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Success and failure of the voluntary action plan: Disaggregated sector decomposition analysis of energy-related CO_2 emissions in Japan

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ABSTRACT

To accomplish the goal of reducing greenhouse gas (GHG) emissions, the Japanese Business Federation (JBF) has implemented the voluntary action plan (VAP), which includes the unique feature of not penalizing industrial organizations for failing to meet the CO_2 emissions or energy consumption reduction targets. This study evaluates the role of the VAP in emission reduction by analyzing highly disaggregated data of 197 sectors from 1980 to 2015 using the logarithmic mean Divisia index (LMDI) method. The results indicate that the increase in CO_2 emissions among Japanese industries is mainly caused by the increase in indirect CO_2 emissions. Moreover, the energy consumption structure has progressively shifted from fossil fuels to electricity. The decomposition analysis highlights two key points. (1) The VAP is ineffective in reducing emissions in sectors with low market concentration. (2) Energy intensity targets of the VAP does not lead to a significant reduction in CO_2 emissions. Thus, this study concludes that the contribution of the VAP in reducing CO_2 emissions is limited. Evidence from our research suggests four directions for future policy design and implications.

1. Introduction

To mitigate the salient impacts of climate change, Japan has actively participated in various conventions, such as the Kyoto Protocol (UNFCCC, 1997) and the Paris Agreement (2016). The Japanese government has also been working to achieve Sustainable Development Goals (2016) (hereafter referred to as SDGs). Among the many goals in the SDGs, climate change policy is one of the priorities of the Japanese government. In the context of climate change policy, the 2016 Paris Agreement has become the most important agenda for the Japanese government. This is not the first time the Japanese government has worked on climate change policy. The government has been working on the issue since the birth of the Kyoto Protocol.

Various environmental policies to reduce CO_2 emissions have been proposed by past Japanese administrations, including current Prime Minister Kishida. Former Prime Minister Abe aimed at an 80% emission reduction by 2050, using nuclear power. He also supported the usage of the voluntary approach. In contrast, Former Prime Minister Suga, who declared carbon neutrality, proposed the discussion of carbon pricing as an important policy instrument. Prime Minister Kishida follows Suga's approach. Our analysis attempts to shed light on the difference between Abe and Suga by analyzing the achievements of voluntary action plans (hereafter referred to as VAPs) by the Japanese Business Federation (hereafter referred to as JBFs).

To avoid governmental intervention in the form of environmental regulations, the JBF implemented the VAP to reduce GHG emissions and solid waste generation from 1997 to 2012 (Sugiyama and Imura, 1999; Sugino and Arimura, 2011). Before 2010, Japan implemented a few voluntary carbon pricing policies to achieve emission reductions, such as the Japan Voluntary Emission Trading Scheme (J-VETS) and Japan-Verified Emissions Reduction (J-VER). J-VETS was a voluntary cap and trade scheme in which only a limited number of firms participated. J-VER was a baseline credit mechanism in which firms could obtain emission credit if they reduced emissions voluntarily. Unlike the European Union (EU) under the Kyoto Protocol, Japan did not implement a mandatory carbon policy, such as a domestic emission trading

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scheme (ETS) or a carbon tax, to combat climate change. In the Japanese manufacturing sector, emission reduction mainly relied on the VAP. Compared with other environmental policies, the regulatory authority cannot penalize industrial associations that fail to meet the emission reduction target when they participate in the VAP. Moreover, individual firms do not face penalties even if they fail to achieve the target. The evaluation of the VAP is important in the context of the Paris Agreement. If the VAP is effective, it can contribute to SDGs as well as climate mitigation. If the VAP is ineffective in the mitigation of CO_2 emissions, the Japanese government cannot rely on the voluntary approach to achieve the target under the Paris Agreement.

This paper also touches upon Procedural Justice, which is the concept explaining the source of energy policy failure defined in Sokołowski and Heffron (2022). The VAP was designed and set by the JBF, which only consists of established large firms. Thus, the VAP did not directly affect emission reduction decisions of small and medium-sized enterprises (SMEs)'. Consequently, SMEs had room to deviate from the reduction of CO_2 emissions expected by the Japanese Kyoto Protocol Target Achievement Plan (MOEJ, 2008).

Furthermore, since the VAP is voluntary, it lacks core principles that constitute existing environmental, climate change, and energy laws (Heffron et al., 2018). For example, the "polluter pays principle" and the "principle of energy justice" is not fulfilled because the VAP targets are based on industrial targets rather than firm-specific targets, which leads to burden inequality. If the VAP is ineffective, then regulatory intervention in the form of energy tax reforms or rational use of energy based on the principle of energy laws will be necessary.

Many studies have investigated the effectiveness of voluntary energy and environmental policy approaches. Brophy et al. (1995) pointed out that it is difficult to improve the environmental performance of firms without using the legislative approach alongside the voluntary approach. Paton (2000) argued that there are uncertainties associated with the effectiveness and efficiency of voluntary programs compared with other policy instruments. The case study found that the environmental policy based on the voluntary partnership in the U.S. did not achieve the interim objectives. Cunningham and Clinch (2004) questioned the feasibility of voluntary approaches as environmental policies. They addressed three issues: the presence free riders, shortage of funds to enforce the regulation, and the lack of public awareness of voluntary approaches. Our study can be categorized in this stream of studies. In particular, it is categorized as a case study of a policy inducing the collapsed incentive of firms. As pointed out by Brophy et al. (1995), JBF's VAP failed to form the proper incentives to encourage firms to reduce emissions.

