Fact-finding Analysis on Decarbonization of the Japanese Manufacturing Industry Based on the Decoupling Concept

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RYU Haku

Introduction

In the 21st century, the balance between economic growth and environmental preservation will become increasingly important. In 2015, the UN Sustainable Development Goals were adopted, and in 2016, the Paris Agreement, which aimed to decarbonize the world in the second half of the 21st century, was put into force. In Japan, the government and Keidanren (Japan Business Federation) declared in 2020 that carbon neutrality would be achieved by 2050.

Against this background, industries must reduce the risks associated with the transition to a decarbonized society and achieve a sustainable growth strategy. In particular, "decoupling" which separates sustainable growth from CO_2 emissions, has become a key issue.

Literature Review

Many researchers have been interested in decoupling economic growth from environmental impact in the past few years. In the context of ongoing climate change, research on carbon decoupling is being conducted in countries, regions, and companies.

The OECD (2002) defines decoupling as "the growth rate of an environmental pressure being less than that of its economic driving force (e.g., GDP) over a given period." The OECD also states that decoupling can be measured using a decoupling index with environmental variables as the numerator and economic variables as the denominator.

Using the concept of decoupling, Takai (2010) examined whether economic growth and carbon dioxide emission reductions were compatible in 146 countries worldwide. The analysis results showed that the decoupling between GDP per capita and carbon dioxide emissions per capita was progressing worldwide.

According to the International Energy Agency (2017), global energy-related CO_2 emissions in 2016 remained flat for the third consecutive year, even as the global economy grew, indicating continued decoupling of CO_2 emissions and economic activity.

Obama (2017) reported that from 2008 to 2015, CO_2 emissions from the energy sector in the United States decreased by 9.5% and that the economy grew by more than 10%. The country succeeded in simultaneously reducing greenhouse-gas emissions and sustaining economic growth.

However, few analyses of the actual situation have been conducted, focusing on Japan's industrial sector, particularly manufacturing. Therefore, this study focuses on the manufacturing industry, the largest CO_2 emission sector in Japan. It aims to find appropriate analytical indicators to visualize its decarbonization, conduct a factual analysis based on such indicators, and clarify the characteristics of each sector.

Research Method

In this study, we specifically defined "Carbon Decoupling" as "In a given period of time, either a decreasing trend in CO_2 emissions relative to a stable or increasing trend in production prices, or a greater decreasing trend in CO_2 emissions relative to a decreasing trend in production prices." The "production price" here is the price at which producers ship or provide the goods and services they produce (producer's price). Greenhouse-gas emissions are expressed as CO_2 equivalents.

1. **Specific calculation index:** Carbon intensity based on production price = CO_2 emissions ÷ production price
2. **Analysis period:** FY2012–2018 (trends, period average, period change rate)

The significance of using carbon intensity based on the prices of production can be considered as follows: First, from the perspective of visualizing the risk of a transition to a decarbonized society, it is useful to identify the average CO_2 emissions required for the same production price. Second, the rate of change of carbon intensity over time can be used to identify the actual decoupling state.

According to the OECD (2002), "decoupling can be either absolute or relative. Absolute decoupling occurs when the environmentally relevant variable is stable or decreasing while the economic driving force is growing. Decoupling is relative when the growth rate of the environmentally relevant variable is positive but less than the growth rate of the economic variable." Here, we define two types of decoupling as follows:

1. **Absolute decoupling:** CO_2 emissions are stable or decreasing, but production prices are increasing. This is the most desirable state.
2. **Relative decoupling:** CO_2 emissions are increasing at a rate lower than the increase in the production price.

However, relative decoupling can be further subdivided into two types. Previous studies have not considered cases where the reduction in CO_2 emissions is greater than that in the price of production. In other words, a situation in which CO_2 emissions could be reduced faster in the face of negative economic growth was not envisioned. Therefore, this study uniquely subdivides relative decoupling into the following two types, which allows for a more detailed analysis.

1. **Strong relative decoupling:** CO_2 emissions increase but less than the increase in production prices (conventional relative decoupling)
2. **Weak relative decoupling:** CO_2 emissions decrease more than production prices.

