Carbon dioxide emissions and institutional factors in developing nations: An application of the GMM technique

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Abstract. Thirty-seven (37) industrialized countries are committed to cut greenhouse gases by 5.2% over a period since 2008-2012. However, understanding the needs of developing countries and their commitment towards social and economic development goals, UNFCCC has somehow adopted a principle of “common but differentiated responsibilities” Economic activities are fundamentally linked to economic growth which is much needed in these nations, thus the parties allow them to grow to meet their ends. But this does not mean the countries should not be responsible for their action. These nations signatory to the Kyoto Protocol has also demanded them to put effort to cut carbon emissions. This study employed a dynamic panel data model that based on the Arellano and Bond Generalized Method of Moments (GMM) technique to investigate the impact of the Kyoto Protocol and four institutional factors political stability, property rights, corruption and freedom of trade on per capita CO2 emissions in 126-developing nations. Three determinants i.e. Kyoto Commitment, Kyoto Clean Development Mechanism and freedom of trade were found to have negative significant effect on CO2 emissions. Thus, the empirical findings confirm that the three institutional factors are relevant in cutting the CO2 emission.

1. Introduction
Global warming, the well-known issue of climate change has taken the centre stage as it is thought to be the world’s greatest challenge that threatens the lives of billions of people. Anthropogenic carbon dioxide (CO2) emissions are believed to be the principal factor responsible for the greenhouse effect. Despite international efforts to reduce the atmospheric level of CO2 emissions of this gas are still growing in many countries. The issue was thus raised as a serious global issue with the adoption of the Kyoto Protocol1 on 11th December 1997 in Kyoto, Japan. The United Nations Framework Convention on Climate Change (UNFCCC)2 is the international environmental treaty aimed at fighting global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005. Adoption of the Kyoto Protocol is the first step which shows the seriousness of the UNFCCC to fight global warming and is responsible for the protocol that was set to be enforced on 16th February 2005.

Developing countries whom signatory to the Kyoto Protocol has somehow be demanded though not mandatory to put effort in reducing the CO2 emissions. The study by [1] stated that the 1997 Kyoto Protocol is an international agreement aiming to reduce GHG emissions seen as a precious milestone to prevent and mitigate global warming. The protocol has placed stringent emissions limit for developed countries, but the merit of the protocol depends too on the actions of developing countries. Realizing

1The Kyoto Protocol was established at the third conference of the parties (COP3) in 1997.
2The UNFCCC was founded in 1992 at the “Rio Earth Summit”.

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this, it is vital to observe and analyse the effects of the Kyoto Protocol as the organizational body to UNFCCC that governs the control of CO₂ emissions in order to provide policy implications that would enhance further its functions. The role of Kyoto Protocol is an interesting aspect to study so that its function as a stable institutionalized platform is adequate and efficient to coordinate all its members and incorporate new members specifically developing countries to shape strong partnership and foster innovation for the sake of future progress in controlling CO₂ emissions and combating global warming. Thorstein Veblen was the earliest advocate of Institutional Economics of which in 1896, he emphasized the essential role and value of institutions is crucial in creating the potential for stability and progress of a nation. On the other hand, in the literature [2] and [3] extended the principal role of institution and its relationship with progress, development and stability integrate well with the works of market mechanism. Hence, it is vital to include in this study the effect of institutional factors specifically political stability, legal structure and security of property rights, corruption and freedom to trade on the level of CO₂ emissions in the developing nations. Despite of their effect on CO₂ emissions are rather ambiguous, it is fruitful to observe their impact in the context of the developing region. There is no concrete evidence on what determines the level of CO₂ emissions, and whether the role of these institutional factors may affect the level of CO₂ emissions in this region. Consequently, this issue should be of interest and remain open for discussion in order to explore and understand the possible determinants of the world’s climate change. Thus, the objective of this study is firstly to examine the significant of the Kyoto Protocol and the four institutional factors which are political stability, legal structure and security of property rights, corruption and freedom to trade on the growth of per capita CO₂ emissions. Secondly, to utilize the technique by [4] GMM estimator in the analysis which limitedly applied in this study.