As Jones and Yoo (2009) argued, pressure from society, the government, and nongovernmental organizations encourages firms to comply with voluntary targets. Thus, firms' reputations may be damaged if they do not participate or fail to meet the targets set forth by the VAP, which would inflict indirect damage on these firms. In addition, the progress of the VAP was monitored by a governmental committee under the Ministry of Economy, Trade and Industry (METI). Furthermore, the JFB allowed associations and industries to set the type of target themselves, which were classified as CO_2 absolute targets, CO_2 intensity targets, energy absolute targets, and energy intensity targets (Arimura, 2015). Few studies have focused on individual firms in terms of whether they met the voluntary targets. For instance, Wakabayashi and Arimura (2016) observed that the VAP encourages small and medium-sized enterprises (SMEs) to set reduction targets. However, Arimura et al. (2019) suggested that agreements on voluntary targets can be relatively achieved easily when emissions are concentrated among few firms.

However, it is necessary to clarify whether emission reduction was achieved successfully through the implementation of the VAP or through other factors, such as changes in the industrial structure, technical innovation, and economic recessions. To do so, this study quantifies the driving factors behind the changes in energy-related CO_2 emissions, which will provide us with valuable information to evaluate the effectiveness of current and future policies and thus enable us to provide options in designing regulations to realize emission reduction targets.

The majority of the literature focusing on the drivers of the changes in CO_2 emissions is summarized in Table 1, which highlights the studies that have explored the factors that contribute to changes in CO_2 emissions. However, most studies have focused only on the manufacturing sector or used highly aggregated data consisting of fewer than 100 sectors (for example, Su et al., 2017; Liu et al., 2019). Highly aggregated data are easy to handle but aggregate vital industries, such as energy-intensive trade-exposed industries, which is not ideal from the policy-making perspective.

Empirical evidence suggests that Japan has successfully reduced its domestic CO_2 emissions from the manufacturing industry (Nishitani et al., 2012). Most studies that have analyzed Japanese CO_2 emissions have focused on direct emissions from the manufacturing industry. For instance, Matsumoto et al. (2019) found that the energy intensity effect[1] was the main driver of increasing CO_2 emissions in the manufacturing sector at the regional level between 1993 and 2013. However, as electricity consumption continues to increase, the indirect CO_2 emissions have become an important part of CO_2 emissions, which cannot be ignored. Furthermore, the service industry, which has expanded in many developed countries, mostly uses electricity, rather than fossil fuel, as a source energy. Thus, the direct CO_2 emissions of this industry are relatively small. Consequently, compared with other industries, the service industry tends to emit a larger share of indirect CO_2 emissions, which indicates the importance of considering indirect emissions (Nansai et al., 2009). In fact, Zhang et al. (2015) showed that indirect CO_2 emissions from the service industry were greater than direct emissions based on a multiregional input–output model between 1995 and 2007.

In this study, we use highly disaggregated data consisting of approximately 197 sectors, including all industries, to explore the factors driving the changes in Japanese direct and indirect CO_2 emissions. Concurrently, we also attempt to bridge the gap in the literature by evaluating whether the VAP successfully reduced CO_2 emissions from the manufacturing sector in Japan.

We use the estimated CO_2 emissions provided by the "Embodied Energy and Emission Intensity Data for Japan Using Input–Output Tables" (3EID). Our results provide evidence that the VAP tends to succeed in reducing emissions in sectors with high market concentration. However, the energy intensity target of the VAP achieves limited success in reducing emissions compared to other targets. Furthermore, the increase in indirect CO_2 emissions is the main driver of the rising CO_2 emissions in Japanese industries. Moreover, the results show evidence of the expansion of the service industry during the study period. This study also reveals the forces driving the changes in CO_2 emissions for 197 sectors. This allows us to present the detailed regulation options that need to be considered when designing regulations.

The contribution of this research is fourfold. First, we investigate the effectiveness of the VAP within the manufacturing industry from 1990 to 2011 by using the decomposition method. To the best of our knowledge, only a few studies have examined the impact of Japan's VAP on CO_2 emissions. Second, compared to the existing literature, which mostly focuses on direct emissions, we consider both direct and indirect CO_2 emissions. Third, the existing literature has focused on the manufacturing sector, whereas this study examines CO_2 emissions from both the service industry and the manufacturing sector. Finally, previous studies have used highly aggregated industrial data. However, this study focuses on 197 sectors representing the entire Japanese economy, which allows us to investigate in detail what happened within Japanese industries.

[1] This is a concept used in Matsumoto et al. (2019) and similar to technique effect in our paper.

Table 1
Summary of the existing literature in the literature review.

Publication	Time period	Target sector	Number of sectors or industries	Research technique	Indirect CO_2
Japan					
Matsumoto et al. (2019)	1993 to 2013	Japan's manufacturing Industry	8	Additive LMDI	N
Okamoto (2013)	1990 to 2005	Japan's primary, secondary and other 2 industries	4	Shapley–Sun decomposition method	N
Shigetomi et al. (2018)	1990 to 2015	Japan's household sector	1	Multiplicative LMDI	N
Other countries					
Xie and Lin (2019)	2000 to 2013	China's food industry	1	Multiplicative LMDI	N
Wang et al. (2020)	1997 to 2016	US's residential, commercial, and other 2 sectors	4	Additive LMDI	Y
Liu et al. (2019)	2000 to 2015	China's agriculture, mining, and other 14 sectors	16	Multiplicative LMDI	N
Cansino et al. (2016)	1995 to 2011	Spain's agriculture, mining, and other 33 sectors	35	Additive LMDI	N
Su et al. (2017)	2000 to 2010	Singapore's agriculture, manufacturing, and other 8 industries	110	Structural decomposition analysis	Y
Lin and Lei (2015)	1986 to 2010	China's food industry	1	Additive LMDI	Y

The remainder of the study is organized as follows. Section 2 describes the methodology and the data. Section 3 presents our analysis and discusses the driving forces of direct and indirect CO_2 emissions. Section 4 concludes the study with policy implications.

