The Relationship of Macroeconomic Factors with Carbon Dioxide Emissions in Japan

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In this empirical research, we examine the relation of economic growth, foreign trade, energy consumption and industrial growth with carbon dioxide emissions in Japan during the period 1970-2010. We have capitalized on the bounds test within Autoregressive Distributed Lag (Pesaran, Shin, & Smith, 2001). Interestingly, our findings clearly demonstrate the existence of a long-term relation of carbon dioxide emissions with the macroeconomic factors. In addition, the estimated long-term model reveals that foreign trade, energy consumption and industrial growth positively effects carbon dioxide emissions. We also observe that the economic growth has statistically no significant relation with carbon dioxide emissions. Finally, the paper finds no evidence to support the Environmental Kuznets Curve hypothesis.

***Keywords*:** foreign trade, industrial growth, carbon dioxide emissions, Japan.

These days, global warming is posing a substantial risk to widespread global environmental health, especially the worrisome climatic changes, which are seeking considerable attention in contemporary global issues. Alarmingly, the global temperatures have risen by 1.1 to 6.4°C and the water level has raised (IPCC, 2007). As a result, people residing in coastal areas would be adversely affected (Lau, Tan, Lee & Mohamed, 2009). Among the global pollutants, carbon dioxide emissions, being a main greenhouse gas, is causing 58.5% of global warming, as well as, serious climatic changes.

After the introduction of The Limits to Growth, the literature on economic development and environmental deterioration has become important to identify the drivers of pollution and measures required to curtail it (see for example, Meadows, Meadows, Randers & Behrens, 1972). This paper examines the relation of macroeconomic variables, i.e., economic growth, foreign trade, energy consumption and indusrtial growth with carbon dioxide emissions (COE) in Japan. Due to a tremendous growth in its overall economy, Japan is subjected to the threat of environmental issues. The reason for selecting Japan as a sample country is that Japan is a part of G-8 economies and arugubily a major contributor to the emission of the world's total carbon dioxide in 2009 (WDI, 2013). The remarkable economic growth of G-8 countries including Japan, is associated with its tremendous

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Contribution of Authors:
1. Dr. Wisal initiated the research idea and as the main author was responsible for the overall development, write-up and completion of the paper.
2. Dr. Shahwali's contribution lies in theoretical framing, development of methodology and data analysis of the paper.
3. Dr. Sohail collected data, assisted in data analysis and overall proofreading, citation and references.

industrial growth. Such an empirical study may be helpful to devise policy recommendations from the perspective of reducing environmental degradation, energy conservation with respect to economic performance in Japan.

Prior research documents the relation of COE with economic growth (Grossman & Kruger, 1991; Selden & Song 1995), real income (Halicioglu, 2009), foreign trade (Chebbi, Olarreaga, & Zitouna, 2010; Khalil & Inam, 2006) and energy consumption (Alam, Begum, Buysse, Rahman & Huylenbroeck, 2009; Ang, 2008; Soytas, Sari & Ewing, 2007). However, literature about COE and industrial growth seems to lack empirical evidence. Acar and Tekce (2014) merely examine the relation of economic growth with industrial emissions. Therefore, further evidence is warranted. No research has been conducted (not at least in authors knowledge) that takes into account all the four macroeconic factors, i.e., economic growth, foreign trade, energy consumption and indusrial growth and observe their relation with COE. In this paper, the dependent variable is COE and economic growth, foreign trade, energy consumption and industrial growth are its regressors.

The bonuds tests show existance of long-term equilibrium relation of COE with the independent variables. The foreign trade, energy consumption and industrial growth have a significant positive effect on COE in both short and long-term. Furthermore, the granger causality test reveals foreign trade and energy consumption are granger cause to the COE, but not vice versa.

