Does the Kyoto Protocol have carbon reduction effects? A panel data rolling regression analysis

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Abstract

In this paper, we investigate the effects of Kyoto protocol on the world emissions of carbon dioxide. The panel data used in this study consists of 21 countries from 1950 to 2009. According to the attitude to Kyoto protocol, we separate countries to three groups. The turning points of EKC models are estimated by fixed effects method with fixed rolling windows. The main finding of this paper is that the Kyoto Protocol does have obvious effects on carbon reduction for the developed countries in Annex B. For the countries that do not include in Annex B of Kyoto protocol, or not ratify Kyoto protocol, there are no clear effects on carbon reduction.

Keywords Carbon dioxide; Environmental Kuznets curve; Kyoto protocol; Panel data; Rolling regression

JEL code: Q54, Q56

Introduction

Since the industrial revolution, fossil fuels have gradually become the world's main energy source. Fossil energy continues to lead to rapid economic growth in many developing and developed countries. Although the usage of fossil energy can increase the pace of economic development, the consumption of fossil fuels causes huge emissions of greenhouse gases (GHGs) that damage the global ecosystem. Carbon dioxide (CO_2) has the highest share at 66% of the GHGS, and its influence on global warming is also the greatest (Stix, 2006). International conformity and long-term cooperative efforts are essential in controlling CO_2 emissions. Numerous countries agreed to reduce GHGs emissions by signing the Kyoto Protocol at the third Conference of the Parties in 1997. Emissions of six kinds of GHGs including CO_2 were to be reduced by an average 5.2% emission level of 1990 during 2008–2012 as the target. Thus, the prudent control of CO_2 emissions to a minimum became a practical issue for many countries in the Kyoto Protocol.

Implementation of international cooperation is, however, always confronted by complex problems. This is the main reason that the Kyoto Protocol was not effective until 2005, although it had been ratified in 1997. There are two main problems with the Kyoto Protocol. First, what are the proper emission reduction commitment percentages of the countries listed in Annex B of the protocol? A criticism by Nordaus (2001) is that current emission reduction targets—which are focused on economic development and emissions status—are based on deficient information. How to achieve more efficiency in emission abatement is a key question in the Kyoto Protocol. In addition to striving for such efficiency, a continuous search for equitable emission reduction targets among the countries in Annex B is essential for the cooperation required to implement the Kyoto Protocol further (Ringius, Torvanger and Underdal, 2002; Strazicich and List, 2003; Wu, Huang and Liou, 2013).

Second, no limitations on CO_2 emissions have been set for most developing and underdeveloped countries, especially those with high annual GDP growth rates, such as China, India, South Korea, and Taiwan. Böhringer (2003) and Socolow and Pacala (2002) find that the developing and newly industrialized countries have become the main GHG producers in recent years. For these countries, there are no emission reduction targets in the Kyoto Protocol. This increases the tendency of these countries to use fossil energy and retards the attainment of emissions reduction.

Several recent studies have attempted to investigate the effects of the Kyoto Protocol on CO_2 reduction (Halkos and Tzeremes, 2014; Kumazawa and Callaghan, 2012), but these studies have only focused on the effects of Annex B countries in the agreement. Halkos and Tzeremes (2014) use data envelopment analysis to derive measurements of efficiency in attaining environmental impact levels under the Kyoto Protocol. Kumazawa and Callaghan (2012) use the environmental Kuznets curve model to detect whether structural breaks exist in Annex B countries. They reveal that CO_2 pollution generated by countries with emission targets has decreased since the signing of the protocol. However, no studies have examined the effects of the differing Kyoto Protocol agreements made by Annex B and developing countries.

Since Grossman and Krueger's seminal paper (Grossman and Krueger, 1995), the environmental Kuznets curve (EKC) has become a popular model in the investigation of GHG emissions. The relationship between environmental quality and GDP per capita is considered to be a quadratic form. EKC analysis shows that GHG emissions rise to a certain point as income increases and then decline from this level of income, commonly known as a turning point. Although the EKC approach has been debated and criticized in the literature (Stern et. al. 1996; Stern and Common 2001; Romero-Avila 2008), it is still a useful model to examine emissions reduction. If carbon reduction policies can decrease the GDP per capita turning point, these policies can be considered efficient in controlling GHG emissions.