2. Methodology and data

2.1. Methodology

The logarithmic mean Divisia index (LMDI) method has been widely used to investigate the drivers of changes in CO_2 emissions. The advantages of the LMDI method include 1) the ability to factor reversal properties without leaving residuals, 2) the handling of zero values, and 3) consistency in aggregation (Ang, 2004, 2005, 2015; Zhang et al., 2016). Moreover, both additive and multiplicative decomposition analyses are used in the LMDI method. Additive decomposition analysis exhibits the aggregation of quantity-decomposed effects with a physical unit (Ang, 2015; Wang and Feng, 2017), while multiplicative decomposition analysis exhibits the aggregation of intensity-decomposed effects without a physical unit (Su et al., 2017).

In this study, the additive LMDI method is adopted to investigate the changes in total[2] CO_2 emissions in Japan from 1980 to 2015. To evaluate how each sector contributes to the changes in CO_2 emissions in the long term, this study follows Grossman (1995) to decompose the changes in CO_2 emissions into scale, composition, and technique effect at the most detailed sectoral level based on Japanese domestic input–output tables from 1980 to 2015. The scale effect reflects the changes in pollution emissions brought about by changes in economic activities, the composition effect represents the changes in emissions induced by changes in the industrial structure, and the technique effect reflects the changes in emissions due to changes in emission intensity.

Since the total CO_2 emissions are emitted by N sectors in an economy, each sector emits e_i. Let yi represent the output for sector i, and Y represent the total output for the entire economy. Thus, following Levinson (2009), the aggerated CO_2 emissions can be written as follows:

$$CO_2 = \sum_{i=1}^{N} e_i = \sum_{i=1}^{N} \frac{co_{2i}}{yi} \times \frac{yi}{Y} \times Y = Y \sum_{i=1}^{N} \varphi_i \theta_i \tag{1}$$

where θ is the share of sectorial output to total output, and φ is the CO_2 intensity for each sector. In the additive LMDI method, the changes in CO_2 emissions between period t and the previous period t-1 are represented by the following three factors:

$$\Delta CO2 = CO2^t - CO2^{t0} = \sum_{i=1}^{N} e_i^t - \sum_{i=1}^{N} e_i^{t-1} = \Delta E_{tot} = \Delta E_Y + \Delta E_{\varphi_i} + \Delta E_{\theta_i} \tag{2}$$

where the three elements in equation (2) represent the scale (ΔE_Y), technique (ΔE_{φ_i}), and composition (ΔE_{θ_i}) effects. The LMDI method leaves no residual in the decomposition process, leading to its uniqueness. Furthermore, logarithmic changes are used to show the effect of changes in E_{tot}, and the logarithmic average of two elements in two periods is used to explore the effect of the contribution of factors. For additive decomposition, the changes in CO_2 emissions are decomposed using the following equation:

$$\Delta E_{tot} = \Delta E_Y + \Delta E_{\varphi_i} + \Delta E_{\theta_i} = \sum_i L\left(e_i^t, e_i^{t-1}\right) \ln\left(\frac{Y^t}{Y^{t-1}}\right) + \sum_i L\left(e_i^t, e_i^{t-1}\right) \ln\left(\frac{\varphi_i^t}{\varphi_i^{t-1}}\right) + \sum_i L\left(e_i^t, e_i^{t-1}\right) \ln\left(\frac{\theta_i^t}{\theta_i^{t-1}}\right) \tag{3}$$

where the element, $L(e_i^t, e_i^{t-1})$, is given by the following:

$$L_i\left(e_i^t, e_i^{t-1}\right) = \frac{e_i^t - e_i^{t-1}}{\ln e_i^t - \ln e_i^{t-1}} \tag{4}$$

Combining equations (3) and (4), the three effects are calculated through the equations in the additive LMDI method as follows:

$$\Delta E_Y = \sum_i \frac{e_i^t - e_i^{t-1}}{\ln e_i^t - \ln e_i^{t-1}} \ln\left(\frac{Y^t}{Y^{t-1}}\right) \tag{5}$$

$$\Delta E_{\varphi_i} = \sum_i \frac{e_i^t - e_i^{t-1}}{\ln e_i^t - \ln e_i^{t-1}} \ln\left(\frac{\varphi_i^t}{\varphi_i^{t-1}}\right) \tag{6}$$

$$\Delta E_{\theta_i} = \sum_i \frac{e_i^t - e_i^{t-1}}{\ln e_i^t - \ln e_i^{t-1}} \ln\left(\frac{\theta_i^t}{\theta_i^{t-1}}\right) \tag{7}$$

2.2. Data and aggregation of sectors

This study utilizes the emission of pollutants for each sector between

[2] Total CO_2 emissions is the sum of direct and indirect CO_2 emissions (Scope 1 and 2). In this paper, direct emissions from the power sector and steam and hot water supply are treated as zero to avoid double counting.

1990 and 2015 from Nansai et al. (2009) and Nansai and Moriguchi (2012), known as 3EID, and the sectoral data provided by Japan's domestic input–output table from 1980 to 2015. The 3EID provides information on energy consumption and emission factors for more than 30 types of fossil fuels, such as coke, fuel oil A, gasoline, and naphtha,[3] which are directly consumed by sectors classified in the Japanese input–output table.

The reason for utilizing 3EID is that the calculation method of CO_2 emissions by using the information of consumption and emission factors of each type of energy source is consistent for all periods, which allows us to analyze the trend of CO_2 emissions.