2. Econometric modelling

Equation (1) portrays the initial eight independent variables (i.e. GDP, EUS, EFF, FDI, URB, IND, AGR and EDU) to be the socioeconomic determinants of CO₂ emissions [5]. Next to eliminate the country-specific effects and to solve the problem of autocorrelation between the lagged dependent variables and the error term, a dynamic panel specification with lagged levels of CO₂ emissions is applied, and thus the equation is:

\[
\text{lnCO}_2i,t = \beta_0\text{lnCO}_2i,t-1 + \beta_1\text{lnGDP}_it + \beta_2\text{lnEUS}_it + \beta_3\text{lnEFF}_it + \beta_4\text{lnFDI}_it + \beta_5\text{lnURB}_it + \beta_6\text{lnIND}_it + \beta_7\text{lnAGR}_it + \beta_8\text{lnEDU}_it + \mu_i \\
\]

\(i = 1, \ldots, N; \quad t = 1, \ldots, T\)

where, \(\beta_1, \beta_2, \beta_3 > 0; \beta_4, \beta_5 > 0; \beta_6, \beta_7 > 0; \text{ and } \beta_8 < 0;\)

\(i = 126 \text{ countries} \quad t = \text{time frame 1971-2009}\)

\(\text{CO}_2 = \text{Carbon Dioxide emission (metric tons)}\)

\(\text{GDP} = \text{Gross Domestic Product per capita (USD$)}\)

\(\text{EUS} = \text{per capita total energy usage (Kt of equivalent per capita)}\)

\(\text{EFF} = \text{fossil fuel energy consumption (% of total energy consumption)}\)

\(\text{FDI} = \text{foreign direct investment (% of GDP)}\)

\(\text{URB} = \text{urbanization (% of urban population growth)}\)

\(\text{IND} = \text{industrial sector production (% of GDP)}\)
AGR = agricultural sector production (index of production)
EDU = education level proxy by average years of total schooling (% of group aged 15+)

Using the dynamic panel specification as described by [4] could eliminate the country-specific effects and help to solve the problem of lagged dependent variable being correlated with the error term. This is so because the method of first difference; the regression model results with: \( E(e_{it} - e_{it-1}) = 0 \) but \( (gCO_{2it} - gCO_{2it-2}) \) is dependent of \( (e_{it} - e_{it-1}) \); therefore, employing the method [4] provides a much better solution when one uses two or more lags of the first difference of CO2 emissions. Hence for \( \mu_{it} \):

\[
\Delta u_{it} = \Delta v_{it} + \Delta e_{it} \quad \text{or} \quad u_{it} - u_{it-1} = (v_{it} - v_{it}) + (e_{it} - e_{it-1}) = e_{it} - e_{it-1}
\]

A selected set of institutional variables are chosen to be possible factors determining the carbon dioxide emissions. The Kyoto Protocol i.e. Kyoto commitment and Kyoto Clean Development Mechanism including political stability, property rights, corruption and freedom of trade represent the institutional factors. On the other hand, socioeconomic determinants in equation (1) would be treated as control variables since the main analysis is to study the effect of institutional factors and hence, the equation is shown as:

\[
\ln CO_{2it} = \beta_0 \ln CO_{2it-1} + \alpha Kco_{it} + \alpha Kcd_{it} + \alpha PS_{it} + \alpha PR_{it} + \alpha CR_{it} + \alpha FT_{it} + \mu_{it} + \epsilon_{it}
\]

where, \( \alpha_0, \alpha_1, \alpha_2 \leq 0 \) and \( \alpha_3 (\pm -) \);

\( \mu_{it} \) = consists of unobserved country-specific effects, \( v_{it} \) & observation-specific errors, \( e_{it} \)
\( \ln CO_{2it} \) = log of per capita CO2 emissions of country \( i \) at time \( t-1 \)
\( Kco \) = Kyoto Protocol commitments
\( Kcd \) = Kyoto’s flexible mechanism the CDM
\( PS \) = political stability
\( PR \) = property rights
\( CR \) = corruption
\( FT \) = freedom of trade
\( X \) = control variables

The GMM technique is utilized to estimate the equation in level and then in first difference. The first estimate uses lagged variables in level of at least one period of instruments of the equation in first difference in order to remove unobserved time invariants and individual characteristics. This complies with the conditions that the error term is uncorrelated and that explanatory variables are weakly exogenous. The second estimate uses variables in first difference lagged of at least one period as instruments of the equation in level. Though the priori expectations are given for each variable, except for corruption (ambiguous), the association of quality governance with carbon emissions is still relatively new in these developing countries.

