# HOW CARBON TAX CHANGE THE PERCEPTION AND BEHAVIOR OF PLAYERS IN A COMPETITIVE ENERGY MARKET?

[Kengo SUZUKI, University of Tsukuba, +81-29-853-6194, kengo@risk.tsukuba.ac.jp]
[Ryohei Ishiwata, University of Tsukuba, +81-29-853-6194, ishiwata.ryohei.su@alumni.tsukuba.ac.jp]

## Overview

The carbon tax is expected to have two effects in the context of encouraging energy transition from fossil fuels to renewables: direct changes in behaviours of energy companies due to the taxation itself and indirect changes in behaviours due to the notice of taxation in advance. The reaction of companies to the carbon tax can be inferred by experiments using games simulating real energy markets while large part of experimental studies on carbon pricing policies focus on the design of trading systems rather than the long-term impact of policies themselves. This study experimentally investigates the impact of carbon tax on the perception of risk and choice of energy technologies by the participants of a competitive energy market by using a multiplayer game. The experiments were conducted 7 times each under the conditions without and with the carbon tax. The objective and subjective data, i.e. record of gameplay and answer to questionnaires, were obtained from experiments. These experiments were completely remoted as a countermeasure against the COVID-19 pandemic. The results of gameplay indicate that the changes in behaviours of participants were limited to after taxation; there is no significant changes in their behaviours before taxation. The results of questionnaire survey indicate that there is no difference in the level of anxiety about price competition and uncertainties in return on investment in renewables perceived by the participants between two conditions. These results suggest that the notice of carbon tax cannot alleviate the level of risk perceived by market participants. In conclusion, the carbon tax must be introduced as soon as possible, and the level of tax must be high enough to convince participants that the active investment in renewable is the optimal strategy.

## Methods

Figure 1 is a conceptual figure of the multiplayer game “Energy Transition”. Participants play the roles of energy companies in a competitive market. They make a profit by selling final energy produced from fossil fuels or renewables. The purpose of participants is to maximize their own profits. In every round, the participants decides the energy mix, selling price, and the amount of R&D investment in renewables. The game continues 30 rounds (data up to the 25th period is used). At the beginning of game, the cost for renewables is higher than that of fossil fuels while it decreases depending on the amount of investments. On the other hand, the price of fossil fuel prices rise over time. Consumers move from companies with higher selling price to these with lower selling price in every round.

Seven experiments were conducted for each of two conditions: with and without rules emulating carbon tax. Totally, 56 students of University of Tsukuba were participated in 14 games. Participants were informed the timing and rate of taxation before the game begin. At the start of games and at the ends of rounds 5, 10, 15, 20, and 25, participants answered questionnaires about their level of anxiety about price competition, recovery of investment in renewables, and fossil fuel price, and acceptance of carbon tax in 7-step scale. After the games, they also answered questionnaire about their recognition of effective strategies and barriers to energy transition. To proceed the research under the COVID-19 pandemic, we constructed a completely remote experimental environment. The game was made into a web application using oTree (Chen et al. 2016) and deployed on an external server. Participants listen the explanation from experimenters via Zoom and then play the game using a web browser. The questionnaires were built into the game application.