When a new important industry in the Japanese economy emerges, a new sector will be defined within the input–output table. On the other hand, a sector will be aggregated into other sectors when the importance of the sector decreases. Hence, the number of sectors and the classification of sectors differ in each input–output table. To overcome this issue, we reaggregate the original data consisting of more than 400 industries into 197 sectors so that the sector classification is consistent for the entire period.

We calculate the direct CO_2 emissions for the 197 sectors based on CO_2 emissions calculated in the 3EID. It should be noted that the service sector consumes electricity and heat but does not consume fossil fuels directly. We estimate the indirect CO_2 emissions from each sector based on the consumption of electricity, private power generation, and steam and hot water supply provided in the Value and Quantity Tables (VQT).[4]

We also calculated the weighted average of the market concentration ratio (top four firms) of relative sectors that corresponds to the sector classification by adopting information from the Japan Industrial Productivity (JIP) database.[5]

3. Results and discussion

3.1. Change trends of total CO_2 emissions

This study attempts to analyze the changes in total CO_2 emissions at the national level. Concurrently, this study makes a modest attempt to analyze the changing trends and characteristics in Japan.

Fig. 1 presents direct and indirect CO_2 emissions at the industrial level, highlighting the manufacturing, service, electricity, gas and heating supply industries. From 1980 to 2015, the Japanese industry experienced an increase in overall CO_2 emissions from 737 mt-CO_2 to 1016 mt-CO_2, with the peak in 2015 (approximately 13% higher than that of the 1990 level). The decline in total CO_2 emissions during the period from 2005 to 2011 reflects the Great Financial Crisis from 2007 to 2008 and the Great East Japan Earthquake in 2011. For instance, we can observe that the total CO_2 emissions of the manufacturing industry gradually increased from 424 mt-CO_2 in 1980 to 477 mt-CO_2 in 2015. In 2015, while the CO_2 emissions of the manufacturing industry dropped by 4.2% compared to 2011, they still accounted for 47% of the total CO_2 emissions. As evident from Fig. 1, direct CO_2 emissions decreased while indirect emissions increased in the manufacturing industry. More importantly, the share of indirect emissions to total emissions increased during the study period, especially in the service industry, indicating that the structure of energy consumption within Japanese industries has gradually shifted away from fuel consumption toward electricity.

Since the structure of energy consumption has shifted to electricity, indirect CO_2 emissions need to be considered. Our analysis reveals that ignoring indirect emissions leads to the illusion that CO_2 emissions have decreased within the manufacturing industry since 1990. However, when indirect CO_2 emissions are considered, CO_2 emissions in the manufacturing industry have actually continued to increase since 2005. This implies that excluding indirect emissions can be misleading.

In contrast to the manufacturing industry, we find that the total CO_2 emissions of the service industry have increased significantly since 1980. It must be noted that the service industry does not use fossil fuels as much as the manufacturing industry. Thus, direct CO_2 emissions alone do not represent the actual total CO_2 emissions situation. Hence, indirect CO_2 emissions are very important. The indirect CO_2 emissions of the service industry grew by 53% from 1990 to 2015, from 43 mt-CO_2 to 67 mt-CO_2. By comparing the share of total CO_2 emissions of the manufacturing and service industry, we find that the share of the manufacturing industry declined from 58% to 48%, whereas the percentage of the service industry doubled from 5.2% to 10.7% during the same period.

By comparing the manufacturing industry results with those of the service industry, the findings show that the shares of total CO_2 emissions of the manufacturing and service industries accounted for 58% and 5.2% in 1980 and 48% and 10.7% in 2015, respectively. The percentage of the service industry doubled during these 35 years in Japan, illustrating the increases in economic activity of the service industry and the growing burden that this industry is placing on the environment. We can also identify this change in a finer sector classification. In the manufacturing sector, we observed a constant decrease in the output from the woven fabric apparel, cement, and video equipment sectors. In contrast, we observe a constant increase in output from the "health and hygiene" and "social welfare" in the service sector. To analyze the driving forces behind the changes in CO_2 emissions, we discuss the results of the additive LMDI method based on equation (4) in the next section.

3.2. Decomposition results at the industrial level

Fig. 2(A) and (B) show the industrial-level results of the composition and the technique effect for the manufacturing and service industries, respectively. Since the scale effect represents the entire effect of all industries, it is not decomposed at the industrial level. The bar on the far right shows the overall effect between 1990 and 2011, when the VAP was implemented. For the manufacturing industry, the technique effect increased emissions by approximately 50 mt-CO_2 between 1990 and 2011, while the composition effect decreased emissions by more than 250 mt-CO_2 during the same period. The technique effect initially increased CO_2 emissions before 2000 and then reduced CO_2 emissions afterward, and the maximum value was achieved between 1990 and 1995. This finding indicates that the CO_2 intensity has gradually improved compared with the prior period. The contribution of the composition effect in reducing emissions from the manufacturing industry reached 250 mt-CO_2 from 1990 to 2011, which may reflect the decline in domestic output and the fact that developing countries attract dirty production processes or investments from developed countries, due to a lack of stringent environmental regulations (Copeland and Taylor, 2004).

In contrast, Fig. 2(B) shows a positive value for the composition effect for most periods, implying that the composition effect of the service industry increases CO_2 emissions. The technique effect from 1990 to 2011 is negative. However, if we examine the technique effect in detail, we observe that the technique effect is positive, meaning that it has increased CO_2 emissions since 2000. This finding indicates that the CO_2 emissions of the service industry cannot be ignored, and thus, it is necessary to consider regulations to reduce CO_2 emissions from the service industry.

3.3. Decomposition results for the sectors that participated in the VAP

The previous section focused on the entire manufacturing and service industry. However, the results for sectors within the manufacturing

[3] The CO_2 emitted from waste matter-based energy sources are not considered in the calculation of CO_2 emissions.

