Dynamics of Japan's Industrial Production and Carbon Emissions: Causality, Long-Term Trend and Implications

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Abstract

While CO₂ emissions from the residential and commercial sectors of Japan have increased significantly since 1990 the country's industrial emissions make up the largest share of those emissions. The historical CO₂ emission performance data also indicate that the iron and steel, chemical, paper and pulp and cement were the top four largest industrial emitters, and these top four emitting industries contributed nearly two-third of the industrial sector's total CO₂ emission amount during 1990-2015. Evidently, any appropriate efforts or strategies guided by an empirical investigation like this are expected to help Japan's industrial emitters move toward a more tolerable and less polluted carbon footprint, which is well-matched with the country's commitment to Kyoto Protocol. This study is thus an effort to empirically investigate the causality and long-run trend/relationship between Japan's industrial production and CO₂ emissions and to propose some corporate environmental strategies using the econometric techniques of Vector Error Correction (VEC) and Granger causality. It found that there exists no Granger causality between Japan's industrial production and CO₂ emissions in any direction. But the VEC estimation reveals that an increase in Japan's industrial production by 1% is associated with a 0.08% increase in the country's CO₂ emissions. It also reveals that any disequilibrium between Japan's industrial production and CO₂ emissions could take about 0.7 quarters for half of the error to be corrected for. The adjustment rate for Japan's industrial production is found to be positive but quite slow at the rate of 0.08% per year. Since Japan's CO₂ emissions vis-à-vis its industrial production is found to have reached above the long-run equilibrium level, its industrial sector is expected to encounter with stricter government regulations requiring reduction of CO₂ emissions to the targeted/equilibrium level in the future.

Key words: CO₂ emissions, industrial production, causality, long-run trend, corporate carbon strategy, corporate environmental strategy, Japan

JEL classifications: Q510, Q530, Q560

INTRODUCTION

It is apparent that carbon dioxide (CO₂) emissions arising from industrialised and industrialising countries' industrial processes are substantial. The industrial processes combine input and raw materials to produce goods and services, which result in large amounts of CO₂ emissions. Evidence suggests that nearly a third of the world's energy consumption and 36% CO₂ emissions are attributable to manufacturing industries (International Energy Agency, 2007). The bulk of these CO₂ emissions are related to the large primary materials industries, such as chemicals and petrochemicals, iron and steel, cement, pulp and paper, and aluminium. Even though over the last decade global industrial energy efficiency has improved and CO₂ emission has declined substantially in many sectors, this progress has been more than offset by growing industrial production worldwide. Consequently, total industrial energy consumption and CO₂ emissions have continued to rise. Scientists predict that over the next 40 years, demand for industrial materials in most sectors is expected to double or triple. Therefore, CO₂ emission reductions are vital across the whole of industry, but action is particularly crucial in the five most energy-intensive sectors, namely iron and steel, cement, chemicals and petrochemicals, pulp and paper, and aluminium.

Therefore, these industrial sectors in any country need to play a greater role to reduce CO₂ emissions in the country.

Some studies have analysed the relationship between industrial/manufacturing production and CO₂ emissions for various countries/regions including the United States, European Union, Great Britain, Korea, and Taiwan. All these studies have revealed the fact, among others, that industrial/manufacturing activities result in significant volumes of CO₂ emissions. In fact, manufacturing and industrial processes all combine to produce large amounts of each type of greenhouse gas but specifically large amounts of CO₂ because of the following two reasons: first, many manufacturing facilities directly use fossil fuels to create heat and steam needed at various stages of production and second, their energy intensive activities use more electricity than any other sector so unless they are using renewable sources the energy that they use is responsible for vast amounts of emissions (United States Department of Energy 2005, 2002). Since the industrial/manufacturing sectors have apparently been proven as the significant contributors to the CO₂ emissions, they reasonably have substantial potential in reducing the same. A study by International Energy Agency reveals that the industrial CO₂ emissions reduction potential amounts to 1.9 to 3.2 gigatonnes per year, about seven to 12% of today's global CO₂ emissions (International Energy Agency, 2007).

