CARBON INTENSITY AND ITS DETERMINANTS IN JAPANESE STEEL INDUSTRY

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Overview

The steel industry is a key sector both for manufacturing supply chain and climate policy. In 2013, the Japanese steel industry (including secondary fabrication) accounted for a 1.34% of GDP and a 16% of carbon emissions. Although the GDP share itself is not so large, the steel industry has an important indirect impact on GDP as it is closely linked to other sectors such as automotive, machinery, electronics, and construction.

The Japanese steel industry as well as other federations/associations have taken actions for the "Voluntary Action Plan on the Environment" from 1997 to 2012 in order to foster further energy efficiency improvement and carbon emission reductions. After that, the framework shifted to the "Commitment to a Low Carbon Society." A research question is whether these frameworks are effective for economic and carbon efficiencies or not.

As a result of the 2008 Financial Crisis and the 2011 Fukushima Accident, Japanese industries have been suffering from unsteady domestic demand, higher prices of grid electricity, and stagnating carbon intensity improvement. This paper focuses on the observation of time series variation in carbon intensity (tCO_2/t of crude steel) from FY2000 to FY2014 that has been reported by Japan Iron and Steel Federation (2015). We empirically explore factors affecting the carbon intensity of Japanese steel industry based on engineering methodology. The objective of this paper is to provide new insight useful for climate policy based on the factorial regression analysis and the measures of improvements/deteriorations of the carbon intensity.

Methods

As shown in Table 1, we developed two types of numerical indices as possible factors affecting carbon intensity (tCO_2/t of crude steel) in the Japanese steel industry. We estimated time series variations in carbon intensity based on public statistics. The two indices were normalized by the reported carbon intensity in FY2005, i.e., 1.743 tCO_2/t of crude steel, in this analysis.

Table 1. Outline and calculation methods of two indices

	Calculation method
Capacity factor index: x_1	Weighted average of (a) blast furnace capacity factor, (b) electric arc furnace (EAF) capacity factor, and (c) Industrial Production Index. The monthly raw data for capacity factor (METI, 2001-2015) and Industrial Production Index is used and converted to annual data.
Production process index: x_2	Combined "hot metal ratio" and "steel product mix." In detail, x_2 is proportionate to sum of ([hot metal ratio deviation from 2005] times [1.42 tCO_2]) and Σ_i([share of steel product *i*] times [typical carbon intensity of steel product *i*]). The "hot metal ratio" represents upstream process effect on carbon intensity. The "steel product mix" represents downstream process effect on carbon intensity.

Table 2. Calculated results of two indices

	FY00	FY01	FY02	FY03	FY04	**FY05**	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14
x_1	93.9	90.6	95.9	99.2	101.3	**100**	103.1	104.8	91.2	82.3	92.7	88.9	89.3	91.4	91.7
x_2	101.7	102.4	100.2	101.0	100.4	**100**	98.6	98.6	100.1	99.9	101.0	101.2	101.2	100.2	101.3

Results

Parametric regression (two-variable linear regression)

We introduce a liner time trend variable of carbon intensity (x_3) and compare the reported carbon intensity of Japanese steel industry with the estimates (x_1, x_2, and x_3). As for analytical method, the effect of the production process index (x_2) is exogenously given, because the x_2 effect on carbon intensity is less uncertain compared with the other variables (x_1, and x_3).
We conduct two-variable linear regression. The explained variable here is the residue that can not be explained by x_2. The two explanatory variables are coefficient of capacity factor index (x_1) and liner time trend variable of carbon intensity (x_3). Figure 1 reveals that the estimates (x_1, x_2, and x_3) well explain the reported carbon

intensity, and indicates the long-term trend of carbon intensity improvement. Note that the reported carbon intensity is based on fixed emission factor for grid electricity, i.e., 0.423 kgCO_2/kWh.