Literature and Construction of Hypotheses

Economic Growth

The seminal work by Grossman and Kruger (1991) examine the relation of economic development with several determinants of pollution. Similarly, other researchers study the relation of economic growth with COE and confirm the Environmental Kuznets Curve (EKC) hypothesis, i.e., initially the economic growth leads to a continuous deterioration of the environment, but later on, after achieving a significant growth level, it drives to a reduction in environmental pollution (see e.g., Selden & Song, 1995; Grossman & Kruger, 1995). Similarly, EKC hypothesis is tested and verified by other studies as well (see e.g., Hettige, Lucas & Wheeler 1992; Panayotou, 1993; Cropper & Griffiths, 1994; Selden & Song, 1994; Martinez-Zarzoso & Bengochea-Morancho, 2004). Furthermore, Kraft and Kraft (1978) also investigate the growth-environmental degradation nexus for the United States and conclude that economic growth has a significant impact on the energy consumption from 1947-1974. Sardorsky (2009) also tests the relation of Renewable Energy Sources (RES) with economic growth, oil prices and COE for G-7 countries. He confirms the existence of long-run relation of economic growth with COE. Similar implications are expected for Japan and the following hypothesis is proposed:
H1: Economic growth has a positive long-run relation with COE

Foreign Trade

One of the factors in environmental deterioration is growth in economies, which is led by increase in foreign trade (Grossman & Kruger, 1991). The deterioration in environment is also affected by another imperative factor of openness of foreign trade. Research conducted in developing countries suggest that openness of foreign trade is positively affecting economic well-being of the masses, thereby, making them capable of urging for a pollution-free environment (Antweiler, Copeland & Taylor, 2001). Countries where production inputs are cheap as driven by weak environmental regulations, become attractive resorts for international investments and various production activities, leading to a deterioration of environment (Wheeler, 2000). However, multinational enterprises may develop a tendency to upgrade environmental standards in investment-targeted regions to meet the expectations of the entrepreneurs and consumers as well

(Dasgupta, Laplante, Wang & Wheeler, 2002). Similarly, in the long-run economic growth and energy consumption are associated with COE. On the other hand, foreign trade affects the environmental pollution positively but is statistically insignificant (Jalil & Mehmood, 2009; Halicioglu, 2009). Furthermore, in the context of developing countries, Baek, Cho and Koo (2009) examine the relation of foreign trade and economic growth with environmental pollution and conclude that unlike developed nations, the environmental pollution is induced by a rise in economic growth and openness of foreign trade. However, a positive association of foreign trade with environmental pollution is observed in Tunisia and Pakistan (Khalil & Inam, 2006; Chebbi et al., 2010). Therefore, in this paper, similar implications are expected for Japan and the below hypothesis is proposed:
H2: Foreign trade has a positive long-run relation with COE

Energy Consumption

According to Masuduzzaman (2012), the level of consumption of energy both for house-hold and industrial activities, is driven by varied factors like kind of living conditions, weather, income, age, technology, machinery etc. But on other hand, the use of latest technology for agro-based activities, rise in population, industrial growth, heavy urbanization etc, are the acute determinants of use of energy. Similarly, an increase in use of renewable energy sources causes an increase in economic growth (Sadorsky, 2009). Moreover, both developed and under-developed nations are found to be under serious threat of environmental deterioration due to a huge rise in the use of energy (Kim & Baek, 2011). Furthermore, the long-run relation of COE with energy consumption leading to environmental deterioration and energy usage is validated by many researchers (for example. Soytas et al., 2007; Ang, 2008; Alam et al., 2009). Therefore, the following hypothesis is proposed:
H3: Energy consumption has a positive long-run relation with COE

Industrial Growth

Among the most energy-intensive sectors, industry is ranked at the top, comprising one-third of global energy demand as industrial activities are causing 20 percent of global COE (IEA, 2012). Exxon Mobil (2013) suggests the main determinant of a rise in emissions is the increasing demand for energy by the industrial sector, as there is expected to be a 30 percent growth in electricity demand for industry by 2010-2040, while 90 percent of energy demand will be attributed to industrial production. Similarly, without the installation of filtration and capture equipment for carbon pollutants from the industries, the pollution is expected to grow by 91% by the end of 2050 (IEA, 2010). Furthermore, Acar and Tekce (2014) study the industrial emissions in connection with economic growth and their results validate the EKC hypothesis in selected Mediterranean countries. Therefore, a similar result is expected for Japan as well and the following hypothesis is proposed:
H4: Industrial growth has a positive long-run relation with COE

Variables' Definitions

Carbon dioxide emission has been used as a proxy for environmental pollution in the literature. This section focuses first on how economic growth might affect COE. Another imperative determinant is openness of foreign trade, as a rise in production activities leads to more consumption of energy, leading to environmental pollution (Wheeler, 2000). The literature also professes energy consumption to be a vital source of COE (Stern, 2004). Similarly, industrial growth leads to rise in energy consumption and economic growth that eventually pollutes the environment. Therefore, this research uses COE as the regressand, while regressors include the economic growth, the foreign trade, the energy consumption and the industrial growth. Table 1 shows the definitions of regressand and regressors used in this paper.