This study examines the levels of CO_2 emission reduction before and after the Kyoto Protocol. We separate the countries into three groups. The first group is the countries listed in Annex B, which have binding emission reduction targets. The second group is the countries that agreed to meet the targets of the protocol, but whose governments have not ratified the agreement or have withdrawn from it. The final group is the countries that do not have any emission targets under the protocol. Group 3 thus comprises the developing and underdeveloped countries. We use rolling regression with a panel EKC model to estimate the turning points of all three groups. After estimates of all the turning points are obtained, we can compare the variations in turning points among the three groups. The effects of the Kyoto Protocol can thus be examined according to the agreement's status in different countries. To the best of our knowledge, this is the first study to investigate the differing effects of the Kyoto Protocol between states committed to CO_2 limitations and those not committed. The findings of this study can therefore provide a reference for carbon reduction policies in the future.

The remainder of this paper is structured as follows. The following section describes the data and presents a discussion of the econometric analysis. The empirical results are stated in Section 3. Section 4 concludes the paper.

Data and methods

Data on per capita CO_2 emissions are from the Carbon Dioxide Information Analysis Center (CDIAC). The emissions are measured in metric tons. Real GDP per capita is from The Conference Board. This study collects data related to GDP and CO_2 emissions of each country from 1972 to 2009. The 16 OECD countries as well as Brazil, Canada, China, India, and the US are included in this research.

In order to estimate the relationship between CO_2 emissions and GDP per capita, we consider the parametric panel EKC curve as follows:

$$\ln e_{it} = \beta_0 + \beta_1 \ln y_{it} + \beta_2 (\ln y_{it})^2 + \lambda_i + u_{it} \qquad (1),$$

where $\ln e_{it}$ is the logarithmic transformation of a per capita measure of CO_2 emissions, $\ln y_{it}$ denotes the logarithmic transformation of per capita GDP, and u_{it} is the error term. The index $i = 1,2,\ldots,n$ indicates the countries and $t = 1,2,\ldots,T$ is the year index. When the CO_2 EKC model satisfies Grossman and Kruger's hypothesis, the coefficients $\beta_1 > 0$ and $\beta_2 < 0$. The turning point with respect to income is given by

$$y_{it} = \exp(-\beta_1 / 2\beta_2) \qquad (2).$$

The λ_i are the country-specific effects that can be correlated with $\ln y_{it}$, while u_{it} is the disturbance. Because the panel CO_2 EKC curve is a reduced form, other omitted variables are likely to be correlated with regressors. Harbaugh et. al. (2002) and Stern (2014) suggest that estimating Equation (1) with fixed effects helps to avoid possible correlations between regressors and country effects.

The CO_2 EKC regression used in this paper makes the assumption of cross-sectional homogeneity. This assumption has of course no drawbacks. The empirical results of Wagner (2008) present some evidence on cross-country differences in CO_2 emissions and GDP data. However, Dijkgraaf and Vollebergh (2006) find that the effects of any neglected cross-sectional heterogeneity in the data do not lead to any further problems. Therefore, we maintain cross-sectional homogeneity in the panel EKC model and focus on the analysis of the effects of the Kyoto Protocol on the CO_2 EKC curve.

When the international treaty on carbon reduction has efficiency, the GDP per capita turning point of the CO_2 EKC curve demonstrates a decreasing trend after the agreement is executed. To evaluate the effectiveness of the carbon reduction treaty, we use fixed window rolling regression to calculate and analyze the GDP turning points before and after the treaty comes into effect. The estimations of the turning points of the panel EKC model are obtained in three steps: First, we estimate the parameters of Equation (1) by fixed effects regression with data from 1950 to 1970. Second, after the estimates of the EKC model have been obtained, we calculate and save the values of the turning points. Finally, we repeat the first two steps with 21-year rolling windows; for instance, the next data period used in the fixed effects estimation of the EKC model is 1951–1971, and so on. The rolling regression approach is often used to analyze the structural stability of nonlinear models in finance (Zivot and Wang, 2001). The benefits of fixed rolling windows are twofold. The first advantage of rolling regression relative to other regime-switching models lies in its greater flexibility and simplicity, as it can capture the time variation of the relationship of interest without imposing any prior assumptions. Second, Doda (2013) finds that the business cycle has some influence on CO_2 emissions; estimating the turning points by rolling regression can lower the impact of business cycles.

Since the Kyoto Protocol came into effect on February 16, 2005, environmental researchers have been interested in whether CO_2 emissions decrease as an effect of the protocol's implementation. To assess the performance of this protocol, we use rolling regression to estimate the parameters of the CO_2 EKC model. There are three steps in this procedure. First, we process the rolling estimations in the CO_2 EKC model and calculate turning points using a window size of 41 years from 1950 to 1990. Second, we drop the initial observation, add one further observation, and re-estimate the CO_2 EKC model. This procedure is repeated until the final window used (from 1970 to 2009). Finally, we can separate the turning points in relation to the year the protocol came into effect, this being 2005. Based on the variation in the turning points, the efficiency of Kyoto Protocol can be judged.

