definition of regional MACCs just "sounded convincing", mainly discussing the role fossil fuel prices played in differentiating MACCs at firm and regional level theoretically, and used general equilibrium DART model for empirical simulations. Criqui, Mima and Viguier [3] generated MACCs from EPPA and POLES, and concluded that although social economic parameters, technological improvement and substitution elasticity varied across models, the rank of regional MACCs didn't change. Elzen and Lucas [4] used FAIR model, which linked long-term global abatement targets with regional emission quotas and abatement costs, illustrating evaluating regimes need both an assessment of initial allocation and distribution of abatement costs.

However, marginal abatement cost at industry level is less mentioned. The pilot work of ETS in China emphasizes the importance of undertaking a comprehensive comparative analysis of industrial MACCs. This paper focuses on marginal abatement costs at industry level in China. Section 2 describes the application, generation methodology and robustness of MACCs. Section 3 shows the comparative analysis of results from different sources. In Section 4, we summarize our work and come up with conclusions as well as policy advice for using MACCs as main basis for policy making and evaluating.

2. Methodology

Figure.1 (a) shows marginal abatement cost curve for industry I and industry II respectively. X-axis and Y-axis stands for absolute reduction emissions amount and cost of reduction. Assuming that the reduction target for industry I is Q_I, while the target for industry II is Q_{II}. Basing on knowledge of calculus, we identify that total cost is determined by expected reduction objective and MACCs. We ease into the result that area under MACCs between zero and given target represents the total abatement cost, for instance, 0-Q_I-A and 0-Q_{II}-B for industries studied. We assume that there are only two industries in ETS, which can be easily generalized to hundreds of industries, and our market is a perfect competition environment, where all industries and enterprises can participate in trading process of emission permits freely and fulfillment its target either by independent reduction actions or trading permits.

Considering situation without flexible emissions trading, industry I and II will reduce their own carbon emissions by Q_I and Q_{II}. As a result, the total abatement cost for industry I and II are shadow area $S_{QI\text{-}0\text{-}}$

$_A$and $S_{QII-0-B}$. In sum, the total cost is (S_I+S_{II}). Now, an open market between industry I and II can lead to a new marginal abatement cost curve $MACC_{I+II}$, the integration of $MACC_I$ and $MACC_{II}$. Then we derive a new curve and target to work out a more effective reduction plan. It is clear to see trading allows overall target to be achieved at a balanced carbon price between MAC_I and MAC_{II}, and the total cost of reaching the overall target will be lower than former scenario. As both industries' managers are rational decision makers, there is no incentive for them to take actions at a marginal abatement cost higher than market equilibrium price MAC_{I+II}. Meanwhile, they can compensate for gap or create profit by trading permits.
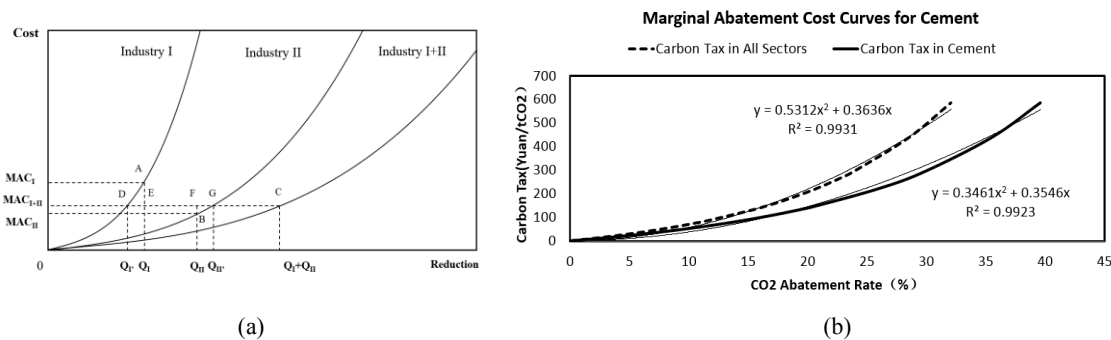

Fig. 1. (a) MACCs analysis; (b) Carbon tax on single sector and all sectors

   Through the study already done, it's clear there can be huge differences between different MACCs. Initial level of energy prices, energy supply structure and potential for developing carbon free energy sources together can explain this phenomenon. Our study intends to derive MACCs at industry level, so the factors mentioned above are relatively weak in determining curve shape when comparing with factors such as sector's energy consumption structure and actual technical conditions. Generally, there are two normal methods to generate MACCs from models with general equilibrium framework, setting ceiling or cap and imposing carbon tax. Due to the fact that there is no dynamic adjustment process in these models, we use linear interpolation method to simulate reactions of actual economy, for example 100yuan RMB in 2020, we should start with establish policy shocks of carbon tax at 33.3yuan RMB in 2010 and 66.7yuan RMB in 2015.
   Many studies have assessed the robustness of regional MACCs, the fundamental question to be defined before empirical analysis. Their studies come to the conclusion that location of regional curves corresponding to any given level of carbon tax derived from a specific model isn't obviously affected by applying different climate policies in other regions. Whereas for MACCs at industry level, it's just a completely different story. Firstly, we should determine scope of carbon tax, shown in Figure 1(b). When generating MACCs from global optimization model, given its division structure we need to apply carbon tax for all industries and check emissions reduction situation of our target industry. In order to eliminate the differences in model structure and maintain the unity of methodology, we adopt the same method in model constructed to simulate China's economy. We also impose carbon tax in single industry for the purpose of reflecting to what extent the deviation is. Being confronted with the choice of evaluation indicators of reduction performance, we have to make a decision between absolute emissions reduction amount and relative emissions reduction rate which can be derived through model results and baseline's information. Considering the trade-off between comparability and accuracy, we choose reduction rate to present the results from different models and use reduction amount to describe our comparison work.