Table 1
Definition of Variable

No.	Name of variable	Main measure used
1	COE (Co2)	Emissions (kt)
2	Economic Growth (GDP)	Gross Domestic Product (constant 2005 US $)
3	Foreign Trade (FT)	Exports plus imports of goods/services (percentage of GD)
4	Energy Consumption (EC)	Energy usage in kg of oil equivalent per capita
5	Industrial Growth (IND)	Industry, value added (constant 2005 US$)

Method

The data for Japan have been extracted from the World Bank databank (2015). We have collected time series data and it spans over the period 1970-2010. E-VIEWS 9 econometric software is used to perform all the estimations.

The model used in the study is adopted in many studies (for instance, Jalil & Mahmud, 2009; Iwata, Okada & Samreth, 2010; Hossain, 2011; Saboori & Soleymani, 2011). Therefore, the model given below is an appropriate linear quadratic model to test the EKC hypothesis.

$$Co_{2t}= \beta_0+\beta_1 GDP_t+\beta_2 FT_t+\beta_3 EC_t+\beta_4 IND_t+\varepsilon_t \quad (1)$$

Where Co_2 represents COE, GDP represents economic growth, FT is the foreign trade, EC is the energy consumption, IND is the industrial growth and error term is given by ε at period t.

In equation (1), with a change in independent variables, the regressand will not adjust quickly to the long-run equilibrium level. Hence, the Error Correction Model, used in many studies (for instance, Jalil & Mahmud, 2009; Saboori & Soleymani, 2011; Saboori, Sulaiman & Mohd, 2012), is employed:

$$\Delta lnCo2_t=\beta_0+\sum\beta_1\Delta lnCo2_t+\sum\beta_2\Delta lnGDP_t+\sum\beta_3\Delta lnIND_t+\sum\beta_4\Delta lnF+\sum\beta_5\Delta lnEC_t+\beta_6\varepsilon_{t-1}+u_t \quad (2)$$

Where, Δ represents a first differences operator of Co_2, GDP, FT and IND. The ε_{t-1} is the one-period lagged error correction term, which removes the disequilibrium between short-run and long-run values of regressand in every period and u_t is the error term[1].

Unit Root Test

In this research paper, integration and co-integration levels for the variables are checked by using the unit root tests i.e., Augmented Dickey-Fuller (ADF); Phillips-Perron (PP); Kwiatkowski, Phillips, Schmidt and Shin (KPSS) and Zivot and Andrews (Z-A) (Dickey & Fuller, 1981; Phillips & Perron, 1988; Kwiatkowski, Phillips, Schmidt & Shin, 1992; Zivot & Andrews, 1992). The null hypothesis of ADF, PP, and Z-A tests is that a series is non-stationary (has a unit root); while the null hypothesis of KPSS is that a series is stationary.

[1] Natural log is taken to transform the data and retain the original equation, i.e., equation 1.

Bounds Test

The bounds test is used to investigate the long-run relation amongst variables regardless of their level of integration (Pesaran et al., 2001). Therefore, integration level for dependent variable in the ARDL model needs to be order one. The following error correction model is developed by using ARDL modeling technique:

$$\Delta lnCo_{2t}=\beta_0+\sum\beta_1\Delta lnCo_{2tj}+\sum\beta_2\Delta lnGDP_{tj}+\sum\beta_3\Delta lnFT_{tj}+\sum\beta_4\Delta lnEC_{tj}+\sum\beta_5\Delta lnIND_{tj}+\sigma_1 lnCO_2+$$

$$\sigma_2 lnGDP_{t-1}+\sigma_3 lnFT_{t-1}+\sigma_4 lnEC_{t-1}+\sigma_5 lnIND_{t-1+}\varepsilon_t \qquad (3)$$

Where ε_t is random error term. The null hypothesis of no level relation is $H_0:\sigma_1=\sigma_2=\sigma_3=\sigma_4=\sigma_5=\sigma_6=0$ and the alternative hypothesis of level relation is $H_1:\sigma_1\neq\sigma_2\neq\sigma_3\neq\sigma_4\neq\sigma_5\neq\sigma_6 \neq 0$.

