A STUDY ON THE LINKAGE BETWEEN CAPACITY PRICING AND CARBON PRICING IN ELECTRICITY MARKET

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Overview

In the liberalized electricity market, in order to ensure the power adequacy and operating security of the electricity system, capacity pricing was introduced to mitigate defects of the electricity market for balancing supply and demand. Meanwhile, carbon pricing was designed to internalize the environmental cost of CO_2 emissions from fossil fuel due to climate change issues. However, besides some special case, in the current electricity system, the main part of providing system adequacy and flexibility is still the fossil fuel power plants, which be paid through capacity pricing while being charged for CO_2 emissions through carbon pricing. Some previous studies [1-4] focused on the barrier and misalignment of integration among electricity market mechanisms during the energy system transition. Nevertheless, the linkage between capacity pricing and carbon pricing are still not clear. This study intends to raise and answer a question: what is the interaction between the carbon pricing and capacity pricing and how it ultimately affects the choices of technologies introduction.

Methods

The methodology in this study is causality mapping, through establishing the subjective conceptual models based on observation and causal inference, thereby understanding and explaining the relationships among phenomena or behaviors [5]. According to this methodology, system dynamics is an approach that can analyze the relationship among variables in a non-linear complex system by constructing the causal-loop and stock-flow model. It is a suitable tool for illustrating the dynamic change in the electricity system regarding different mechanism design and decision making.

This study firstly constructed a subjective conceptual model to explain the interactions between carbon pricing and capacity pricing. Secondly, an additional design was proposed to improve the current mechanism. At last, system dynamic approach was adapted to conduct the simulation of conceptual models for quantitative verification.

Results

For the capacity pricing, there are mainly two objectives: first, the price formation through years ahead auction based on the forecasted capacity demand, thereby ensure the electricity system adequacy and avoid the boom-bust investment phenomenon. Second, providing subsidies for the technologies which contribute to the security of electricity systems supply-demand balance operating. For carbon pricing, the main objective is to internalize the CO_2 environmental externality of fossil fuel, in order to promote the variable renewable energy penetration and gradually reduce the proportion of fossil fuel energy. After clarifying the aim of two mechanism design, the causality among factors and the effects on behaviors in this study are illustrated in Fig. 1.

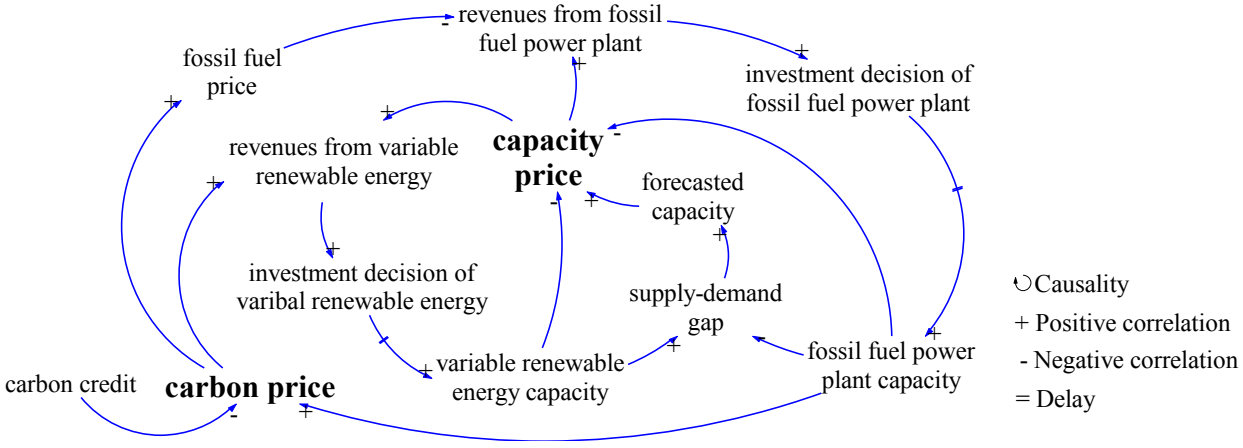

Figure 1. Causal-loop diagram between carbon pricing and capacity pricing.