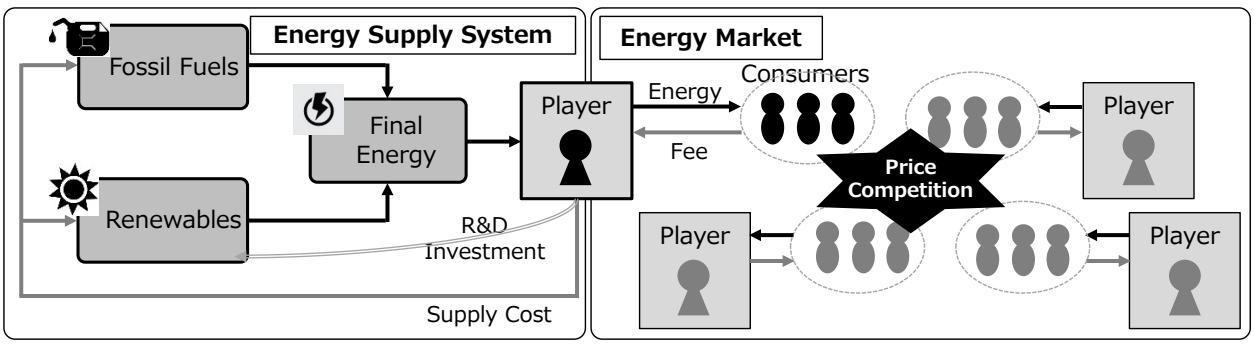


Figure 1: Time Series Changes in Renewable Energy Supply

## Results

Table 1 shows the summary of experimental results. At the end of the 25th round, the cumulative renewable energy supply was higher in the condition with carbon tax compared with the condition without tax; there was a significant difference at the 10% level as a result of Mann-Whitney U test. There were no significant differences in other indicators such as mean selling prices, total R&D investments, total profits, and final renewable energy supply costs. Figures 2 and 3 show the time-series changes in renewable energy supply and R&D investments in the conditions without and with carbon tax (black and red lines). The transition to renewables occurred after the 16th period under both conditions; the rate of transition is higher in the condition with carbon tax. There was a significant difference in the amount of renewable energy supply from the 16th to 20th rounds at the 5% level. The R&D investment decreases as the games proceed in both conditions. There was no significant difference in the amount of investment between the conditions. As the results of questionnaires about the levels of three types of anxieties, there is no significant difference between the two conditions. These results suggest that the changes in the behavior of market participants by carbon tax is limited after taxation, and that the anxieties of participants about price competition and uncertainty in the investments in renewables cannot be alleviated by tax notices.

## Conclusions

From the viewpoints of participants, the carbon tax reduces the absolute benefits of a strategy continuously utilize fossil fuels, but does not guarantee a relative advantage of a strategy actively promotes renewables. As the return on investment in renewables and future fossil fuel prices are unknown, the notice of introducing carbon tax does not form the expectation that energy transition is the best strategy for participants. In conclusion, the carbon tax must be introduced as soon as possible, and the level of tax must be high enough to convince participants that the active investment in renewable is the optimal strategy.

## References


Chen, D. L., Schonger, M., & Wickens C. (2016). "oTree—An Open-Source Platform for Laboratory, Online, and Field Experiments." *Journal of Behavioral and Experimental Finance*, 9: 88–97. https://doi.org/10.1016/j.jbef.2015.12.001


Table 1: Summery of Experimental Results in 25th Round (* Indicates Significance in 10% Level).

| | Mean value of seven games | | Mann-Whitney *U* test | |
|---|---|---|---|---|
| | Without Tax | With Tax | *U*-value | *p*-value |
| Renewable Energy Supply (Total) | 147.7 | 186.7 | 11 | *0.097 |
| Selling Price (Mean) | 9.7 | 9.9 | 18 | 0.443 |
| R&D Investment (Total) | 273.1 | 259.9 | 25 | 1.000 |
| Profit (Total) | 31.0 | 53.1 | 18 | 0.443 |
| Renewables Supply Cost (Mean) | 9.9 | 9.8 | 25 | 1.000 |

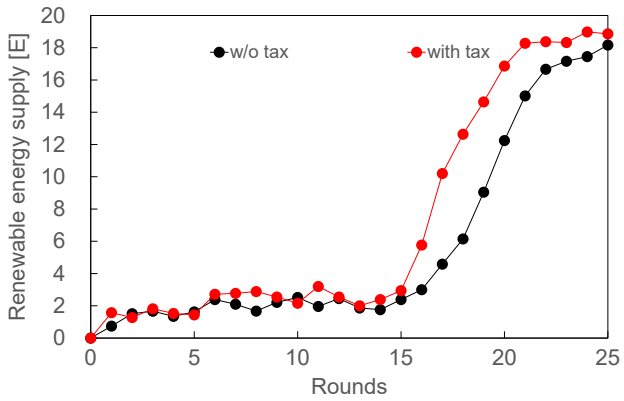


Figure 2: Time Series Changes in Renewable Energy Supply

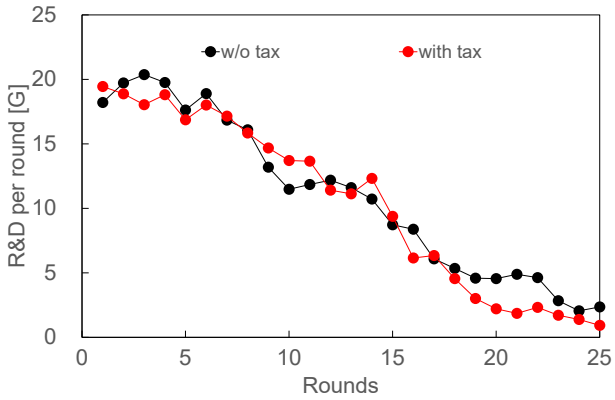


Figure 3: Time Series Changes in R&D Investments in Renewables