Also a very recent study by the United States Environmental Protection Agency reveals that the largest source of CO₂ emissions globally is the combustion of fossil fuels such as coal, oil and gas in power plants, automobiles, industrial facilities and other sources (United States Environmental Protection Agency, 2011). This study further reveals that a number of specialised industrial production processes and product uses such as mineral production, metal production and the use of petroleum-based products can also lead to CO₂ emissions. Studies on the European Union and the Great Britain also reveal similar findings. Referring to Britain, a study by the Committee on Climate Change stated that as the economy and industrial production return from recession to growth, CO₂ emissions will rise again (Committee on Climate Change, 2010). The study on European Union reveals that global downturn is forcing industrial installations to cut back on production and therefore on their CO₂ emissions (Singh, 2007).

The empirical findings from some studies on Asian countries are also found to have matched with those obtained on the United States, European Union, and Great Britain. For example, the rate of growth of industrial CO₂ emissions has drastically decreased since the 1998 financial crisis in Korea (Lim *et al.*, 2009). This study further reveals that of all the individual factors, economic growth accounted for the largest increase in CO₂ emissions in Korea. The empirical results of a similar study conducted on Taiwan indicate that industrial production has the closest relationship with aggregate CO₂ emission changes (Chang & Lin, 1999). Also the empirical results obtained by another study on Taiwan indicate that the primary factor for the increase of CO₂ emission is the level of domestic final demand and exports (Chang & Lin, 1998). Moreover, some recent studies have studied the link between firms' CO₂ emission strategy and their performance in a comprehensive way. The results of one of those studies conducted by Lee (2012) indicated a significant relationship between a firms' carbon strategy and its sector and size. But a significant relationship between the carbon strategy and firm performance was not confirmed by that study. Another study by Sariannidis *et al.* (2013) revealed that a firm's financial performance is closely related to its environmental behaviour. The empirical findings of the study have also revealed that the

performance of socially responsible firms is negatively related to an increase of global CO₂ emissions. That means firms' commitment to do corporate social responsibility does help decrease global CO₂ emissions. In fact, many firms are facing increasing pressure by governments, shareholders and other stakeholders to reduce their CO₂ emissions in order to mitigate climate change. The importance of managing CO₂ emissions and crafting adequate CO₂ strategies has increased for those firms affected (Weinhofer & Hoffmann, 2010). This study found that firms with different CO₂ emissions reduction strategies significantly differ in terms of company size and absolute amount of CO₂ emissions they contribute.

Furthermore, the study by Alvarez (2012) found an interesting finding revealing that CO₂ emission variation is a significant but negative variable for firm's rate on asset (ROA). This study, on the other hand, also revealed that CO₂ emission variation is insignificant but positive variable for rate on equity (ROE). A similar but very recent study conducted by Fujii *et al.* (2013) at Japanese context added further to the literature. The study argued that environmental performance increases ROA through both returns on sales and improved capital turnover and that there exists a significant positive relationship between financial performance and environmental performance based on CO₂ emissions. The authors of the Japanese study also argued that these findings may provide evidence for the consequences of firms' environmental behaviour and sustainable development. Another study by Boiral *et al.* (2012) argued that there is win-win relationship between the commitment to reduce greenhouse gas emissions and financial performance. But an earlier study by Sprengel and Busch (2011) found that firms' response strategies do not actually relate to individual stakeholder groups, but rather the firms' level of pollution measured as its greenhouse gas intensity is identified to have an influence on the environmental strategy. Nevertheless, stakeholders' influences on and their close associations with firms are still important for firms to get motivation to undertake sound environmental strategies will help reduce CO₂ emissions from their productions and operations. In fact, the firms that are close-to-consumers are more likely to undertake environmental activities for which there was no explicit cost-reduction benefit, suggesting that reputation with consumers/society may be a particular business motivator for them (Haddock-Fraser & Tourelle, 2010).

