

IMPACT OF KYOTO PROTOCOL IN CONJUNCTION WITH WORLD DEVELOPMENT INDICATORS ON CARBON EMISSIONS BY JAPAN

*Manvi Tiwari, Nandini Joshi, Poonam Dey
Miranda House, University of Delhi*

Abstract

Greenhouse gas (GHG) emissions have been on a continuous rise since the industrial revolution, increasing manifold over the past few decades. This has posed a severe threat to environmental balance and all forms of life on earth. With the subsequent rise in environmental concerns, a number of climate conservation treaties have been adopted and enforced to curb GHG emissions by different countries over time. One such attempt had been made through the Kyoto Protocol in 1997 to set up binding and non-binding targets on signatory countries to curb GHG emissions over its first commitment period (till 2012).

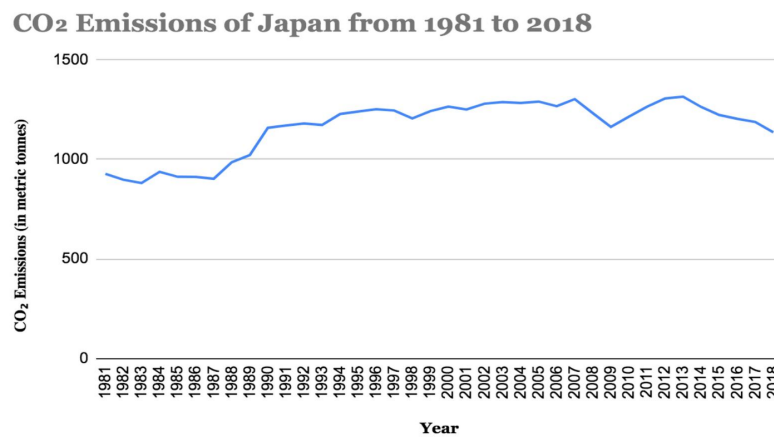
The effectiveness of the Kyoto Protocol, however, has been brought under scanner over time, with many countries not opting to sign up for the second commitment period of the treaty. Along this parallel, the objective of this paper is to determine, (a) the impact of the World Development Indicators on carbon emissions by Japan and, (b) the effectiveness of Kyoto Protocol (post-enforcement) in the country of interest. The paper is also aimed at checking if Japan exhibits the Environmental Kuznets Curve (EKC) in the time period 1981-2018.

For purposes of the same, time series regression analysis is employed through Ordinary Least Squares (OLS) estimation. The presence of pure autocorrelation found thereafter is corrected using the Prais-Winsten estimation (thereby rendering it as a case of feasible generalized least squares estimation). The results reveal that research and development expenditure exerts a significant influence on carbon emissions, while GDP does not exert any significant influence. Further analysis also reveals the statistical insignificance of the effectiveness of the Kyoto Protocol in Japan's context. The corollary analysis on EKC is followed up in the paper.

Introduction

Carbon Dioxide (CO₂) is a greenhouse gas (GHG) that plays an equally important role in maintaining a habitable temperature on Earth. While its atmospheric constitution is approximately 0.04%, the onset of the Industrial Revolution has led to a dramatic rise in energy-driven consumption, thereby resulting in increased emissions. The consequent disruption of the global carbon cycle has stirred up climate change and climate conservation concerns, beginning with the Rio Summit (1992), which aimed to reconcile world economic development with environmental conservation.

Along the parallels of the Rio Summit, the Kyoto Protocol was adopted in 1997 (and enforced in 2005) with the objective to reduce greenhouse gas emissions, while setting emission targets (binding and non-binding) based on the signatory party's assigned amount. In this context, the research paper seeks to quantitatively examine the impact of world development indicators and the enforcement of the Kyoto Protocol on the level of carbon emissions by Japan for the period 1981-2019.



Japan ratified the Kyoto Protocol in 2002, becoming the 74th country to ratify the treaty. However, Japan's stance on the effectiveness of the Kyoto Protocol has changed significantly over the years, wherein the country has expressed its intention to withdraw from the second commitment period of the treaty. On account of the same, this paper pursues to employ descriptive World Development Indicators (published by the World Bank) to quantify their influence (if any) on carbon emissions, while also checking for the effectiveness of policies like Kyoto Protocol in reducing the levels of carbon dioxide emitted by Japan.