Granger Causality Test

In order to make our analysis more comprehinsive, we employ Granger Causality test. The test investigate whether any of the regressors have granger cause to the regressand, or vice versa. Causality tests answer the following queries, whether change in a variable brings about a change in another? This argument follows that if one variable causes the other one, lags of the first variable should be significant for the other variable. According to brooks (2008), the relation of the present value of one variable with the previous values of some other variables is called Granger-causality.

Results

Unit Root Tests

This study takes into account ADF, PP, KPSS and ZA tests to know about the trending characteristics of the variables and integration levels of the data. Table 2 gives results for ADF, PP, KPSS and Z-A unit root tests. The ADF test results show that the Co2, FT, EC, and IND are not stationary at level form following all the three models, while the GDP series is also not stationary at the level form following both the general and restricted models. PP test demonstrates that our variables are not stationary at level form following all the three models, while the GDP is also not stationary at the level form following both the general and restricted models. KPSS test also showed that GDP is not stationary (model with drift and without trend). The structural breaks in the data cause the conventional unit root tests to exhibit low power (Perron, 1989). Therefore, a new (superior than ADF, PP and KPSS) test of unit root with structural break is employed (Zivot & Andrews 1992) which takes into account the highest break point (given in Figure 1) for the series during the study period. The results of Zivot-Andrews test shows that the variables are not stationary at level form following all the three models, except GDP, which is also not stationary at level form following the model with intercept only. As a conclusion, these test results come up with mixed outcomes and do not suggest that all series might be I(0) or I(1) but none of them is I(2). Therefore, the long-run level relationship is investigated using bounds test.