As the world's third-largest national economy as well as the world's second-largest developed economy, Japan is the world's fourth-largest emitter of greenhouse gases, which comprise of about 95% CO₂ emissions in the country (Huang & Nagasaka, 2011). This is likely to continue to grow in the future (Ministry of the Environment, 2011; Ogawa, 2008). Since CO₂ gas was dominant, most of the reduction policy or activity was targeting on CO₂ emission reduction (Huang & Nagasaka, 2011). Japan's CO₂ emissions have increased by 11.3% since 1990 and there was a gap of 12.2% in 2006 compared to the country's emission reduction target under the Kyoto Protocol (Ministry of the Environment, 2008). It is worth noting to mention that under the Kyoto Protocol Japan has made a commitment for a 6% reduction in greenhouse gas emissions compared to the base year of 1990. This means that not enough efforts by the Japan's Ministry of Environment have been taken to meet its emission reduction target. While CO₂ emissions from the residential and commercial sectors have increased significantly since 1990 the country's industrial emissions account for the largest share, which is 36% of total emissions (Kiko Network, 2008). The historical CO₂ emission performance data also indicate that the Iron and Steel, Chemical, Paper and Pulp and Cement were the top four largest emitters in Japan's industrial sector, and these top four emitting industries contributed nearly 62% of the industrial sector's total CO₂ emission amount during 1990-2008 (Ministry of the Environment, 2011; Ogawa, 2008). Evidently, any

effort or policy guided by an empirical investigation like this will help Japan to move toward a more tolerable and less polluted carbon footprint, which is well-matched with the country's commitment to Kyoto Protocol.

This study is thus an effort to empirically investigate causality and long-run trend between Japan's industrial production and CO₂ emissions. It also discusses the implications of the empirical results for the country's industrial sector and suggests some appropriate corporate environmental strategies that are expected to help move the trend between CO₂ emissions and industrial production towards the long-run equilibrium.

DATA AND METHOD

Keeping the research objective in mind, this study has gathered relevant time series data and information from several secondary sources. The data for two time series variables covering the period 1990-2015 were collected from the United Nations online database (UNdata, 2016). The variable of Japan's CO₂ emissions (Thousands metric tonnes) was coded as *JPCO₂* while Japan's industrial production index was coded as *JPIP*. Both series of variables were tested for stationarity or non-stationarity using the widely used augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests for a unit root. The unit root tests on time series variables were conducted in order to determine whether data are suitable for advanced econometric analysis and to defend the econometric models against the characteristics of spurious time series regressions.

A Vector Error Correction (VEC) estimation of the paired time series was conducted in order to observe the long-run adjustment coefficients on cointegrated equation of the model. Since VEC model is a special type of restricted Vector Autoregression (VAR), which is an econometric model used to capture the evolution and the interdependencies between multiple time series, the unrestricted cointegration test and VEC Pairwise Granger Causality test were also reasonably conducted for the model. Other features of the combined model such as inverse roots of Autoregressive (AR) characteristics polynomial were checked and VEC lag exclusion Wald test, VEC residual serial correlation LM test, VEC residual normality test, VEC residual heteroskedasticity test, and impulse responses of the variables to Cholesky test were also conducted.

RESULTS AND DISCUSSION

Unit Root Test

In the ADF test an automatic lag length of 7 using a Schwarz Information Criterion (SIC) was used. The lag length criterion is used to ensure that there is no autocorrelation in the ADF regression residuals. Hence choosing the minimum lag length is necessary for the ADF regression to avoid an autocorrelation problem in residuals. For example, an ADF test result value of -4.50 and a lag length of 5 is not interpreted differently from an ADF test result of -3.50 and a lag length of 0. This is to say that lag length in the ADF test does not affect the ultimate result. So in this study, choosing an automatic lag length of 7 does actually not have an impact on the strength of the ADF model as well as the findings. Most importantly, 7 lag lengths were actually chosen automatically by the ADF test based on some criteria. The ADF test results have been summarized in Table 1.