The paper also proposes to check for the hypothesized relationship between per capita income and various indicators of environmental degradation (carbon emissions, in this paper), as depicted by the Environmental Kuznets Curve (EKC). The EKC hypothesis states that at the growing stage of economic growth (income) the environmental degradation increases, but after reaching the economic growth at certain levels the quality of the environment slowly starts to improve. Therefore, an attempt of this paper will be aimed at detecting whether income inequality first rises and then falls for Japan as economic development progresses.

Objective

This paper aims to examine the factors underlying trends in carbon emissions as exhibited by Japan, and the effect of the Kyoto Protocol on the same. The paper also intends to find out if the Environmental Kuznets Curve (EKC) is projected by the carbon emission trends in Japan during 1981-2018.

The choice of Japan for the study strongly relies on the objective to assess the extent to which the third-largest economy in the world (in terms of nominal GDP) realizes its liability in curbing

carbon emissions in view of common but differentiated responsibilities. The Kyoto Protocol has been widely adopted and ratified in many countries. Moreover, the effectiveness of a policy intervention of such a large measure has an important role in the reduction of carbon emissions. As such, an analysis of the role of the Kyoto Protocol is undertaken in the paper. World Development Indicators are included in the study to measure the simultaneous effect of development processes (as measured in terms of R&D expenditure and GDP per capita) on overall carbon emissions instead of other nationalized and localized units of measurement to maintain consistency of analysis across the body of literature available.

In support of the research objective, it was observed in the available literature that the simultaneous impact of development indicators and policies/ treaties on carbon emissions for individual countries are seldom looked into. As such, assessing the overall success of a policy measure/ treaty with regards to environmental conservation gets undermined for individual countries. The concurrent effects of other economic development measures have a potential to offset or positively impact the level of carbon emissions by any country. The Environmental Kuznets Curve depicts one such relationship between economic growth indicators and environmental degradation, the existence of which is tested in the context of Japan for the study.

Literature Review

The existing body of literature reveals that studies have analyzed the various parameters that affect carbon emissions across countries and time.

An empirical investigation of the impact of the Kyoto Protocol on CO₂ emissions using a sample of 170 countries was conducted over the period 1992-2009 in [3] using difference-in-difference estimators with matching to address the endogeneity of the policy variable. The main results of estimating a panel data model indicated that Kyoto Protocol commitments have a measurable reducing effect on CO₂ emissions, indicating that a treaty often deemed a 'failure' may in fact be producing some non-negligible effects for those who signed it.

Another study [1] examined the complex effect of research and development (R&D) intensity on carbon dioxide (CO₂) emissions in the G-7 countries between 1870-2014 using a non-parametric panel data model. The relationship between R&D and CO₂ emissions was shown to have largely been negative, with the main exception being the period between 1955 and 1990. The findings suggested that there is a role for investment in R&D in addressing climate change.

In [13], an attempt was made to statistically test the contrasting hypotheses on the emission of SO₂, O₂ and energy consumption in Japan and China for the last few decades. The basic model to estimate EKC used an indicator of emissions of environmental pollutants as the dependent variable, and per capita income and its squared term as the explanatory variables. The study revealed that the EKC has an inverted U-shape only in the case of SO₂ emissions in Japan, even though it is possible that China is on the flat turning portion of the EKC in the case of SO₂. Both Japan and China are on the rising portion in the case of CO₂. The results suggested that there are variables other than GDP per capita affecting SO₂ and CO₂ emissions, and are likely to have a serial correlation at least in the case of Japan.

In effect, there have been extensive studies on the trends of historical emissions and how the same has increased over time. It is also observed that panel data studies have attempted to quantify the level of effectiveness of climate conservation treaties such as the Kyoto Protocol (2005). Another broad area of study has focussed on quantifying how social and economic indicators affect the level of carbon dioxide emitted by groups of countries over the years.

Statement of Hypothesis

This paper aims to study the following hypotheses,

Hypothesis 1: The Kyoto Protocol which came into effect in 2005 was able to reduce CO₂ emissions in Japan.

Hypothesis 2: Japan exhibits the hypothesized relationship between environmental quality and GDP growth, as suggested by the Environmental Kuznets Curve (EKC). Various indicators of environmental degradation tend to get worse at the growing stage of economic growth, but after achieving certain levels of economic growth, the quality of the environment slowly starts to improve.

Data and Econometric Methodology

The study is retrospective in nature wherein the quantitative data for territorial carbon emissions (in metric tonnes), GDP per capita (in current US Dollars) and R&D expenditure (in million Dollars) are collected from secondary sources like the World Bank, Organization of Economic Cooperation and Development and Global Carbon Atlas. A sample data of 38 years is selected from 1981 to 2018 for the analysis. This time period was selected in order to study the impact of the Kyoto Protocol (enforced in 2005).