[4] See Appendix A for the detailed method used to calculate the indirect emissions for each sector.

[5] The website of the database is https://www.ier.hit-u.ac.jp/English/databases/jip.html.

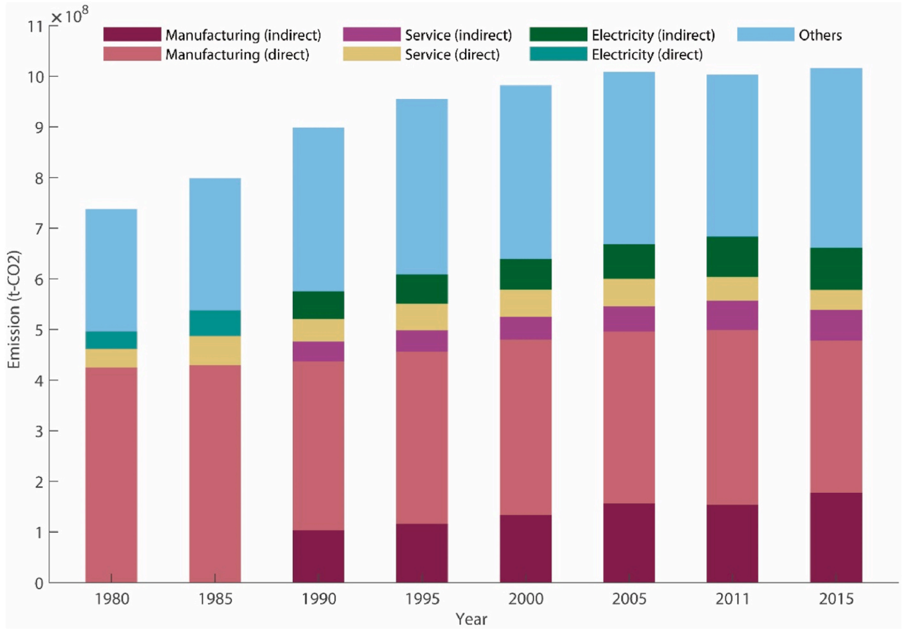

Fig. 1. Direct and indirect CO_2 emissions at the industrial level.
Note: We use 1990 emission intensities to calculate sectoral CO2 emissions for 1980 and 1985. Thus, the CO2 emissions from 1980 to 1985 are not decomposed into direct or indirect emissions. The light color represents direct CO2 emissions.

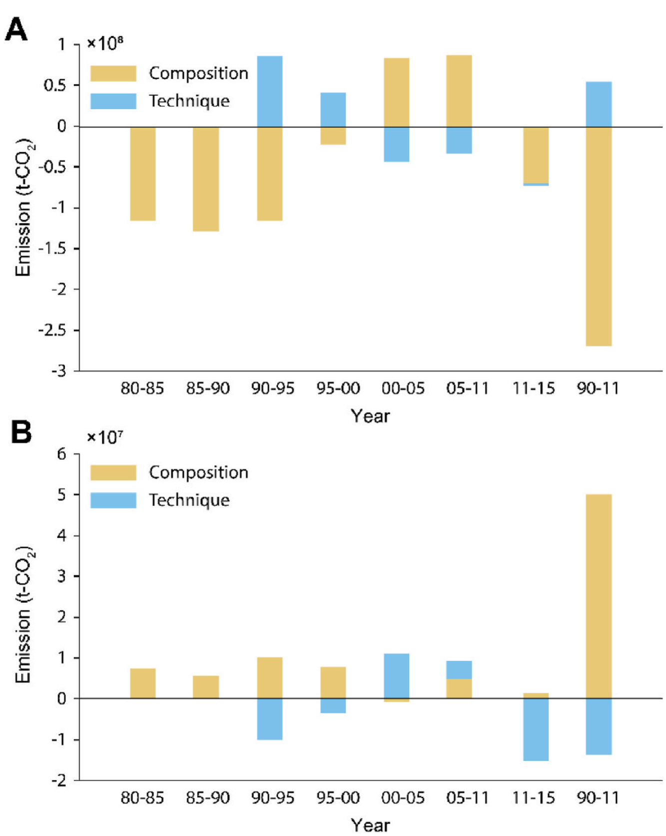

Fig. 2. Composition and technique effects for the manufacturing and service industries.
Note: "80–85" in the figure indicates the period from 1980 to 1985.

industry may differ greatly due to the VAP. Thus, in this section, we will focus on sectors that participated in the VAP, which not only provides the most detailed emission reduction information but also allows us to investigate the effectiveness of the targets set forth under the VAP.

JFB announced the "Voluntary Action Plan on the Environment" in an effort to reduce emissions while inhibiting a firm's economic burden. JFB's VAP allows industrial or trade associations to voluntarily set targets regarding CO_2 emissions, CO_2 intensity, energy consumption, and energy intensity, with the aim of reducing the emissions from relevant firms by installing new environmental technology or improving the efficiency of their production processes. Note that none of the firms are obligated to achieve the target set by the associations within their sectors. Although the VAP is free from regulatory surveillance, the Japanese government conducts annual evaluations and verification of the progress made through relevant advisory councils.

Table 2 summarizes the sectors that participated in the VAP. These sectors are categorized into three groups by the type of target set by each sector. The first group is the absolute target, which specifies the total amount of GHG emissions or energy consumption reduction that must be achieved. The second group is the intensity target, which aims to improve the emissions intensity or energy intensity. The third group is the mixed target, which contains both absolute and intensity targets. Since emission reduction in the manufacturing sector in Japan mainly relied on the VAP before 2010, the technique effect between 1990 and 2011 can be partially reflected by the impacts of the VAP.