Table 1. ADF test results for a Unit Root in two time series variables

Series	ADF Test Statistic	Test Critical Values (t-statistic)			Probability*	Unit Root Test Decision
		1% Level	5% Level	10% Level		
LJPCO ₂ <i>I</i> (0)	0.02	-4.30	-3.21	-2.75	0.94 ^{NS}	Nonstationary
LJPCO ₂ <i>I</i> (1)	-3.90	-3.92	-3.07	-2.67	0.01 ^{***}	Stationary
LJPIP <i>I</i> (0)	-1.13	-3.89	-3.05	-2.67	0.68 ^{NS}	Nonstationary
LJPIP <i>I</i> (1)	-3.60	-3.92	-3.07	-2.67	0.01 ^{***}	Stationary

*MacKinnon one sided p-values (MacKinnon 1996)

^{NS}Not significant at $P>0.1$, ^{***}Significant at $P\geq 0.01$

We have then conducted PP test on *LJPCO₂* and *LJPIP* at their first order [*I*(1)], but the result was supporting the trend of stationary in both series (Table 2). Having found both the series as statistically significant we can reject the null hypothesis, which confirms their stationary nature at *I*(1).

Table 2. PP test results for a Unit Root in two time series variables

Series	PP Test Statistic	Test Critical Values (t-statistic)			Probability*	Unit Root Test Decision
		1% Level	5% Level	10% Level		
LJPCO ₂ <i>I</i> (0)	-2.14	-3.89	-3.05	-2.67	0.23 ^{NS}	Nonstationary
LJPCO ₂ <i>I</i> (1)	-3.90	-3.92	-3.07	-2.67	0.10 [*]	Stationary
LJPIP <i>I</i> (0)	-1.32	-3.89	-3.05	-2.67	0.60 ^{NS}	Nonstationary
LJPIP <i>I</i> (1)	-3.59	-3.92	-3.07	-2.67	0.01 ^{***}	Stationary

*MacKinnon one sided p-values (MacKinnon 1996)

^{NS}Not significant at $P>0.1$, ^{***}Significant at $P\geq 0.01$, ^{*}Significant at $P\leq 0.1$

Since the above two prominent unit root tests clearly reveal that both time series variables are non-stationary at *I*(0) and stationary at *I*(1), our conclusion on the nature of data and their suitability to use to develop the appropriate time-series econometric models can be taken with confidence. The presence of a unit root in both the series at their *I*(0) and its absence at their *I*(1) suggest that we need to adopt a more sophisticated econometric model to analyse their long-run relationship. Since VECM is widely used for explaining the long-run relationships between or among time series variables we have developed the model to attain the objective of this study.

VECM Estimation

A vector error correction model (VECM) is a special type of restricted Vector Autoregression (VAR). For that reason, the general equation of a VECM with two dependent variables {hence, $(\log JPCO_2)$ and $(\log JPIP)$ } using the best ‘Lag Interval for Endogenous,’ option of ‘1 3’ can be presented in the following form:

$$D(Y_{g,t}) = A(g,1) * Coint + \sum_{k=1}^G C(g,3k-1) * D(Y_{g,t-1}) \\ + \sum_{k=1}^G C(g,3k-2) * D(Y_{g,t-2}) + \sum_{k=1}^G C(g,3k) D(Y_{g,t-3}) + C(g,3G+1) + \mu_{g,t}$$

In the above equation, $Y_{g,t}$ is the g^{th} endogenous variable at the time t , for $g = 1, 2, \dots, G$.

