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## Preliminary study on policy mix effects on economic viability of carbon capture and storage project in Japanese steel industry

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### Abstract

This paper explores policy mix effects on economic viability of CCS project in Japanese integrated steel plant. We conducted a Monte Carlo simulation under uncertainties of firm's capacity factor (pre-tax profit) and carbon price. The results indicate that tax credit (35 US\$/tCO<sub>2</sub>) improve economic viability of CCS in the case of favorable business conditions. Subsidies for CCS costs improve economic viability of CCS even in the case of recessions; however, the subsidy effect is sensitive to carbon price. Tax credit could be one of key policy measures as a part of policy mix both for Japanese economy and CO<sub>2</sub> mitigation.

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*Keywords:* Monte Carlo method; carbon capture and storage; integrated steel producer; iron and steel; carbon price; tax credit

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### 1. Introduction

In the given long-term climate mitigation goals, such as 2 degree C, carbon capture and storage (CCS) is of key technology for cost effective measures. On the other hand, early large-scale diffusion of CCS is not straightforward partly because CCS lacks both a sufficient policy framework and a business model so far[1]. A firm's CCS investment inevitably involves uncertainty about the economic viability as well as technical feasibility and social dimensions.

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In terms of the Japanese steel industry, there has been several energy and climate policies for further energy saving and carbon emission reductions, such as (i) the Energy Conservation Act, (ii) voluntary actions (negotiated agreements), (iii) energy and carbon taxes, (iv) energy subsidies for energy saving investments, (v) tax credit for energy saving investments and for private R&D, and (vi) public R&D expenditure.

These energy and climate policies have been significant and workable; however, the energy and carbon intensities have been close to technological limitations. Based on these circumstances, the Japanese steel industry has conducted R&D project named “COURSE 50” with the financial support of Japanese government. The “COURSE 50” includes increase of hydrogen concentration in coke oven gas, waste heat recovery from blast furnace slag, and carbon capture from blast furnace gas. If these developed systems including CCS will be adopted into Japanese integrated steel plants, carbon intensity would decline by around 0.6 tCO<sub>2</sub> per ton of crude steel, which accounts for about 30% of CO<sub>2</sub> emissions from integrated steel plants. According to the planned time schedule, these technologies will be established by around 2030 with full scale deployment (options) from 2030 onwards, e.g., 2035.

This paper focuses on economic viability of CCS project in Japanese integrated steel plant. The purpose of this study is to explore the policy mix effects on economic viability of CCS project and to provide new insight regarding climate policy for the Japanese steel industry. We conducted a Monte Carlo simulation under uncertainties of firm’s capacity factor (pre-tax profit) and carbon price. We assumed two policy mix cases: policy mix A and B. The policy mix A mainly depends on tax credit (35 US<sub>2007</sub>\$/tCO<sub>2</sub>) as well as carbon price. The policy mix B mainly depends on subsidies for CCS cost (subsidy rate: one-half) as well as carbon price.

Carbon price is useful indicator that represents overall strength of climate mitigation policies. Previous research and discussion on CCS diffusion have mainly referred to carbon price, which indicates the gap between (economically and politically) viable policy framework and sufficient policy support for CCS diffusions[1]. This paper explicitly considers tax credit and subsidy for CCS costs. The current international competition in global steel market implies a necessity of wide-range of policy measures, not only carbon price (as a stick) but also tax credit and subsidy measures (as a carrot).

Tax credit, including tax incentive, break, and exemption, has been widely introduced fostering encouragement of general economic activity and specific purpose, such as energy saving, energy security, and climate mitigation. In the United States, for example, several tax credits, including the 10 US\$ of tax credit for CO<sub>2</sub>-EOR, the 20 US\$ of tax credit for CO<sub>2</sub> storage in deep saline aquifers, and the 30% investment tax credit for solar projects, have been implemented.

## 2. Simulation framework and methods

### 2.1. Overview

We consider a case of an integrated steel producer which produces 30 million tons of crude steel per year when the capacity factor index is 100 (FY2010 = 100). For reference, Nippon Steel & Sumitomo Metal Corporation (NSSMC) produced 42.2 million tons of crude steel, and JFE Steel Corporation produced 27.4 million tons on a non-consolidated basis in FY2015.

Fig. 1 shows the historical trend of pre-tax profit and tax amount of major Japanese integrated steel producers including Kobe Steel, Ltd. In around FY2006 they earned a large profit partly because the business conditions were favorable on a global scale. At the same time, tax amount including corporation tax was also large.

To ensure transparency, we simplified the model framework as shown in Fig. 2. We assumed a liner relationship between capacity factor and “pre-tax profit without carbon cost” (Fig. 2(a)). The firm’s capacity factor represents overall global economy condition (of steel products market) in this study. Since the one-third of produced steel products has directly been exported to foreign countries, and the other one-third of steel has indirectly been exported to foreign countries as a form of cars, machines, etc., the overall global economy condition inevitably affects the capacity factor and profit of Japanese steel producers.

The assumed tax amount consists of the fixed amount and the variable amount (Fig. 2(b)). In fact, the relationship between pre-tax profit and tax amount is very complicated, e.g., (1) provisional tax incentives for R&D and investment, (2) systematic difference between taxable income and pre-tax profit based on individual corporate

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