Table 3 shows the results of the composition and technique effect from 1990 to 2011. The composition effect is negative for approximately 70% of the sectors that participated in the VAP. In contrast, the technique effect was negative for only 40% of the sectors. Compared with the decomposition results at the industrial level, the reduction in emissions for the sectors that participated in the VAP is attributed to the composition effect, not the technique effect. Moreover, the relationship between the types of VAP targets and the signs of the technique effect is ambiguous. In particular, the technique effect for sectors with energy intensity targets does not exhibit negative values (i.e., a decrease in emission intensity), except for the aluminum sector. This fact implies the followings. (1) The energy intensity target of the VAP failed to reduce CO_2 emissions by improving production processes. (2) The VAP failed to

Table 2
Sectors that participated in the VAP.

Sector name	Code
Sectors with an absolute target	
Pig iron	1
Industrial equipment	2
Sugar	3
Railway	4
Sake (liquors)	5
Sanitary equipment (medical instruments)	6
Pharmaceuticals (medicaments)	7
Residential	8
Electric wire	9
Glass	10
Sectors with an intensity target	
Petroleum product	11
Chemical-related sectors	12
Paper	13
Cement	14
Construction	15
Mining (gravel, quarrying)	16
Aluminum	17
Copper	18
Bearing	19
Beverage	20
Limestone	21
Machine tool	22
Milling	23
Ship	24
Sectors with a mixed target or other target	
Production of car bodies and parts	25
Rubber	26

Note: The translation of the sectors in this table is based on the report of VAP.

Table 3
Effects from 1990 to 2011.

	Effects (10^5 t-CO_2)	
Sector name	Composition	Technique
Sectors with an absolute target		
Pig iron	−768.01	−369.603
Industrial equipment	10.34	−2.199
Sugar	−13.76	−3.324
Railway	0.16	−0.207
Sake (liquors)	−0.36	−6.146
Sanitary equipment (medical instruments)	1.55	0.01
Pharmaceuticals (medicaments)	1.57	9.34
Residential	−10.03	4.83
Electric wire	−5.42	5.08
Glass	−28.95	1.60
Sectors with an intensity target		
Petroleum product	−218.01	−32.88
Chemical-related sectors	−107.57	106.75
Paper	−76.25	39.82
Cement	−296.11	126.67
Construction	3.47	−8.27
Mining (gravel, quarrying)	−29.82	21.39
Aluminum	−8.80	−22.33
Copper	−3.64	2.67
Bearing	−10.01	12.65
Beverage	38.21	−2.49
Limestone	−29.82	21.39
Machine tool	10.34	−2.19
Milling	−3.14	2.54
Ship	−2.62	0.65
Sectors with a mixed target or other target		
Production of car bodies and parts	20.58	−8.68
Rubber	−13.04	2.14

achieve energy justice in the manufacturing industry. If the Japanese government intends to achieve the 2030 Japanese targets, it cannot rely on only the VAP. Other sectors, such as the household and transportation sectors, need to compensate for the shortcomings of the manufacturing industry.

The decomposition results at the sector level did not show a clear-cut relationship between the type of target set under the VAP and the technique effect. To further explore why the impact of the VAP shows different signs for the technique effect at the sectoral level, we investigate the correlation between the technique effect and the market concentration (Fig. 3). It is well known that the market concentration[6] of a given sector is one of the most important characteristics that affects firm behavior.

We find that sectors with markets that are more concentrated tend to have larger technique effects. This trend can be observed for the following reasons. First, social pressure from investors and consumers has caused firms to become more socially responsible for their production and management, which leads to larger firms reducing CO_2 emissions. In addition, stakeholders have increasingly demanded that firms disclose information about their energy consumption and GHG emissions (Melville and Whisnant, 2014). Second, the Japanese government conducts an annual evaluation and verification of the progress in terms of how much each sector has fulfilled its VAP target. These evaluation and verification reports are publicly available through the internet. Third, the smaller the number of firms in a given sector, it is more likely that the social and association pressure placed on each firm is to increase (Azar et al., 2020). Hence, firms in a sector with higher market concentration are highly motivated to achieve the sectoral VAP target through the adoption of green production technologies, which is reflected in the technique effect. In other words, the impact of the VAP is smaller for sectors with lower market concentration. Fourth, despite the non-penalty nature, the VAP successfully reduced emission to a certain degree. This may be related to strong social norms within the Japanese culture. Thus, firms continue to make efforts towards reducing emissions because of peer pressure. COVID-19 is interesting evidence of this cultural tendency: Although there are no penalties, most Japanese people still wear masks and have been vaccinated.

We can consider another reason for this observation. In addition to large firms, SMEs that joined the JFB are also restricted under the VAP. However, the total R&D expenditure of large firms is 15 times higher than that of SMEs, based on a whitepaper on SMEs in Japan. This indicates that large firms have more financial resources to carry out technological innovation than SMEs to meet the VAP target. Moreover, the sector with high market concentration is dominated by large firms. Thus, individual outcomes of efforts to reduce CO_2 emissions by large firms in a sector with high market concentration can appear more directly. In contrast, if a sector is constituted by many SMEs (a lower level of market concentration), the emission reduction effect from the VAP may be difficult to observe, since actions taken by small firms are not apparent compared to those of large firms. Thus, a positive sign of the technique effect is observed in Fig. 3 for sectors with low market concentration.

4. Conclusions and policy implications

This study evaluated the effect of the VAP by adopting the additive LMDI method from 1980 to 2015 in Japan. Concurrently, this study explored the driving forces behind CO_2 emissions at the disaggregated level in Japan and investigated the trends of direct and indirect CO_2 emissions. Our analysis revealed that the VAP might contribute to emission reductions among sectors with higher market concentration. In other words, the VAP failed to reduce CO_2 emissions in sectors with lower market concentration. Moreover, the results also indicated that the energy intensity target of the VAP failed to reduce CO_2 emissions.