The estimated results based on the above VECM of $\log JPCO_2$ and $\log JPIP$ with lag specification ‘1 3’ reveal that the cointegrating equation has a significant effect on each of the endogenous variables. With a coefficient value of 0.08 for $\log JPIP_{(t-1)}$ in the cointegrating vector the critical value for t with 12 degrees of freedom is -4.8 $\{(0.08-1.0)/0.19\}$, which is statistically significant ($P < 0.01$). Using the above VECM we have actually estimated the changes in Japan’s industrial production on Japan’s CO_2 emissions and the changes in Japan’s CO_2 emissions on Japan industrial production. The cointegrating system within the VECM includes the variables of Japan’s CO_2 emissions and Japan’s industrial production. Outside the cointegrating system, variables include differences in lags of all endogenous variables to the first, second and third orders. The cointegrating vectors represent the coefficients of the linear combination of nonstationary variables, which are now stationary in nature. The estimated cointegrating equation is presented below:

$$\log JPCO_{2(t-1)} = -14.40 + 0.08 \log JPIP_{(t-1)} \\ [0.42]$$

We begin with by examining the coefficient estimates within the cointegrating relationship. The above equation presents the estimated cointegrating vectors with normalisation on the variable of the $\log$ Japan’s CO_2 emissions. Since we intend to know the movements of Japan’s CO_2 emissions to Japan’s industrial production, normalising on the $\log$ Japan’s CO_2 emissions will serve this purpose. The only cointegrating coefficient estimate for $\log$ Japan’s industrial production suggests the degrees of influence that Japan’s industrial production can have on the country’s CO_2 emissions in the long-run. The estimated coefficient for Japan’s industrial production is 0.08, which is also considered as the elasticity of coefficient. Assuming all other factors remain constant, an increase in Japan’s industrial production by 1% is associated with a 0.08% increase in the country’s CO_2 emissions. This suggests that Japan’s industrial production and the related policy have considerable effects on the country’s CO_2 emissions. However, the estimation of VEC models with the two dependent variables can be presented as:

$$\begin{aligned}
D(\log JPCO_2) = & -0.99(\log JPCO_{2t-1} + 0.08\log JPIP_{t-1} - 14.40) \\
& \quad \quad \quad [-2.64] \quad \quad \quad [0.42] \\
& + 0.39D(\log JPCO_{2t-1}) + 0.37D(\log JPCO_{2t-2}) + 0.01D(\log JPCO_{2t-3}) \\
& \quad \quad \quad [1.20] \quad \quad \quad [1.88] \quad \quad \quad [0.04] \\
& + 0.24D(\log JPIP_{t-1}) - 0.06D(\log JPIP_{t-2}) + 0.20D(\log JPIP_{t-3}) + 0.01 \\
& \quad \quad \quad [1.43] \quad \quad \quad [-0.35] \quad \quad \quad [1.13] \quad \quad \quad [-0.10]
\end{aligned}$$

$R - squared = 0.82, F - statistic = 3.80$

$$\begin{aligned}
D(\log JPIP) = & 0.08(\log JPCO_{2t-1} + 0.08\log JPIP_{t-1} - 14.40) \\
& \quad \quad \quad [0.07] \quad \quad \quad [0.42] \\
& - 0.78D(\log JPCO_{2t-1}) + 0.13D(\log JPCO_{2t-2}) + 0.88D(\log JPCO_{2t-3}) \\
& \quad \quad \quad [-0.77] \quad \quad \quad [0.21] \quad \quad \quad [1.11] \\
& + 0.02D(\log JPIP_{t-1}) - 0.36D(\log JPIP_{t-2}) - 0.31D(\log JPIP_{t-3}) + 0.01 \\
& \quad \quad \quad [0.04] \quad \quad \quad [-0.65] \quad \quad \quad [-0.55] \quad \quad \quad [0.49]
\end{aligned}$$