Figure 1: *Logarithmic Time Series Plot of Variables*

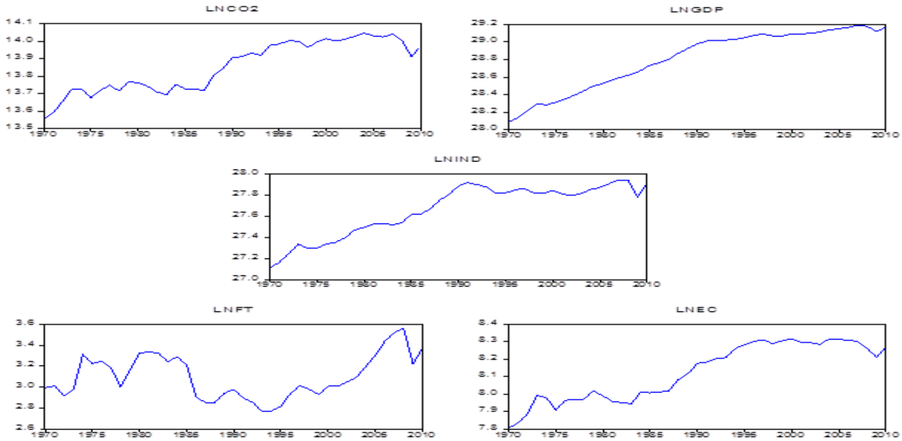

Table 2

ADF, PP, KPSS and Z-A Tests forUnit Root

Statistics (Levels)	lnCO2	Lag	lnGDP	Lag	LnFT	Lag	lnEC	Lag	LnIND	Lag
τ_T (ADF)	-1.97	0	-0.4	0	-1.72	0	-1.47	0	-1.47	0
τ_μ (ADF)	-2.02	0	-4.34***	0	-1.68	0	-1.89	0	-2.39	0
t (ADF)	1.7	0	2.66	1	0.38	0	2.03	0	2.51	0
τ_T (PP)	-2.03	1	-0.45	1	-1.8	0	-1.58	1	-1.8	0
τ_μ (PP)	-2.03	1	-4.08***	1	-1.77	1	-1.88	1	-2.48	2
t (PP)	1.77	2	4.22	4	0.50	5	1.95	1	2.51	0
τ_T (KPSS)	0.11*	4	0.21***	5	0.14**	5	0.13**	4	0.19**	5
τ_μ (KPSS)	0.73***	5	0.75	5	0.16*	4	0.73***	5	0.71***	5
Z-A Both	-3.94	1988(0)	-4.90*	1988(0)	-4.15	1986(0)	-3.41	1988(0)	-4.68	1988(0)
Z-A Trend	-2.91	2004(0)	-4.64**	1992(0)	-3.12	1995(0)	-2.58	2000(0)	-3.99	1991(0)
Z-A Intercept	-3.93	1988(0)	-1.75	1984(0)	-4.18	1986(0)	-3.46	1988(0)	-2.93	1985(0)
Statistics (First Differences)										
τ_T (ADF)	-6.25***	0	-5.16***	0	-5.72***	0	-5.66***	0	-5.80***	0
τ_μ (ADF)	-6.09***	0	-3.87***	0	-5.78***	0	-5.52***	0	-5.51***	0
t (ADF)	-5.79***	0	-2.11**	2	-5.83***	0	-5.13***	0	-4.86***	0
τ_T (PP)	-6.25***	3	-5.07***	3	-5.75***	6	-5.61***	3	-5.75***	2
τ_μ (PP)	-6.09***	3	-3.86***	1	-5.79***	5	-5.47***	3	-5.51***	0
t (PP)	-5.78***	1	-2.57**	0	-5.83***	5	-5.13***	0	-4.80***	2
τ_T (KPSS)	0.08*	4	0.07*	2	0.11*	6	0.09*	3	0.06*	3
τ_μ (KPSS)	0.22*	2	0.70***	4	0.14**	5	0.23*	1	0.35**	0
Z-A Both	-7.60***	1988(0)	-6.66***	1992(1)	-6.08***	1988(0)	-4.98*	1988(4)	-6.43*	1992(0)
Z-A Trend	-5.12***	1993(1)	-5.23***	1988(1)	-5.94***	1987(0).	-3.23	1991(4)	…….	…….
Z-A Intercept	-7.70***	1988(0)	-5.97***	1992(0)	-6.06***	1995(0)	-4.80*	1988(4)	-6.58*	1992(0)

Note: Co2 represents Carbon Emissions; GDP is Economic Growth; F T is Foreign Trade; EC is Energy Consumption and finally IND is Industrial Growth.τ_T represents the most general model with a drift and trend; τ_μ is the model with a drift and without trend; τ is the most restricted model without a drift and trend. Z-A Both represents the model with trend and intercept; Z-A Trend is the model with trend; Z-A Intercept is the model with intercept.

For ADF, PP and Z-A: ***, ** and * represent the rejection of the null hypothesis at the 1%, 5%, and 10% levels respectively.

For KPSS: ***, **, * denote non-rejection of the null hypothesis at just the 1%, 5% and 10%level respectively.

Bounds Test

The findings for bounds test are reported in Table 3, which suggests that using ARDL approach, the *F*-test confirms a level relationship (long-run relationhip) of COE with the determinants variables that are presented in equation (1). Since the null hypotheses of no level relationship among the variables is rejected as calculated *F*-statistics (3.803) is greater than upper bound critical value (3.380) at 5% significance level. Therefore, in case of Japan, COE are said to be in a level relationship with economic growth, foreign trade, energy consumption and industrial growth.

Table 3

Bounds Tests Result

Sample: 1970 2010		
Number of observations: 40		
Null Hypothesis: No long-run relationships exist		
Test Statistic	Value	K
F-statistic	3.803	5
Critical Value Bounds		
Significance	I (0) Bound	I (1) Bound
10%	2.080	3.000
5%	2.390	3.380
2.50%	2.700	3.730
1%	3.060	4.150

Note: k representes the total number of regressors.