Empirical results

Table 1 lists the countries used in this study. Before we derive the empirical results of the CO_2 EKC model, we apply the panel unit tests proposed by Levin, Lin, and Chu (2002) to detect whether the series of CO_2 emissions and GDP per capita are nonstationary. The results, displayed in Table 2, show the series without unit roots for the 16 OECD countries and for the group 2 countries, while the series of CO_2 emissions and GDP are both nonstationary for countries in group 3. According to the outcomes of panel unit statistics, we use the fixed effects method to estimate the parameters of Equation (1) for the countries of groups 1 and 2 and we apply panel cointegration as proposed by Kao (1999) to obtain estimations of Equation (1) for the countries of group 3. Table 3 shows the estimated coefficients for the period 1950–2009 using the EKC model specified in Equation (1). We find that the CO_2 EKC models of all groups demonstrate an inverted U-shape. The in-sample turning points of the three groups (in US dollars) are \$30,445, \$31,912, and \$65,931, respectively. The outcomes show levels of GDP per capita that are above the turning points for countries of groups 1 and 2, but not for group 3.

The parameter estimates of the EKC model for the three groups are obtained employing fixed effects regression within the rolling regression framework for the period 1950–2009. Rolling windows are set to 41 years. Figure 1 presents the estimates of the turning points in Equation (1) from a sequence of rolling samples. Compared with the pre-Kyoto period, the turning points of group 1 maintain a stable low level after the Kyoto Protocol comes into effect. This result shows that the Annex B countries under the agreement are able to maintain a steady state of CO_2 emissions. The CO_2 emissions do not worsen after the Kyoto Protocol is ratified for the industrial countries.

As for group 2, the estimates of the turning points demonstrate a gradually increasing pattern in Figure 2, especially after 1998. Although Canada and the US had agreed to reduce their CO_2 emissions according to the Kyoto Protocol, these countries have different reasons not to execute the agreement. We find that the turning points in group 2 increase after 1998. This result indicates that even though countries in group 2 committed to follow the CO_2 emissions caps in the Kyoto Protocol, the carbon emission reduction targets were not achieved where the protocol was not ratified.

The estimates of turning points for the countries in group 3 are the highest among all three groups. These high turning points show that CO_2 emissions cannot be decreased without adherence to the Kyoto Protocol. Countries in group 3, such as China and India, do not belong to the Annex B nations of the agreement and are not subject to its CO_2 emission caps. Although countries in group 3 are parties to the protocol, these countries are still concentrating on economic growth and using non-renewable energy sources. The absence of Kyoto targets causes these countries to emit more CO_2 into the atmosphere; it appears that the total amount of CO_2 emissions cannot be slowed down in group 3. From this empirical outcome, we conclude that without reduction targets for all countries in the Kyoto Protocol, the total emissions of CO_2 cannot be easily maintained at a fixed level.

Conclusion

The evidence presented in this article shows that the Kyoto Protocol does have obvious effects on carbon reduction for the developed countries in Annex B. These countries have different patterns of carbon dioxide emissions from those nations that have not ratified the agreement or that have not been set emissions reduction targets under the Kyoto Protocol since its ratification in 1997.

However, this study has limitations. Because the panel data set ends in 2009, we cannot adequately compare the differing effects after the Kyoto Protocol came into force in 2005. Two possible extensions to this study can be considered in the future. First, we can compare CO_2 emissions among the countries of the three groups from 2005 and see whether there exist clear differences in emissions after the first commitment period (2005–2012) has ended. Second, it can be established whether those countries that are excluded from the Kyoto Protocol have different patterns of CO_2 emissions.

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Table 1

List of countries included in the study

Group 1	Group 2	Group 3
Austria	Canada	Brazil
Australia	USA	China
Belgium		India
Denmark		
Finland		
France		
Germany		
Greece		
Italy		
Japan		
Mexico		
Netherlands		
New Zealand		
Spain		
Sweden		
United Kingdom		

Table 2

Results of Panel Unit tests of Levin, Lin and Chu (2001)

	CO_2	Y	Y^2
OECD countries			
statistic	7.8413***	-11.409***	-10.2306***
	(<0.0001)	(<0.0001)	(<0.0001)
Canada and US			
statistic	-2.31***	-1.6465**	-1.4276*
	(0.0104)	(0.0498)	(0.0767)
Brazil, China and India			
statistic	0.5053	4.8622	5.2218
	(0.6933)	(>0.9999)	(>0.9999)

The P-values are displayed in brackets；*P-value<0.1，**P-value<0.05，***P-value<0.01.