$R - squared = 0.32, F - statistic = 0.41$

The adjustment coefficient on CointEq1 for Japan's CO₂ emissions is negative as it should be. The estimated speed of adjustment to disequilibrium is -0.99 and it indicates how fast the equilibrium is restored. A coefficient of -0.99 means that a change of 1% caused by lagged changes in the other variable rises to a change of 1.99% because of adjustment to equilibrium. Taking half-life formula of $Q = \ln 2 / \beta$, which was developed by Haeussler & Paul (1996), this in fact suggests fast adjustment as it would take only 0.7 quarters for half of the error to be corrected for. On the other hand, the adjustment coefficient in the same equation for Japan's industrial production is positive as it should be and is quite slow at the rate of 0.08% a year. Therefore, most of the adjustment is being done by Japan's CO₂ emissions. The results also reveal that two lagged variables of Japan's industrial production $D(\log JPIP_{(t-1)})$ and $D(\log JPIP_{(t-3)})$ are both statistically significant in the Japan's CO₂ emissions equation at the probability value of 0.025, but $D(\log JPIP_{(t-2)})$ was found to be statistically insignificant in the same equation. Furthermore, all three lagged variables of Japan CO₂ emissions are statistically insignificant in the Japan industrial production equation. The results also reveal that the regressions with the dependent variables of $D(\log JPCO_2)$ and $D(\log JPIP)$ have positive R -squared values (0.82 and 0.32 respectively), which indicate that 82% of the variation in $D(\log JPCO_2)$ and 32% of the variation in $D(\log JPIP)$ could be explained by the above VEC models. F-statistic supports the models are well specified.

The cointegration tests for the above VEC models were also conducted in order to justify the applicability of the model in the real world situation. In fact, there are two tests, the Trace statistic, which is more reliable and the Max-Eigenvalue statistic. The results show that there is one cointegrating equation at the 0.05 level based on the Trace test and that the Max-Eigenvalue test indicates one cointegrating equation at both 0.01 and 0.05 levels. So based on these findings, the VECM of $(\log JPCO_2)$ and $(\log JPIP)$ should be considered as a highly acceptable model.

The above VEC models also reveals that when Japan's CO₂ emission levels deviate from the long-run equilibrium, the error correction will be triggered automatically. As a result the speed of adjustment is expected to have a negative sign. For example, whenever Japan's CO₂ emissions move higher than the equilibrium level the CO₂ emissions will soon start correcting itself by lowering the emission levels.

Causality test

In our effort to check other characteristics of the above models, the VEC Pairwise Granger Causality test was also conducted. The results reveal that there is no bidirectional causal relationship between Japan industrial production and the country's CO₂ emissions. Since the null hypothesis is that the coefficients are zero, there is clearly no Granger causality between the variables. The inverse roots graph of the lag polynomial was also generated in order to check the model stability. Figure 1 below shows that one of the eight roots lies on the unit circle corresponding to the stochastic trend while the all other roots lie inside. Since no root lies outside the unit circle the model appears to be stable.

Figure 1. The inverse roots graph of the lag polynomial for Japan's CO₂ emissions and industrial production

Model Diagnostic Test

The VEC Lag Exclusion Wald Tests were also conducted and the results reveal that the joint effects of the first, second, and third differentiated lags of Japan's CO₂ emissions and the country's industrial production are statistically significant ($P < 0.05$). The VEC Residual Serial Correlation LM Tests were also conducted to check the serial correlation problem in the model. With the null hypothesis that there is no serial correlation at lag order $h (= 12)$, however the probability values from Chi-square at all 12 lags are not statistically significant ($P > 0.05$). This is clearly an evidence of no serial correlation problem in the model. Then VEC Residual Normality Tests were also conducted to check the multivariate normality of the residuals. With the null hypothesis that residuals are multivariate normal, Jarque-Bera statistic of 7.79 for the joint component is found to have been statistically insignificant ($P > 0.05$). That means the model residuals are clearly multivariate normal. Finally, the impulse response combined graphs with Cholesky – degrees of freedom adjusted were generated in order to check the effect on the system of shocks to each variable. Figure 2 provides a graphical view of the Cholesky (One S.D. Innovations) impulse response function using the estimated VEC models. It actually provides the dynamic responses of the Japan's CO₂ emissions and the country's industrial production to a shock in the equilibrium.