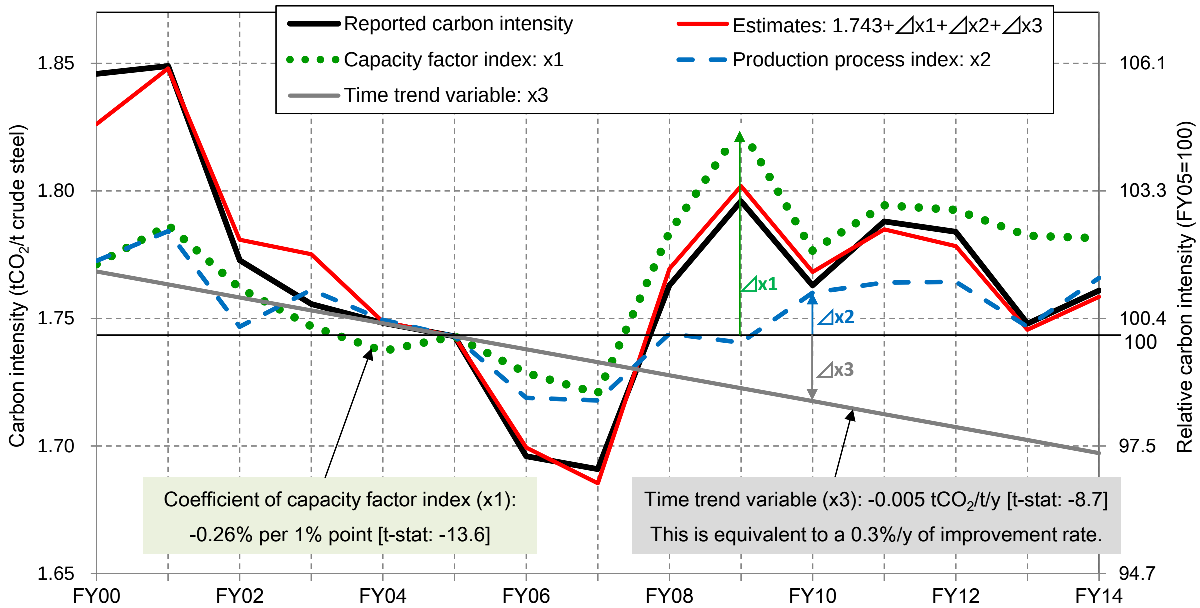

Figure 1. Results of two-variable linear regression

Nonparametric regression (smoothing spline)

We conduct one-variable regression, i.e., smoothing spline. The explained variable here is the residue that can not be explained by x_1, and x_2. The time trend variable is not necessarily linear. The effects of x_1, and x_2 are exogenously given here. Figure 2 shows that the residue has been decreasing with time. We reconfirm the long-term trend of carbon intensity improvement.

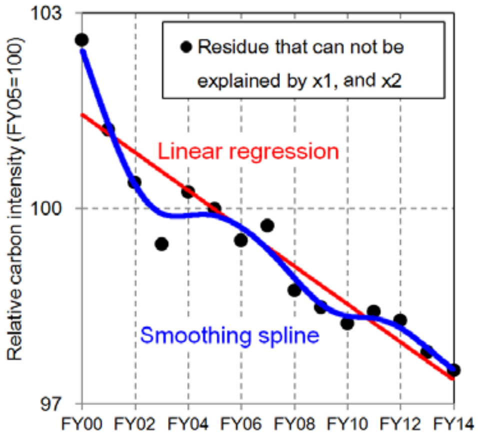

Figure 2. Results of nonparametric regression

Qualitative discussion

The observed long-term trend of carbon intensity improvement represent net effects of “improvement factor” and “worsening factor” shown in Table 3. Figure 2 implies that “improvement factors” have been overweighing “worsening factors” as a net effect.

Table 3. Factors affecting the observed long-term trend of carbon intensity improvement (selected)

(a) Improvement factor	(b) Worsening factor
Diffusion (retrofitting) of technologies such as (a1) regenerative burner, and (a2) use of waste plastics in coke oven and blast furnace.	Aging effects of facilities such as (b1) aging of silica bricks in coke oven, and (b2) accident partly being caused by the aging.
Replacement and/or aggregation of facilities such as (a3) blast furnace, (a4) EAF, and (a5) combined cycle power plant firing by-product gases.	Implementation of environmental measures such as (b3) air pollution abatement measures, and (b4) dust recycling system.

Conclusions

This paper empirically examined factors affecting the carbon intensity trajectory in the Japanese steel industry. The capacity factor, hot metal ratio, and steel product mix well explain the reported carbon intensity trajectory from FY2000 to FY2014. We observe the long-term trend of carbon intensity improvement even after the 2008 Financial Crisis.

References

Japan Iron and Steel Federation (2015): Steel Industry Measures to Combat Global Warming; Report of "Commitment to a Low Carbon Society."

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