3. Results Analysis

Some precautions must be taken into consideration as different models establish different baselines. When comparing results from models of different categories, we set up carbon tax levels adopting 2010 constant price to ensure the consistency and comparability of different marginal abatement cost curves.

Figure 2(a) summarizes MACCs at industry level from top-down and bottom-up models, indicating reduction ratio of TIMES model is in between of SICGE and GCAM. In addition, autarkic marginal cost of abatement for electricity is higher than cement and steel in SICGE and GCAM. Meanwhile, MACCs generated from bottom-up TIMES model show that difference between cement and steel is limited and along with rising carbon tax, the actual reduction effects are much less remarkable. As industry division differs, we select the simultaneously appearing sector "Cement" to be the objective of comparison.

Through data from potential and cost study on China's carbon mitigation technologies, we derive a ladder diagram in Figure 2(c) for cement, where X-axis stands for CO_2 reduction potential, instead of reduction rate in above figures. When checking the abatement amount, we simply accumulate the reduction potential of all measures that have a lower abatement cost than any given level. Negative abatement cost is the easiest feature to identify of MACCs based on individual evaluation of abatement technical measures. Model-derived cost curves always pass through the origin point, meaning that "no carbon tax, no emissions reduction". In order to make comparison of MACCs from different sources more convincing and successive, we come up with a reasonable solution to this contradiction by accumulating reduction potentials of those measures that have negative marginal costs and regarding it as corresponding reductions when tax level changes in a small range near zero.
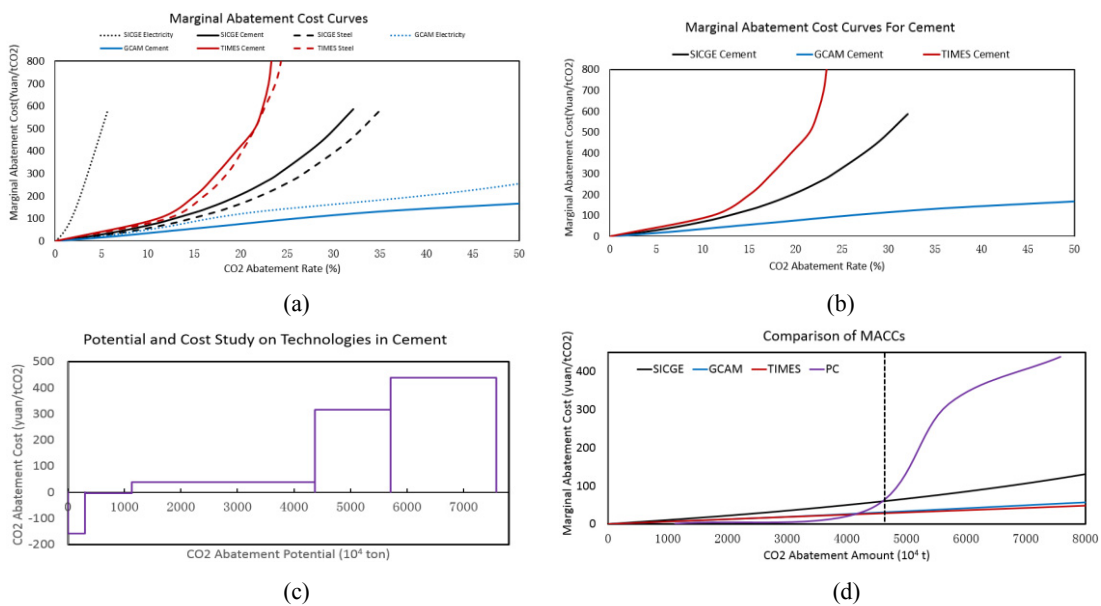

Fig. 2. (a) SICGE & GCAM; (b) TIMES; (c) Potential and cost study; (d) Comparison

In Figure 2(d), it's clear that MACCs analyzed are relatively close when reduction amount is below 47 million tons, resulted from model stability to deal with slight carbon tax shocks. Getting rid of underlying assumption of technologies' penetration rates to be 1.0, it's possible for specific technology to reduce less

CO_2 at original cost level and the actual curve depicts results from potential and cost study will move up and probably locates between MACCs from bottom-up and top-down models. Despite these empirical results in line with our expectations, curve from potential and cost study shows step phenomenon when carbon price rises up to 60yuan/tCO_2 and corresponding reduction amount reaches 47 million tons. From technological perspective, gap of 240yuan in cost between two technologies causes obvious variation in MACCs for potential and cost study, and prompts the comparability of our results to decline seriously.

4. Conclusions

MACC have been considered as an analytical tool to provide quantitative evidences of technical feasibility and economic effectiveness of ETS. Our comparative study also confirms this statement to some extent. However, as we ignore the indirect effects, for instance, tax distortions and non-financial costs during above simulation, the emissions reduction cost we achieve by using integral calculus won't be equivalent to the real cost. Thus, we recommend that MACCs can be an illustrative tool in a package of analysis approaches during the process of discussion over climate policies, but shouldn't be used as the only reference to rank them. In addition, MACCs with different sources vary obviously, so it's necessary to elucidate models' assumptions and frameworks transparently. Otherwise, policy makers can be misled into "an unworkable or unaffordable portfolio of policies". Some studies also suggest a system-wide approach is needed and should be used to understand the consequences of implementing several different abatement measures together and ensure path dependencies, important behavioral interdependencies, interactions between measures and international interactions are identified and taken into consideration within policymaking process [5]. Therefore, it's a wise decision for government department and research institute to be cautious when using MACCs as the main basis of policy making and academic studies.

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Biography

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