3. Data Sources
The Kyoto commitments (Kco) is represented by a dummy variable that takes the value of one (1), if a country has ratified the protocol otherwise it takes the value of zero (0). The dummy takes the value one beginning from the year in which the country ratified the protocol. The countries with emission reduction
obligations ratified the protocol in 2002. Kcd is evaluated based on the number of CDM projects the country has implemented with the help of developed countries, with a target to reduce their emission levels. The data on the number of implemented CDM projects by host country is gathered from the UNEP Centre on Energy, Climate and Sustainable Development.

Data for four quality governance dimensions are gathered from the World Bank, Fraser Institute, Worldwide Governance Indicators and Economic Freedom of the World’s Annual Report, respectively. Data of the eight socioeconomic variables are collected from the Carbon Dioxide Information Analysis Centre, Environmental Sciences Division, Penn World Table, International Energy Agency statistics (IEA), United Nations Conference on Trade and Development (UNCTAD), Food and Agriculture Organization of the United Nations (FAOSTAT), Barro and Lee, 2010 and World Development Indicator (WDI).

4. Results of analysis and discussions

There are three fundamental empirical criteria to note regarding the estimations of these variables. First, it is foreseen that the problem of multicollinearity may arise among these independent variables even though they differ individually yet could possibly overlap since they might convey essentially the same information. Second, is the issue of data availability. PS and CR indicators start off with years 1996, 1998, and 2000 then continues to yearly basis from 2002 until 2009. PR and FT data are available every five years from 1975 up to 2000 after which it is then recorded annually. Third, the raw data of each variables are utilized for estimations purpose except for Kcd whereby the number of projects in each country is normalized to bring them to a common scale. The software Stata 10 was utilised to analyse these data.

Table 1 documented the results from the one-step first differenced and system GMM estimators. The Sargan test statistic for over-identification does not reject the null hypothesis that the error term is uncorrelated with the instruments. A satisfactory significant $m_1$ (reject the null of no autocorrelation at 1 percent level) and $m_2$ (fail to reject the null of no autocorrelation) tests reveal a first-order autocorrelation but no evidence of second-order autocorrelation. Both findings indicate an acceptable diagnostics test. Although three main control variables (i.e. $\text{CO}_2$, $\text{IND}$ and $\text{AGR}$) exhibit a negative coefficient, two of them are insignificant except for $\text{AGR}$. A most credible reason is that agriculture impact in developing nations emits high nitrous oxide and methane rather than $\text{CO}_2$ emissions per se. The main results on the governance dimensions show three coefficients (Kco, Kcd and FT) are consistent with the priori expectations of having the expected negative signs whilst three others (PS, PR and CR) are inconsistent and insignificant. The coefficient of Kco is the sole indicator describing result statistically significant at 10 percent level based on the one-step GMM system. It means signing the Kyoto protocol does cause developing nations to commit cutting their per capita emissions unfortunately not in the case of Kcd perhaps it is yet too early to look for an effect from this variable. Three previous empirical studies by [1], [6] and [8] found that the protocol obligations do have positive impact in reducing the carbon emissions for both developed, developing countries and, Asia and Pacific region. FT shows a significant (at 10 percent level) negative coefficient value under the one-step first differenced GMM implying a high index of FT able to decrease the per capita emissions level, ceteris paribus yet insignificant under the one-step system GMM, which is similar to [8]. However, previous empirical results by [9] and [7] found trade openness will result in the development of pollution-intensive industries and environmental degradation in developing countries. The research by [7] described with greater trade openness would cause movement of goods produced in one country for either consumption or further processing to be a source of pollution in three income panels (positive relationship) but not for global panel. A study by [10] using vector error correction model (VECM) on 49 high-emission countries in the Belt and Road regions from 1991-2014 indicated that trade openness had shown a long run causal effect on $\text{CO}_2$ emissions.
Table 1. Effects of institutional factors on per capita CO2 emissions.