[6] The market concentration becomes higher as the number of firms in the sector decreases, and vice versa.

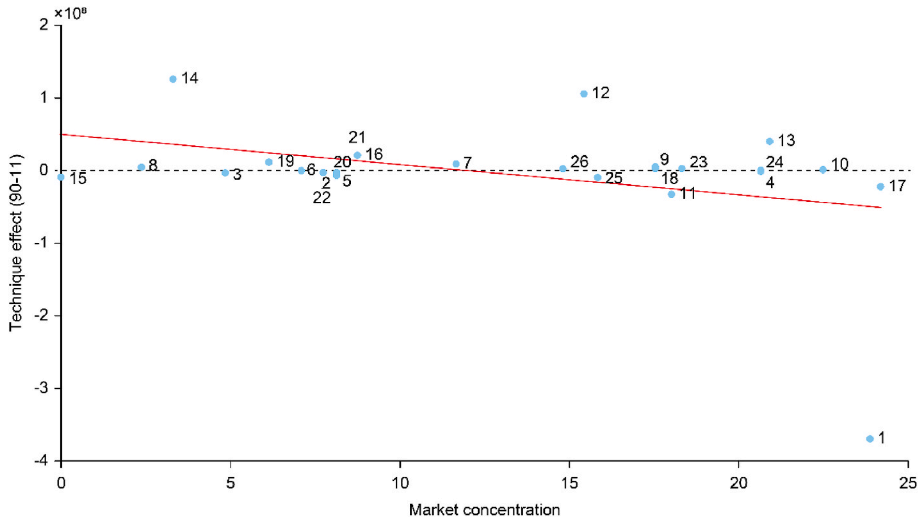

Fig. 3. Relationship between the technique effect and market concentration.
Note: The numbers in this figure correspond to the numbers in Table 2. The R-square value and t statistic are 0.12 and 1.84, respectively.

The major findings of our analysis can be summarized as follows. (1) National CO_2 emissions,[7] excluding households, increased by 26% from 1980 to 2015. However, indirect CO_2 emissions increased by 62% in the same period. This increase in indirect emissions contributed to the increase in emissions from Japanese industries. (2) The energy consumption structure, which has progressively shifted from fossil fuel to electricity in Japan, was explored in this study. (3) The decomposition result indicates that the emission reduction should be attributed to the composition effect, not the technique effect. (4) The VAP was ineffective in reducing emissions in sectors with low market concentration. This can be considered the consequence of the exclusion of SMEs from the VAP. Thus, the VAP failed to directly affect SMEs' emission reduction decisions. This suggests that the VAP lacks Procedural Justice and it caused energy policy failure (Sokołowski and Heffron, 2022). (5) The decomposition results also hint that the composition effect of the service industry led to an increase in CO_2 emissions. This result is due to the increase in the share of the service industry in the Japanese economy. Based on the above findings, we provide the following four policy recommendations aimed at the manufacturing, service, and power sector.

(1) Our analysis suggests that the VAP failed to provide incentives to sectors with low market concentration to reduce CO_2 emissions. Additionally, we showed that the VAP failed to reduce CO_2 emissions for sectors in the manufacturing industry with energy-intensive targets. The contribution of the VAP to CO_2 emissions reduction was limited. The energy efficiency was not improved through the VAP. It can be concluded that relying on the VAP is insufficient to achieve the goal of the Kyoto Protocol. An example to prove this conclusion is that, in meeting the Kyoto Protocol targets, the purchase of Clean Development Mechanism (CDM) credits was necessary to achieve the targets for the Japanese economy. Even though the VAP failure was shown in this paper, our findings can still provide implications for the current and future climate policy discussion. As Sokołowski and Heffron (2022) mentioned, energy policy failures need to pay attention to the support of meeting the objectives of the Paris Agreement, SDGs and other climate policies. Our results also suggest that mandatory policies, such as a carbon tax and national ETS, may be more appropriate to achieve the target under the 2016 Paris Agreement and carbon neutrality.

(2) We observed that the technique effect has reduced CO_2 emissions in the manufacturing industry since 2000. However, in recent years, the reduction from the technique effect has become smaller. Therefore, we propose the following policy recommendations. First, policies to promote technological innovations are necessary. The government should implement policies that focus on providing incentives to invest in low-carbon technologies. They can do so by adopting instruments such as carbon pricing. Second, the combustion efficiency of fossil fuels has limited future improvement potential; thus, it is necessary to promote electrification or expansion of renewable energy.

(3) The results show an increase in indirect CO_2 emissions in Japan. In particular, the service sector suffers from an increase in indirect emissions. Therefore, it is crucial to implement low carbonization and decarbonization regulations targeting the service industry. However, Japan's service industry is not fully covered by the VAP. In the service industry, unlike in the manufacturing industry, it is probable that the power of industrial associations is weaker and thus, the VAP cannot be successfully implemented. One successful policy toward the service sector in Japan is ETS. The Tokyo ETS has succeeded in reducing emissions from the service sectors (Arimura and Abe, 2021). Therefore, ETS will be effective in reducing emissions from non-manufacturing industries.