The ARDL Long- and Short-Terms Models

Based on the results of bounds test, we proceed to estimate the equations (2 and 3) by employing the ARDL technique of Pesaran and Shin (1999). The results of error correction model of equation (3) are given in Table 4. The error correction term (ECT) value equals -0.697, which is negative and statistically significant, indicating that by using the channels of the economic growth, foreign trade, energy consumption and industrial growth, COE will reach to the long-term level by 69.7% speed of adjustment in Japan. In addition, the ARDL long-term levels equation as estimated shows that there are significant positive impacts of foreign trade, energy consumption and industrial growth on carbon dioxide emission. Moreover, economic growth negatively effects COE, but the effect is not statistically significant, which gives us no evidence for the validity of EKC hypothesis. Others, including intercept are insignificant as well. The following is the long-run equation with p-values in brackets:

$$lnCo2_t = 49.14 - 3.23 lnGDP_t + 0.066 lnFT_t + 0.885 lnEC_t + 0.172 lnIND_t + \varepsilon_t$$
$$(0.218) \quad (0.248) \quad (0.000) \quad (0.000) \quad (0.025) \qquad (4)$$

Table 4

The Short-Run Estimations

Dependent Variable: $LNCo_2$				
Model: ARDL(1, 0, 1, 1, 0, 0)				
Sample: 1970 2010				
Var	**Coef**	**Std. Error**	**t-Statistic**	**Prob**
D(LNGDP)	-4.524	5.097	-0.888	0.382
D(LNFT)	0.064	0.020	3.168	0.003

D(LNEC)	0.885	0.073	12.053	0.000
D(LNIND)	-0.172	0.095	-1.820	0.078
ECT	-0.697	0.142	-4.911	0.000

Granger Causality Test

The findings for granger causality test are presented in Table 5. The findings reveal foreign trade and energy consumption are granger cause to the COE at 1% and 5% levels respectively, but not vice versa. Furthermore, the findings show that COE is granger cause to economic growth at 1% level, but not vice versa.

Table 5

Granger Causality Test

Null Hypothesis:	Obs	F-Statistic	Prob
LNGDP does not Granger Cause $LNCo_2$	39	1.499	0.238
$LNCo_2$ does not Granger Cause LNGDP		5.791	0.007
LNIND does not Granger Cause $LNCo_2$	39	10.583	0.000
$LNCo_2$ does not Granger Cause LNFT		0.303	0.741
LNFT does not Granger Cause $LNCo_2$	39	4.751	0.015
$LNCo_2$ does not Granger Cause LNEC		2.201	0.126
LNEC does not Granger Cause $LNCo_2$	39	0.767	0.472
$LNCo_2$ does not Granger Cause LNIND		0.920	0.408

Conclusion

The study examines the relation of economic growth, foreign trade, energy consumption and industrial growth with COE in Japan for the period 1970-2010. The study proposes carbon dioxide emission as the dependent variable while economic growth, foreign trade, energy consumption and industrial growth are its regressors. Findings of bounds tests show that there is a long-term equilibrium relationship of regressand with regressors. In addition, foreign trade, energy consumption and industrial growth are significantly positively related with COE in the long and short-term. Moreover, the results shows no evidence to support the validity of EKC hypothesis. Furthermore, the error correction model shows that by using the channels of the regressors, carbon emissions will touch the long-term level (following a 69.7% speed of adjustment) in Japan. The Granger causality results show that foreign trade and energy consumption are granger cause to the COE, but not vice versa.

Our findings contribute to the literature of energy economics by confirming the long and short run association of foreign trade and energy consumption with COE in Japan. This study also incorporates a new determinant i.e., industrial growth and finds that COE increases as industrial growth rises in Japan. The policy makers in Japan must devise new policies to overcome the growing menace of environmental deterioration caused by increased economic growth, foreign trade and industrial growth. This study may be applied in an environmentally degraded country like Pakistan to seek interesting results. In Pakistan, the level of COE has reached to level of 189.19 metric tons in the year 2017, showing an increase of 7% as compared to the year 2016[2]. Moreover, apart from the economic and industrial growth rate, the content of economic and industrial growth too is an imperative factor affecting foreign trade and industrial activity. Therefore, two countries with similar overall growth rate may have different implications in terms of CO_2 emission. This has important message for developing countries in particular who often take for granted industrialization and foreign market penetration as features of economic progress.

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