The paper employs time series analysis as a statistical methodology for the analysis. Given the assumptions of the Classical Linear Regression Model, the method of Ordinary Least Squares (OLS) estimation and Prais-Winsten estimation (PWE) was used to experiment with different models as follows:

1. $\ln \text{CO}_t = \beta_0 + \beta_1 \ln \text{GDP}_t + \beta_3 \ln \text{RD}_t + \beta_4 D_t + u_t$ (OLS)
2. $\ln \text{CO}_t = \beta_0 + \beta_1 \ln \text{GDP}_t + \beta_2 (\ln \text{GDP}_t)^2 + \beta_3 \ln \text{RD}_t + \beta_4 D_t + u_t$ (OLS)
3. $\ln \text{CO}_t = \beta_0 + \beta_1 \ln \text{GDP}_t + \beta_2 (\ln \text{GDP}_t)^2 + \beta_3 \ln \text{RD}_t + \beta_4 D_t + u_t$ (PWE)

where,

$D = 0$, for the time period, when the Kyoto Protocol is not enforced, $D = 1$, for the time period, when the Kyoto Protocol is enforced, $\ln \text{CO}_t$ is the natural logarithm of carbon dioxide emissions, $\ln \text{GDP}_t$ stands for the natural logarithm of per capita income, $\ln \text{RD}_t$ stands for the natural logarithm of expenditure on research & development, β denotes the regression parameter, u_t is an error term and t refers to the t^{th} time period.

Empirical results reveal the model with the best fit to be chosen as the main functional form for analysis, which is checked and remedied for the loss of efficiency due to the presence of serial autocorrelation.

Empirical Results

The empirical results of the three different regression models are reported as follows:

Table 1 : Dependent variable: $\ln CO_t$

Variables	(1) OLS	(2) OLS	(3) PWE
constant	2.670*** (0.5709)	18.17*** (4.647)	9.107 (5.682)
$\ln GDP_t$	0.1168** (0.04757)	-3.200*** (0.9895)	-1.085 (1.189)
$(\ln GDP_t)^2$		0.1645*** (0.04904)	0.05722 (0.05889)
$\ln RD_t$	0.2737*** (0.08353)	0.3756*** (0.07926)	0.2598*** (0.09420)
D_t	-0.06933** (0.02736)	-0.1217*** (0.02862)	-0.02731 (0.03678)
Observations	38	38	38
Adj. R^2	0.8464	0.8820	0.9250

Standard errors in parentheses

* significant at the 10 percent level

** significant at the 5 percent level

*** significant at the 1 percent level

Model 3 (PWE) was chosen as the main functional form for analysis as it offers sufficiently high adjusted R^2 and remedies for the loss of efficiency of the OLS estimators due to autocorrelation. It also includes the squared term of $\ln GDP$, (an essential part of the study to test the EKC hypothesis for Japan) which is not present in model 1 (OLS).

Model 3 (PWE) is also corrected for the problem of autocorrelation which was a significant problem in model 2 (OLS).

The empirical results of regression model 3 are stated in a tabular format as given below:

Table 2 : Regression results for Model 3 : Prais-Winsten Estimation, using observations 1981-2018 (T = 38); Dependent variable: $\ln CO_t$
Rho = 0.828814

	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-ratio</i>	<i>p-value</i>	
constant	9.10715	5.68158	1.603	0.1185	
$\ln GDP_t$	-1.08530	1.18923	-0.9126	0.3681	
$(\ln GDP_t)^2$	0.0572187	0.0588871	0.9717	0.3383	
$\ln RD_t$	0.259823	0.0941953	2.758	0.0094	***
D_t	-0.0273068	0.0367825	-0.7424	0.4631	

*** significant at the 1 percent level

Statistics based on the rho-differenced data:

Residual sum of squares	0.041395	Standard Error of regression	0.035418
Explained sum of squares	0.577716	Adjusted R-squared	0.925034
R-squared	0.933138	P-value(F)	6.39e-36
F(4, 32)	1324.151	Durbin-Watson	1.8240351
rho	0.042556		

According to the regression results, it is found that the relationship between the dependent variable, $\ln CO_t$, and the independent variables - $\ln GDP_t$, $(\ln GDP_t)^2$, D_t is insignificant. The finding that the per capita income is not a significant factor affecting the emissions of CO2 in Japan is also consistent with the findings of the recent literature [7], [8].