(4) The current Japanese regulation only focuses on energy efficiency and fails to provide incentives for decarbonization toward the power sector. The power sector was also under the VAP. The power sector achieved the emission reduction target under the VAP by purchasing credits through the CDM. This allows the emissions from the power sector to increase. It leads to an increase in the total CO_2 emissions from all sectors through indirect emissions. Thus, regulation supporting the reduction of carbon content and decarbonization from electricity is required. For instance, the expansion of renewable energy or a set of limits or standards for CO_2 emissions from electricity generating units in Japan's power sector would be effective. If the Japanese government legally sets a threshold for the ratio of minimum power generation by renewable energy in the energy sector, the emission reduction from the energy sector can be directly expected. Japan has already adopted feed-in tariffs and is now moving to feed-in premiums. The Japanese government has also

[7] In this study, we calculated the sectoral CO_2 emission in 1980 and 1985 using the CO_2 intensity of 1990.

implemented a requirement for non-fossil fuel power generation through the non-fossil fuel credit market. These policies must be continued and expanded to offer an incentive for reducing emissions from the electric power industry. Moreover, to promote the procurement of renewable energy by private firms, the Ministry of the Environment of Japan encourages participation in RE100, which is a global initiative for enterprises committing to using 100% renewable electricity. This trend towards RE100 will be useful in improving the CO_2 intensity of the power sector.

Data availability

The data set used in the analysis is available upon request.

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CRediT authorship contribution statement

Guanyu Lu: Conceptualization, Formal analysis, Software, Data curation, Writing – original draft, Writing – review & editing, Visualization, Funding acquisition, Methodology, Validation. **Makoto Sugino:** Conceptualization, Supervision, Project administration, Writing – review & editing, Funding acquisition, Validation. **Toshi H. Arimura:** Conceptualization, Supervision, Project administration, Writing – review & editing, Funding acquisition. **Tetsuya Horie:** Conceptualization, Supervision, Writing – review & editing, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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A. Appendix

A.1 Calculation of indirect CO_2 emissions

Indirect CO_2 emissions are defined as CO_2 emissions emitted from power generation and heat. First, we calculate the emission intensity for electricity, private power generation and steam and hot water supply for all periods t using the following equation:

$$Emissionintensity_j^t = \frac{CO_2emissions_j^t}{TC_j^t} \tag{A.1}$$

where j represents electricity, private power generation, and steam and hot water supply; t represents 1980, 1985, 1990, 1995, 2000, 2005, 2011, and 2015; and TC_j^t represents the total consumption of energy j at time t. Next, using the emission intensity calculated above, we can calculate the indirect CO_2 emissions for sector i at time t as follows:

$$IndirectCO_2emissions_{ij}^t = Emissionintensity_j^t \times EC_{ij}^t \tag{A.2}$$

where EC_{ij}^t is the consumption of electricity, private power generation, or steam and hot water supply for each sector i at time t.

In theory, we can calculate indirect emissions for each industry using equation (A.2). However, there is a critical issue that needs to be addressed concerning the VQT. The volume of energy consumption for a few sectors fluctuates from the previous year, which leads to drastic increases and decreases in the value of indirect CO_2 emissions.[8] Therefore, we apply the share of consumption reported in the VQT for 1995 to estimate the amount of energy used for 1990, 2000, 2005, 2011 and 2015. This means that we ignore the energy consumption improvements achieved by each sector i.

We estimate the amount of energy used for 1990, 2000, 2005, 2011 and 2015 using the following equations for electricity, private power generation, and steam and hot water supply:

$$Inputratio_{ij}^{1995} = \frac{EnergyConsumption_{ij}^{1995}}{\sum_i^{197} EnergyConsumption_{ij}^{1995}} \tag{A.3}$$

$$\widehat{EC_{ij}^t} = Inputratio_{ij}^{1995} \times \sum_i^{197} EnergyConsumption_{ij}^t \tag{A.4}$$

[8] The indirect emissions calculated from the data reported in the VQT differs from the national inventory data provided by the National Institute for Environmental Studies of Japan, https://www.nies.go.jp/gio/aboutghg/index.html.

where the total consumption of energy j is the sum of the consumption of energy j in all sectors. Finally, we calculate indirect emissions for each sector by replacing EC_{ij}^{t} with $\widehat{EC_{ij}^{t}}$ in equation (A.2).

A.2 Limitations

The VAP is a sectoral-level effort by industry associations. Therefore, to investigate the impact of the VAP at the detailed sectoral level, researchers can use input–output tables as an analytic tool. In this sense, we provide reasonable results in the sectoral-level analysis of the VAP. However, our results should be interpreted with caution for several reasons. First, we adopt a factor based on the VQT, which is supplementary information provided along with the domestic input–output table, of 1995 to recount the tables in the other years because the quantity of the business power and heat supply sector in the VQT suddenly decreased in 2000 and 2005, leading to the calculation of the outlier of indirect CO_2 emissions compared with the data from the Greenhouse Gas Inventory Office of Japan.

Second, this study did not analyze the impact of energy prices and innovation from other factors within the technique effect, as we focused on the effect of the VAP. Although the impact of energy prices is not considered, the Japanese economy relies on fossil fuel imports from other countries; thus, the fossil fuel impacts on each sector will be similar. Therefore, the missing fossil fuel price influences the results of every sector uniformly, and hence, bias may be limited. The innovations resulting from factors other than the VAP or energy prices cannot be observed through the input–output table, which is also a limitation in our analysis.

Finally, although we confirmed the drivers behind the changes in CO_2 emissions and proposed policy recommendations at the sectoral level, we may have oversimplified the results. For countries with decentralized systems, it might be challenging to introduce new regulations at the national level. In this case, regulations at the regional level may be more appropriate. If so, a regional analysis will be useful in designing regulations at the regional level. However, the limitations of the data restrict us from performing sectoral analysis at the regional level.

Furthermore, this study does not consider the technical changes in the energy sector, which may lead to an overestimation of CO_2 emissions in recent years. How much did the technical innovation of the power and heat supply sector contribute to reducing indirect emissions? Are there cobenefits, such as SO_2, SPM, and NO_x reduction, by reducing CO_2 emissions? We leave these questions for the future.

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