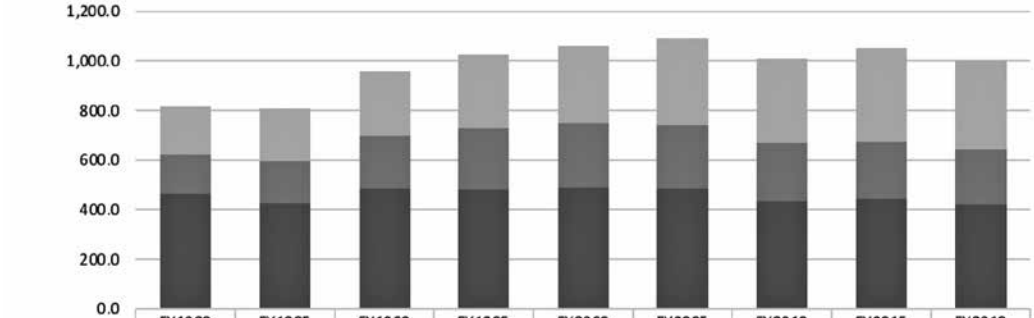
Results

In FY1980, Japan's real GDP (2010 prices) was USD 3,019 billion; by FY2018, it had increased to USD 6,170 billion, representing an economic growth of approximately 204%. In contrast, Japan's final energy consumption (oil equivalent) in FY1980 was 232 million tons, an increase of approximately 127% to 294 million tons in FY2018. Similar to the trend in energy consumption, Japan's energy-derived CO_2 emissions in FY1980 were 904 million tons, which increased by approximately 127% to 1,147 million tons in FY2018. The data presented by Ryu (2021) suggest the realization of a relative decoupling between CO_2 emissions and economic growth in Japan over the same period. This study focuses on the Japanese manufacturing industry by analyzing the reality of decoupling and identifying the characteristics of each sector.

Figure 1 shows that from FY1980 to FY2018, in order of CO_2 emissions, the industrial sector ranked first, followed by the consumer sector in second place and the transportation sector in third place. The industrial sector decreased by approximately 9% over the same period, the consumer sector increased by approximately 87%, and the transportation sector increased by approximately 38%. Overall, it can also be seen that CO_2 emissions began to decrease in FY 2005.

The enactment of the "Energy Conservation Law" in 1979, energy rationalization in the 1990s, the "Global Warming Countermeasures Law" in 1998, the introduction of the "Kyoto Protocol"

Figure 1 CO_2 emissions from energy use by sector in Japan
($Mt\text{-}CO_2$, fossil fuel, and electricity consumption)



	FY1980	FY1985	FY1990	FY1995	FY2000	FY2005	FY2010	FY2015	FY2018
Consumer	192.5	212.2	258.8	298.3	313.8	350.0	338.6	378.7	359.8
Transportation	158.8	169.0	213.5	248.3	259.7	258.2	236.5	226.7	218.7
Industry	464.8	426.6	484.1	479.5	488.5	484.2	435.2	445.9	423.5

Source: EDMC *Handbook of Japan's & World Energy & Economic Statistics* - Editions of each year

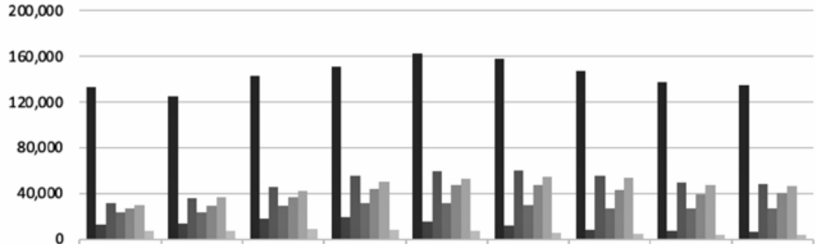
in 2005, and the "Paris Agreement" in 2016 have greatly accelerated the reduction of CO_2 emissions. Especially in the industrial sector, after the two oil crises, technological innovation in oil removal, the sophistication of industrial structure, and automation of manufacturing processes have greatly contributed to the reduction of CO_2 emissions.

In contrast, in the consumer and transportation sectors, CO_2 emissions increased owing to a sharp rise in electricity consumption resulting from increased final consumption expenditures, especially IT-related demand. The increased movement of goods also significantly impacts the increase in CO_2 emissions in the tertiary sector.

The next section analyzes the changes in energy consumption in each sector. Figure 2 further subdivides the three main sectors and shows trends in final energy consumption and the source of CO_2 emissions. Overall, the final energy consumption has been on a downward trend since FY2000. In descending order of final energy consumption, the industrial sector ranks first, followed by the consumer sector (households, tertiary industry, and other business sectors) and the transportation sector.

When energy consumption in the industrial sector is divided into manufacturing and non-manufacturing sectors, the manufacturing sector is the largest energy-consuming sector, increasing by 1.03% in FY2018 as compared to FY1980. In contrast, the non-manufacturing sectors, such as agriculture, forestry, fisheries, and construction, have made significant progress in energy conservation, reducing the final energy consumption in FY2018 by 49.38% as compared to FY1980.