Table 3

Fixed effects Panel regressions for three groups (T=61)

Dependent variable: ln(Per capita CO2)					Turning point
Variable	Coefficient	Std. Error	t-Statistic	Prob.	
OECD countries (N=16)					$33,487
Y	10.2772***	0.3852	26.6780	<0.0001	
Y^2	-0.4931***	0.0198	-24.8732	<0.0001	
C	-52.6111***	1.8680	-28.1651	<0.0001	
Canada and US (N=2)					$31,912
Y	11.6353***	0.8502	13.6856	<0.0001	
Y^2	-0.5610***	0.0420	-13.3536	<0.0001	
C	-58.7229***	4.2968	-13.6667	<0.0001	
Brazil, China and India (N=3)					$65,931
Y	3.3054***	0.45	7.3462	<0.0001	
Y^2	-0.1490***	0.03	-5.0158	<0.0001	
C	-17.756***	1.6874	-10.5229	<0.0001	
Kao residual based ADF t-Statistic			-2.0866**	(0.0185)	

:*P-value<0.1，**P-value<0.05，***P-value<0.01

Figure 1

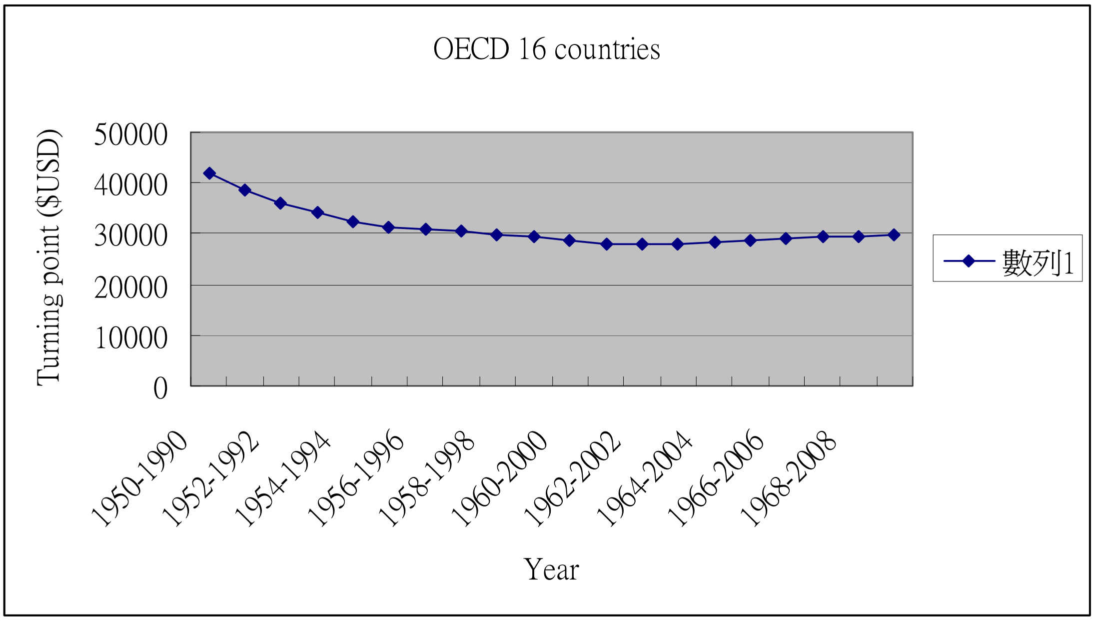


Figure 2

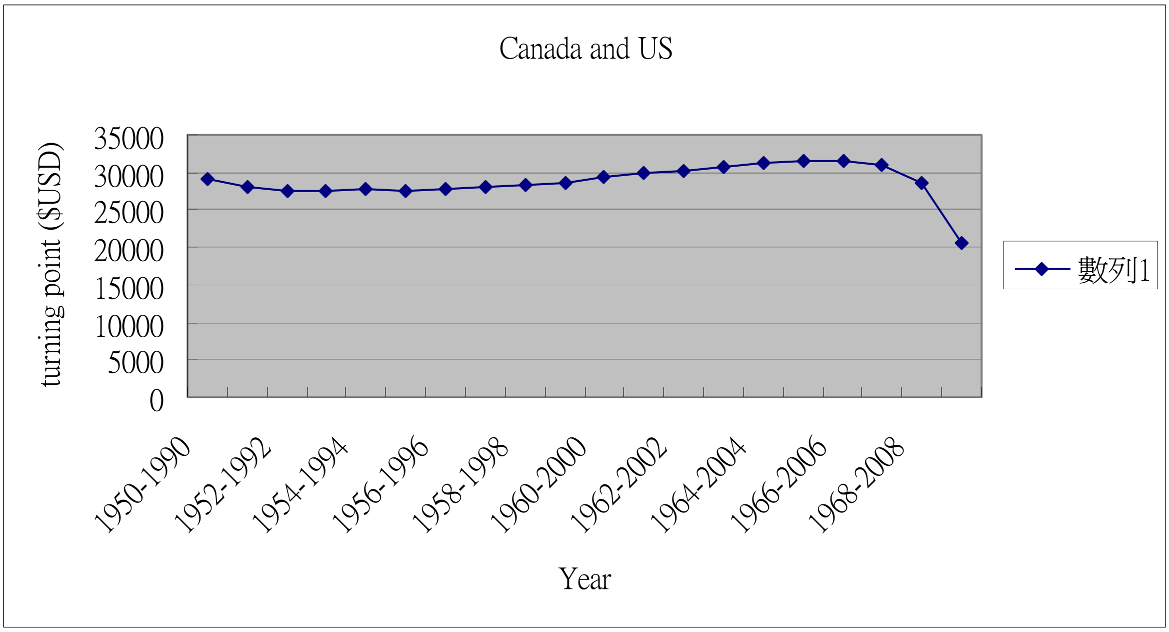
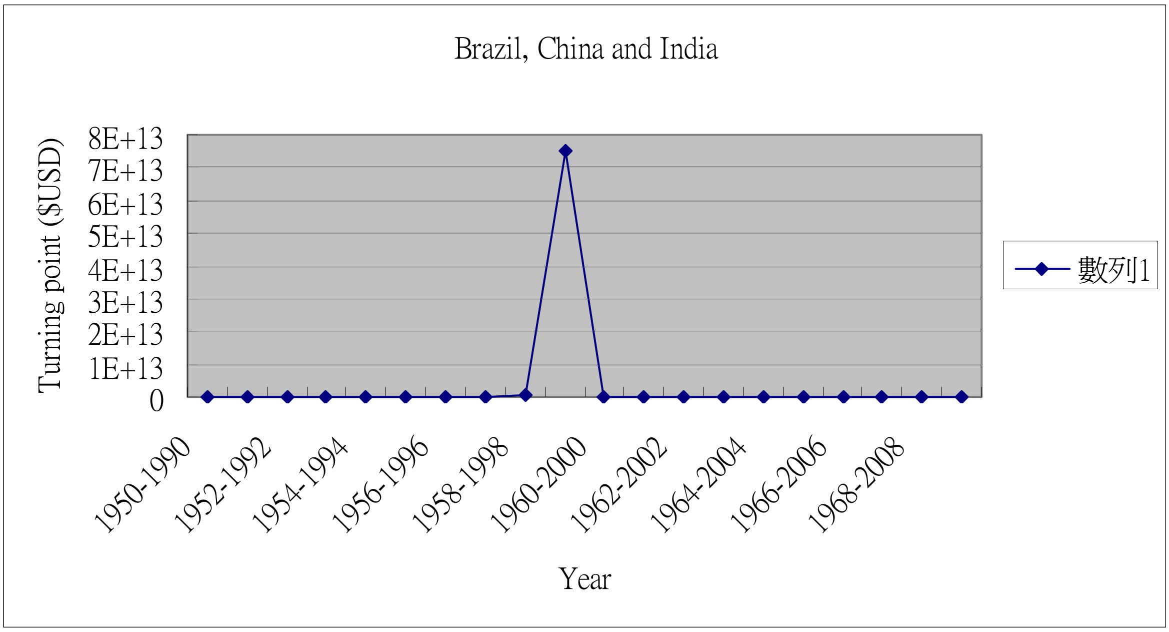


Figure 3


Brazil, China and India
Turning point ($USD)
8E+13
7E+13
6E+13
5E+13
4E+13
3E+13
2E+13
1E+13
0
1950-1990
1952-1992
1954-1994
1956-1996
1958-1998
1960-2000
1962-2002
1964-2004
1966-2006
1968-2008
Year
數列1