|               | GMM 1-DIFF | GMM 1-SYS |
|---------------|------------|-----------|
| Log of CO2-1  | -0.256***  | -0.066    |
| Log of GDP/cap| 0.586***   | 0.582***  |
| Log of EUS    | 0.226***   | 0.153**   |
| Log of EFF    | 0.800***   | 0.762***  |
| Log of FDI    | 0.022      | 0.159*    |
| Log of URB    | 0.054      | -0.375**  |
| Log of IND    | 0.387      | -0.032    |
| Log of AGR    | -0.086     | -1.599*** |
| Log of EDU    | 0.077      | 0.636**   |
| K_co          | -0.187     | -0.476*   |
| K_cd          | -0.069*    | -0.010    |
| PS            | 0.145      | 0.177     |
| PR            | -0.108     | 0.057     |
| CR            | -0.185     | 0.031     |
| FT            | -0.191*    | -0.173    |
| F-statistic   | 0.000      | 0.000     |
| No. of observations | 42 | 42 |
| m1-test m2-test | 0.000 0.259 | 0.000 0.740 |
| Sargan test   | 0.159      | 0.942     |
| Difference-Sargan | 1.000 | 0.966 |
| No. of instruments | 42 | 42 |

Notes:
1. *, ** & *** denote significance at 10%, 5% & 1% level, respectively.
2. Values of m1 & m2 are the \( p \)-values for first & second order auto correlated disturbances.
3. Values of F-statistics, Sargan & the Difference-Sargan tests are the \( p \)-values.

Three other main institutional governance coefficients i.e. PS, PR and CR portray similar insignificant values in the one-step first-differenced GMM. [11] analysis on ASEAN countries discover that countries with political stability have lower carbon emission. But then an interesting empirical study comparing between developed and developing countries by [12] on corruption and CO2 emission witnessed that a unit increase in corruption index (meaning a fall in corruption levels) will decrease carbon emission in developing countries. However, carbon emission is no longer affected by the corruption levels in developed countries or in other words decrease in corruption has insignificant effect on their carbon emission levels. Basically, the data collected for these three variables in majority of the 126 developing countries portray a weak index. This could be: (i) substantial number of these countries are either facing political unrest or having unstable government till now (Africa and Middle East); (ii) legal structure and security of property rights (PR) on carbon emissions are rather sparse in most developing regions except South East Asia that has tightened up their awareness in addressing this issue; (iii) corruption level seems to be high in the developing countries. As a matter of fact, as described by [13] corruption on
environmental degradation in these countries are likely to occur from bribery and cronyism at the level of developing national policy and embezzlement in implementing environmental programs to bribery in issuing permits and licenses and collecting “rents” while enforcing environmental regulations.

5. Conclusion
The empirical evidence proved that good governance should play a key role in controlling the level of CO₂ emissions in these developing nations. However, the results certainly suggest a rather ambiguous finding due to the commitment towards their social and economic development goals. The Kyoto Protocol has somehow adopted a principle of “common but differentiated responsibilities” of which under this principle the parties agreed that the per capita emissions and the share of emissions of developing countries were still relatively low and thus they would be allowed to grow to meet their social and economic development needs [14]. Therefore, they are much focus on achieving a high economic growth to ensure a better standard of living for their citizens rather than emphasizing on policies to curb environmental problems.

A great sign shows by these nations is their willingness to sign the Kyoto Protocol would mean they too are required to put efforts into lessening their CO₂ emissions. On 8 December 2012, the Doha Amendment has established the Kyoto Protocol’s second commitment period from 2013 to 2020. The ratification of this amendment would henceforth express the parties to continue strengthening their commitments to reduce emissions target [15].

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**Acknowledgement**

We are grateful to Malaysia Institute of Transport (MITRANS), Universiti Teknologi MARA, Shah Alam for the financial support in presenting our research at the Green Technology and Sustainability Development (GTSD2019) Conference on 23rd October 2019 at Grand Bluewave, Shah Alam Malaysia.

**Appendix**

List of developing nations under the Kyoto Protocol.