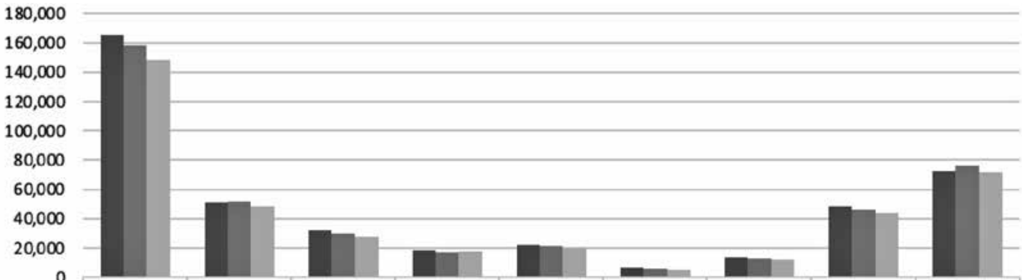
Figure 2 Final energy consumption by sector in Japan (10^10 kcal)



	FY1980	FY1985	FY1990	FY1995	FY2000	FY2005	FY2010	FY2015	FY2018
■ Industry (manufacturing industry)	132,978	125,058	142,762	150,864	162,552	157,483	146,698	137,369	134,350
■ Industry (non-manufacturing industry)	13,161	13,503	18,102	18,973	15,622	12,317	7,640	6,862	6,662
■ Transportation (passenger)	31,595	35,392	45,396	55,275	59,301	60,082	55,389	49,670	47,646
■ Transportation (cargo)	23,407	23,488	28,989	31,365	31,439	29,903	27,046	27,139	26,690
■ Consumer (home)	26,363	28,913	36,466	43,608	46,973	46,994	43,139	39,242	40,731
■ Consumer (business)	30,120	36,883	42,380	50,573	52,688	54,901	53,955	47,043	46,675
■ Others	6,917	7,308	8,772	8,137	7,164	5,357	4,380	3,450	3,581

Source: EDMC *Handbook of Japan's & World Energy & Economic Statistics* - Editions of each year

Figure 3 Production Price Trends by Manufacturing Sector
(Billions of yen converted to FY2015 prices)



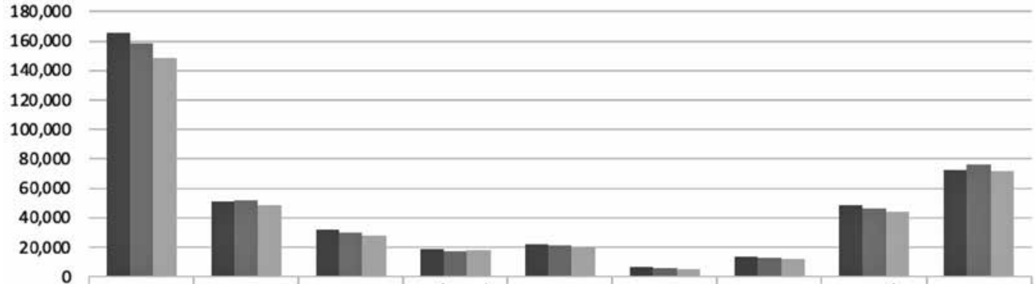
	steel	chemical	ceramic	pulp and paper	food	textile	nonferrous	metal machinery	others
■ FY2012	165,583	51,163	31,744	18,282	21,990	6,862	13,675	48,118	72,578
■ FY2015	158,278	52,171	30,243	16,848	21,277	5,836	13,163	46,156	76,130
■ FY2018	148,352	48,108	27,952	17,961	20,076	5,389	12,437	43,764	71,859

Source: EDMC *Handbook of Japan's & World Energy & Economic Statistics* - Editions of each year

Figure 3 shows the price of production trends in the manufacturing industry. First, by sector, the amounts from FY2012 to FY2018 were metal machinery in the first place, food in second place, chemicals in third place, steel in fourth place, other (lifestyle-related and commercial manufacturing) in fifth place, nonferrous metals in sixth place, paper and pulp in seventh place, ceramics in eighth place, and textiles in ninth place.

Next, looking at the percentage change in the prices of production in FY2018 versus FY2012, metal machinery ranked first (+18.03%), chemicals second (+12.44%), other third (+7.17%),

Figure 4 CO_2 Emissions by Manufacturing Sector
(1,000 tons of fossil fuel + electricity consumed)