However, it is also found that $\ln RD_t$ as an explanatory factor has a significant relationship with the dependent variable, $\ln CO_t$. In other words, expenditure on research and development is a significant factor affecting the carbon emissions in Japan.

The R^2 shows the amount of observed variance explained by the model, which in this case is 93.31%. The adjusted R^2 is 92.50%, and it is observed that the Root Mean Squared Error is 0.035 (close to zero), implying that the model is a good fit.

The F-test results in a p-value of 6.39×10^{-36} , implying the observed R^2 value is reliable and depicts a statistically significant relationship between the dependent variable and all the explanatory variables combined.

Testing the EKC hypothesis:

If Japan exhibits the hypothesized relationship between environmental quality (carbon emissions) and GDP growth, then the relationship between the two variables will be an inverted U-shape, as is supposed in the EKC hypothesis. Thus, β_1 should be positive and β_2 should be negative, i.e., at the initial stage of economic growth (income) the environmental degradation should increase, but after reaching a certain level of growth, the quality of the environment tends to get better.

However, as per the sample regression function in this model, it was found that the coefficient of $\ln GDP$ (-1.08530) is negative and the coefficient of its squared term (0.0572187) is positive. Hence, we reject the hypothesis for the given sample that the relationship between the environmental indicator and GDP per capita gives an inverted U-shape EKC. The result that Japan does not exhibit the hypothesized EKC relationship in the case of carbon emissions for the period 1981-2018 is consistent with the findings of [13].

Analysis And Implications

In accordance with the econometric results, it is evident that per capita income is not a significant factor affecting the emissions of CO₂ in Japan. This finding is consistent with the fact that governments have little incentive to reduce emissions on their levels [7].

Japan decided not to renew their commitment for the second period of the Kyoto Protocol. The reasonable worry about Japan's actions, however, is that moving away from a second commitment period for the protocol would signal developed countries to abandon the binding system of emissions cuts and adopt a system with voluntary measures only. This makes it more difficult to build a binding agreement requiring sufficient carbon cuts. So, this passive enforcement mechanism of environmental policies like the Kyoto Protocol does not have any significant impact.

The fact that Japan does not exhibit the EKC is consistent with the finding in [7] that the statistical analysis on which the environmental Kuznets curve is based is not robust. There is little evidence for a common inverted U-shaped pathway that countries follow as their income rises. The only robust conclusions from the EKC literature (see [8]) appear to be that concentrations of pollutants may decline from middle income levels, while emissions tend to be monotonic in income.

The significant impact of research and development expenditure on carbon emissions is attributed to the fact that carbon emissions may decline simultaneously over time in countries at widely varying levels of development. Given the poor statistical properties of most EKC models [7], it is hard to⁶⁹ come to any conclusion about the multidimensional roles of the variable across time and countries.

Scope And Limitations

Using time-series data instead of panel data does not allow for comparison of results of the study between the countries which have ratified the Kyoto Protocol with those which haven't. Moreover, the results of the effectiveness of the Kyoto Protocol cannot be generalized for other countries from a single study using time series analysis.

The present study thoroughly studied three factors namely R&D expenditure, GDP per capita, and Kyoto Protocols that influence the CO₂ emission levels and this study was strictly limited to macro level investigation. The breakdown of various components affecting CO₂ emissions and other variables influencing the effectiveness of Kyoto Protocol were not investigated. Therefore, there is a need for more micro level studies to identify the factors that influence Japan's CO₂ levels.

The model has a presence of collinearity between $\ln GDP_t$ and $(\ln GDP_t)^2$ since both of these variables are functionally related, However, $(\ln GDP_t)^2$ is a nonlinear function of $\ln GDP_t$ and does not violate the assumption of no perfect collinearity. Furthermore, the model has a high R^2 and adjusted R^2 . Hence, this regression model is fit to be estimated in the usual manner.

Recommendations

There is a need to make the agreement global and effective in dealing with cost uncertainty. Developing countries can however have “non-binding” targets, given the importance of their ascent to development . This could be achieved through emission trading, which can be made possible only if the emission levels are below the set target. Such a scheme will in effect, provide countries incentives to reduce their GHG emissions.

Alternatives to the Kyoto Protocol should also be explored. One such measure could be the implementation of carbon tax and carbon permits. Both carbon taxes and permit systems aim to reduce the total quantity of carbon emissions by creating a price for emitting CO₂ pollution. Countries should also indulge in collaborative research and development of new technologies. A regular followup protocol will help in developing credible incentives for participation and enforcement mechanisms.

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