Figure 2. Impulse response graphs showing the system of shocks to Japan's CO₂ emissions and industrial production

CONCLUSIONS AND IMPLICATIONS

This study is an attempt to investigate the causality and long run trend between Japan's industrial production and CO₂ emissions and to discuss their implications for the country's industrial sector, using time series data over the period 1990 to 2015. The results obtained from the cointegration equation reveal that when Japan's industrial production increases by 1%, the CO₂ emissions in the country increases by 0.08%. We understand that an increase in Japan's industrial production by 1% per se does not contribute to the increase by 0.08% in the country's CO₂ emissions, but there are more business and economic activities that also contribute to this increase in the emissions. Since both variables are proven to have been positively co-integrated in the long-run we can just confirm their important relationship. Also the results obtained from the VEC models reveal that any disequilibrium between Japan's CO₂ emissions and industrial production could take only 0.7 quarters for half of the error to be corrected for. We also understand that any equilibrium or disequilibrium between the variables must be explained with caution as mentioned earlier that not only the industrial production activities cause CO₂ emissions in the country. That being the case, any convergence to the long-run equilibrium will be shorter due to CO₂ emissions reduction

responses from other economic sectors. Hence the government's carbon tax policies or emissions trading schemes and other regulations could also make the convergence time considerably shorter.

Also, the VEC models reveal that the adjustment rate for the Japan industrial production is positive as it should be, but it is quite slow at the rate of 0.08% a year. So in the long-run, any disequilibrium will be corrected mostly by Japan's CO₂ emissions. This implies huge potential for Japan's CO₂ emissions reduction strategies and policies to the country's competitive industrial sector. The long-run disequilibrium between Japan's industrial production and CO₂ emissions implies that there must be taken some appropriate carbon strategies by the government and actions by the industrial sectors to implement those carbon strategies in order to achieve any targeted level of CO₂ emissions. These carbon reduction strategies may consider promoting alternative energy technologies and introducing fiscal incentives to the actors in various industrial sectors. In particular, government may promote alternative energy technologies that enable use of less carbon such as energy efficiency improvements and energy conservation. Government's fiscal incentive strategies may consider providing incentives to the industrial actors for fuel switching, CO₂ re-using, carbon capturing and storage, as all of these strategies could result in less CO₂ emissions caused by the country's industrial activities. While these strategies are already in implementation, for instance, some flexible approaches by the government to motivate the industrial actors in order to generate less CO₂ emissions should also be in place. Depending on the type of industrial sector, however, market-based incentives or permits; governmental loan guarantees; investment tax credits; performance standards; tax reform; incentives for technology; research, development and deployment; and other appropriate policy tools are also proven to be the highly effective tools to reduce CO₂ emissions, especially in the industrialised countries. Since implementation of any sorts of corporate CO₂ reduction strategies pose significant challenges to firms that produce large volumes of CO₂ emissions, adaptable business strategies offer a potential solution to these perceived concerns and problems (Martin and Rice, 2010). But in reality, if reduction of CO₂ emissions to a targeted level is the goal, a mix of regulatory and market-based government strategies is necessary for any industrialised countries including Japan.

Finally, as confirmed by the VEC estimations, with regards to Japan's industrial production the present CO₂ emissions in the country are above the equilibrium level. This is considered as an alarming situation for the country as its industrial sector, which is the most emitter of carbon, will be embracing stricter regulations requiring considerable amount of reduction in CO₂ emissions in the future. Consequently, at the first case in point, it can be concluded that Japan's industrial production could have significant effects on the country's level of CO₂ emissions. But contrary to this finding is the Granger causality test result, which reveals the fact that neither Japan's industrial production is a Granger causal for its CO₂ emissions nor its CO₂ emissions are a Granger causal for its industrial production. It is thus worth mentioning that having observed a cointegrating relation between two variables does not necessarily mean they are causal one to other. This is because two or more time series variables could be found as cointegrated if they share a common stochastic drift, which can be described as the change of the average value of a stochastic (random) process. That being the case, the crucial conclusion of this study should actually be based on the findings obtained from the VEC estimations. While the nexus between CO₂ emissions and industrial production is being debated widely, a solid and universal conclusion on whether they are actually causal and if yes, what actually causes what and why and how they are mutually

causal require a more in-depth investigation using a multidisciplinary approach at the levels where the relevant stakeholders practically encounter with both the phenomena.

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