A study of “CO2 efficiency” for industry and company

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Overview
"CO2 efficiency" was calculated to discuss the environmental efficiency of industries using the results of the I-O table analysis. The ratio of the CO2 emissions including indirect emissions as well as direct emissions in an industry to its producer's price was defined here as the “gross CO2 efficiency” of the industry. On the other hand the ratio of the direct CO2 emissions excluding indirect emissions in an industry to its gross value added was defined as the “net CO2 efficiency” of the industry. The difference of the net CO2 efficiencies between industries was significant, which reflected the energy intensity of each industry, but the gross CO2 efficiencies between industries comparatively small. The ratio of the indirect CO2 emissions excluding direct emissions to the cost paid by the industry was also defined here as the “upstream CO2 efficiency”. The difference of upstream CO2 efficiency between industries was smaller than the difference of the gross CO2 efficiencies. It reflects the similarity of the average gross CO2 efficiency of industries. To confirm the gross CO2 efficiency, we compared them with the ratio of the CO2 emission of materials obtained using LCI analysis to the market price of certain materials, which was called here as the “LCI data based efficiency”. It was almost similar to the gross CO2 efficiency in the case of materials of the chemical industry. In ferrous and nonferrous metals, the LCI data based CO2 efficiencies were smaller than that of the gross CO2 efficiency of the industry. Moreover, in order to confirm the net CO2 efficiency, we compared the ratio of direct CO2 emissions of certain companies cited by their environmental reports to their gross income with the net CO2 efficiency of the industry to which the companies belong. In this analysis, it was obtained that the indirect tax was included in the gross value-added in the industries, which must be paid attention in this kind of studies.

INTRODUCTION
Recently, many people pay attention in improving the “Environmental efficiency” for the sustainability1-3). However, the definition of “Environmental efficiency” is still unclear.
It might need the different definitions for each level (material, company, industry and country levels).

In this study, some types of the CO2 efficiencies of industries were defined. And they were calculated using the data such as producer’s price, gross value-added and cost of each industry published in the I-O tables and the data obtained by the I-O table analysis such as direct and indirect CO2 emissions (339/32 classification (I-A)-1 1995: Domestic). The first one was the “gross CO2 efficiency (1)” of the industry, which was defined as the ratio of the CO2 emissions including indirect emissions as well as direct emissions in the industry to its producer’s price. The second one was the “net CO2 efficiency (2)” of the industry, which was defined as the ratio of the direct CO2 emissions excluding indirect emissions in the industry to its gross value added. And last one was the “upstream CO2 efficiency (3)” of the industry, which was defined as the ratio of the indirect CO2 emissions in the industry to its cost. The concept of these CO2 efficiencies is shown in Fig.1.

Fig.1 Concept of CO2 efficiency

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\text{Gross CO2 Efficiency} = \frac{\text{Producer’s price}}{\text{Direct & Indirect CO2 emission}} \quad (1)
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\[
\text{Net CO2 Efficiency} = \frac{\text{Gross value-added}}{\text{Direct CO2 emission}} \quad (2)
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\[
\text{Upstream CO2 Efficiency} = \frac{\text{Cost}}{\text{Indirect CO2 emission}} \quad (3)
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RESULTS and DISCUSSION

The gross CO2 efficiency for each industry (32 sectors) from the I-O table analysis was shown in Fig. 2. It was clarified that there was a large difference of the gross CO2 efficiencies between service sectors (e.g. finance and insurance, real estate) and
manufacturing sectors (e.g. iron and steel, electrical equipment). It was also confirmed that there was a big difference in manufacturing industry in the sectors of the primary materials (e.g. chemical products, iron and steel) and the assembly sectors (e.g. electrical equipment, transport equipment). This reflects the tendency of the order of the energy intensity of primary materials industry, assembly industry, and then finally service industry.

It is possible to divide the gross CO2 efficiency into two parts. The first one is the ratio of the gross value-added per the direct CO2 emission of the industry, which was defined here as the net CO2 efficiency. The second is the ratio of the gross cost per the indirect CO2 emission, which is defined here as the CO2 efficiency of the upstream industries. The results are shown in Figs.3 and 4. In Fig. 3, the difference in the net CO2 efficiencies among industries increases more than the gross CO2 efficiencies, because the net CO2 efficiency shows the CO2 efficiency of the industrial activity itself. On the contrary, as shown in Fig.4, the difference in the CO2 efficiency of the upstream industries was smaller than that in the gross CO2 efficiencies. As the upstream of service industries are the manufacturing industries and the materials industries, the CO2 efficiency of upstream industries shows the average of the gross CO2 efficiencies of those industries.

![Fig.2 The gross CO2 Efficiency (Producer Price / Direct and Indirect CO2 emission) for each Industrial Sector](image-url)
Fig. 3 The net CO2 Efficiency (Gross value-added / Direct CO2 emission) for each Industrial Sector

Fig. 4 The upstream CO2 Efficiency (Cost / Indirect CO2 emission) for each Industrial Sector
In order to reliability of the gross CO2 efficiency, we compared them with the ratio of the CO2 emission of basic materials such as chemicals, iron & steel and nonferrous metals obtained by the LCI data by using the bottom up approach method to their market price, which was defined here as the LCI data based CO2 efficiency, shown in Fig. 5. Horizontal lines in Fig. 5 show the gross CO2 efficiencies calculated by I-O table analysis of 399 classifications. In the case of chemical industry, it was shown that the LCI data based CO2 efficiencies of each material are larger than the gross CO2 efficiency of the industry. However, in the case of iron and steel and nonferrous metal industries, the LCI based CO2 efficiencies are smaller than the gross CO2 efficiency. Generally there is a difference in the CO2 emission between the methods using the bottom up approach and using the I-O table analysis. This might be reflected in the difference of the results and it was increased by the difference between producer’s price and market prices.

![Fig.5 LCI data based CO2 Efficiency (Producer Price / Direct and Indirect CO2 emission) for Typical Industrial Materials](image)

In order to confirm the reliability of the net CO2 efficiency, we compared the ratio of direct CO2 emissions of certain companies cited by their environmental reports to their gross income with the net CO2 efficiency of the industry to which the companies belong. In our tentative results, we found that there was a great difference in the CO2 efficiencies calculated using the data in the environmental reports between the companies that belong to the same industry. The system boundary of calculating energy consumption reported in the environmental report might be different in each company.

The typical results of the CO2 efficiencies calculated by the data of the environmental reports of 3 companies, which belonged to the industrial sector A, were illustrated in Fig. 6. It was shown that the CO2 efficiencies based on gross income reported in the environmental reports of three companies were lower than that of the net CO2
efficiency of the industrial sector, to which these 3 companies belong. If the indirect tax, that was included in gross value-added, was excluded, the net CO2 efficiency of the industry was almost similar to the CO2 efficiency of three companies calculated by the environmental reports. We should pay attention that gross value-added is not exactly identical from the gross income. However, in other industries, the effect of the indirect tax is comparatively smaller than that shown in this industry.

![Diagram showing CO2 efficiency (yen/kg-CO2) for Company A, Company B, Company C, and Industry Sector 1. The diagram illustrates the comparison of net CO2 efficiency in the industry with the efficiencies obtained from three companies' environment reports.]

**CONCLUSION**

In this study, a few types of CO2 efficiencies were calculated for service industry (e.g., finance, real estate), assembling industry (e.g., electrical machinery and apparatus, transportation equipment) and primary materials industry (e.g., chemical, iron and steel). Further examination and comparison of company's “Environment Efficiency” and its detailed investigation in relation to economic value index should be explored.

**REFERENCES**