On the one hand, the value of electricity system adequacy and flexibility provided by fossil fuel power plants are not being weighed in carbon pricing, on the other hand, the capacity pricing rarely measures the environment factor while paying for the system value. Eventually, due to the system value payment of fossil fuel power plant from capacity pricing offset the internalized CO_2 emission cost which from well-designed carbon pricing mechanism. Even if adding the emission limitation as an entry threshold into the capacity pricing, it still weakens the decarbonization incentive from carbon pricing.

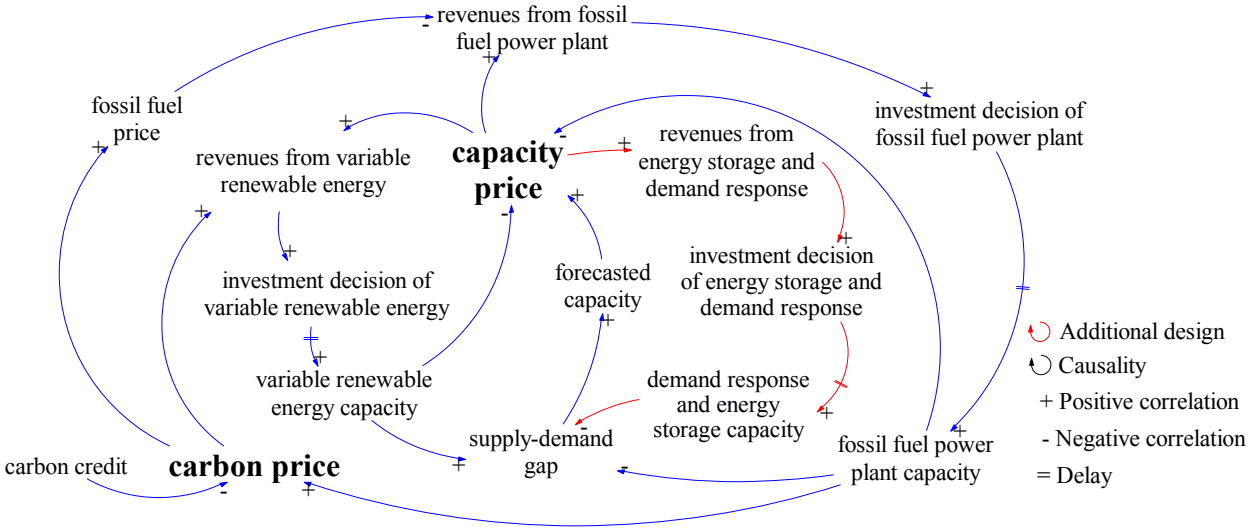

Figure 2. Causal-loop diagram including low-carbon capacity alternatives.

Fig. 2 demonstrated a proposal that considering the linkage between two mechanisms, the causality lines in red color represent the additional design. If the energy storage and demand response can fully participate in capacity pricing, thereby offer low-carbon capacity alternatives for the electricity system, then the carbon pricing and the capacity pricing will bring out consistent incentives, diverting the capacity payment from fossil fuel power plant to demand response and energy storage. Furthermore, the carbon pricing will provide incentives for the initial motivation of energy storage and demand response investments, simultaneously， the capacity pricing can provide a long-term stable signal of low-carbon capacity alternatives and cover a portion of the capital cost, as it designed for the objectives in the beginning.

Conclusions

Through constructing the causal-loop, this study proposed that the design of capacity pricing needs to link with the carbon pricing, otherwise the offset of two mechanisms will lead to social inefficiency. When the design of capacity pricing only focuses on conventional fossil fuel power plants and lacks the participation of low-carbon capacity alternatives (e.g. energy storage and demand response), then the payment from capacity pricing will counteract the incentives from carbon pricing. Nevertheless, in the case of allowing low-carbon capacity alternatives to participate in capacity pricings, the increase of carbon price will promote the competitiveness of low-carbon capacity over fossil fuel power plants, and enhance the power adequacy and operating security of the electricity system. Details of the simulation results and quantitative verification will be explained in the full paper.

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