	steel	chemical	ceramic	pulp and paper	food	textile	nonferrous	metal machinery	others
■ FY2012	165,583	51,163	31,744	18,282	21,990	6,862	13,675	48,118	72,578
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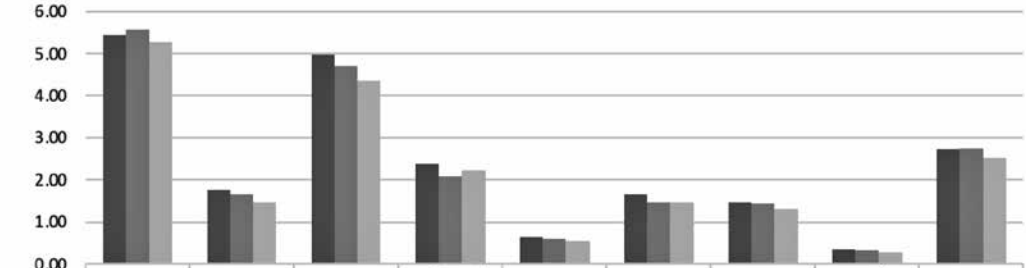
pulp and paper fourth (+5.3%), and food fifth (+4.5%). In contrast, textiles (−10.74%) and steel (−7.59%) showed negative growth due to capital expansion in emerging countries and sluggish market conditions.

Figure 4 shows CO_2 emissions by sector from FY2012 to FY2018. In order of emissions, steel is first, others second, chemicals third, metal machinery fourth, ceramics fifth, food sixth, pulp and paper seventh, nonferrous eighth, and textiles ninth.The percentage change in CO_2 emissions from FY2018 to FY2012 shows textiles ranked first (−21.47%), ceramics second (−11.95%), steel third (−10.41%), metal machinery and non-ferrous metals fourth (−9.05%), food fifth (−8.70%), chemicals sixth (−5.97%), pulp and paper seventh (−1.76%), and others eighth (−0.99%). These data confirm that CO_2 emissions have been reduced throughout the manufacturing industry.

Figure 5 shows the change in production-price-based carbon intensity calculated from the production price data in Figure 3 and the CO_2 emissions data in Figure 4. These data show that in increasing risk of transition to a decarbonized society, steel ranks first, ceramics second, others third, pulp and paper fourth, and chemicals fifth. When the manufacturing sector was broadly divided into materials-based and non-materials-based industries (processing and assembly), it was found that most industries with high carbon intensity were material-based. This means that the high dependence on fossil fuels in high-materials industries (steel, ceramics, and chemicals) impacts carbon intensity.

The highest percentage improvement in production-price-based carbon intensity ranking in

Figure 5 Production-Price-Based Carbon Intensity by Manufacturing Sector
(1,000 tons/billion yen, converted to FY2015 prices)



	steel	chemical	ceramic	pulp and paper	food	textile	nonferrous	metal machinery	others
FY2012	5.44	1.76	4.99	2.39	0.64	1.66	1.45	0.36	2.73
FY2015	5.57	1.67	4.71	2.09	0.59	1.45	1.44	0.32	2.76
FY2018	5.28	1.47	4.35	2.23	0.56	1.46	1.32	0.28	2.52

Source: EDMC *Handbook of Japan's & World Energy & Economic Statistics* - Editions of each year

FY2018 versus FY2012 shows that metal machinery ranked first, chemicals second, ceramics third, food fourth, textiles fifth, nonferrous metals sixth, others seventh, pulp and paper eighth, and iron and steel ninth. In particular, the steel industry showed a low rate of improvement in carbon intensity over the period, indicating the need to strengthen decarbonization measures in the future.

Conclusion and Discussion

In this study, we focused on the Japanese manufacturing industry, analyzed the changes in the prices of production and CO_2 emissions by sector, and clarified the actual situation of decoupling using a production-price-based carbon intensity index.

As a result, decoupling was achieved with improved carbon intensity in all sectors. The sectors that achieved absolute decoupling in 2018 versus 2012 were Metal Machinery (18.03% / −9.05%), Chemical (12.44% / −5.97%), Other (7.17% / −5.97%), pulp and paper (5.30% / −1.76%), food (4% / −8.7%) and ceramics (0.94% / −11.95%). We also found a weak relative decoupling in textiles (−10.74% / −21.47%), steel (−7.59% / −10.41%), and non-ferrous metals (−0.16% / −9.05%).

As these results show, there is an urgent need for growth strategies and risk reduction to transition to a decarbonized society in the textile, steel, and non-ferrous metal sectors. In particular, the steel industry emits the highest amount of CO_2, and reducing fossil fuel use in the steel industry is crucial for the decarbonization of the Japanese economy. Accelerating efforts to make steel zero-carbon is essential, including increasing the share of electric furnaces with low CO_2 emissions and developing hydrogen reduction and low-carbon technologies.

The concept of decoupling, which decouples companies' sustainable growth from their CO_2 emissions, requires absolute decoupling. In addition, to reduce the risk of transitioning to a decarbonized society, it is necessary to provide policy support for relevant innovations that can generate higher added value while strategically reducing carbon emissions. We hope this study will help us understand the state of decarbonization in the Japanese industry. Decarbonization of the primary energy transformation is also essential. As a topic for future research, we plan to analyze decoupling in the electricity sector.

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