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Carbon emission patterns in different income countries

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Abstract
In order to find the main driving forces affecting CO_2 emission patterns and the relationship between economic development and CO_2 emissions, this paper uses models of σ-convergence, absolute β-convergence and conditional β-convergence to analyze the inner characteristics of CO_2 emissions and the income level of 128 countries (and regions) in the world. The countries (and regions) are divided into 5 groups based on their per capita income levels. The results show that in the past 40 years, all the groups showed trends of convergence on the CO_2 emissions. In terms of emission levels, lagging countries (and regions) tend to catch up with advanced nations, with convergence tending to be conditional on country-specific characteristics such as energy use and energy structures rather than absolute convergence. Then this paper examines the impacts of selected variables such as GDP per capita, population, oil, gas, coal etc. on the emission trends. The analysis on the impacting factors shows that for the developing countries (and regions), the levels of economic development have greater effects on their carbon emissions patterns. And for the developed countries (and regions), the energy consumption structures wielded a big influence for the past 40 years. We find that the growth speed of CO_2 emissions in developed countries (and regions) would get slower, and those of the developing countries (and regions) give expression to catching-up effects. These findings are expected to shed a light on the global policy making in coping climate change.

Keywords: Carbon emission, Convergence, Catch up, Income level, Impact factors.

1. Introduction

The research on the relationship between economic growth and greenhouse gases (GHG) emissions can be traced back to the well-known IPAT identity [1]. Ehrlich and Holdren discussed the environmental impacts on GHG emissions from population, affluence and technology. After that, there were many discussions on different styles of IPAT models, including those in the IPCC special report Special Report on Emissions Scenarios [2].

Besides the IPAT model, many researches focused on the experience curve of economic growth and emissions, which combines per capita incomes and measures of environmental degradation, and was known as an Environmental Kuznets Curve (EKC). The Environmental Kuznets Curve suggests that low-income countries (and regions) experience low emissions. When the per capita income rises, the emissions will initially increase followed with decrease after getting the peak [3-12].

Roberto Ezcurra concluded that the spatial distribution of CO_2 emissions has so far received little attention in the literature, despite several motivations for such an analysis [13]. The geographic distribution analysis of CO_2 emissions is meaningful to the need for environmental policies and predicting their potential impact [13-15]. The study of spatial distribution of CO_2 emissions is useful to complete and qualify some of the findings documented in the vast literature over the last two decades dedicating to analyze the world income distribution and test the neoclassical convergence hypothesis [16-25].

Despite the potential importance of this issue, there are very few papers studying the cross-country data: Strazicich and List studied the temporal paths of carbon dioxide emissions in twenty-one industrial countries (and regions) from 1960 to 1997 [26]. They tested stochastic and conditional convergence. Both panel unit root tests and cross-section regressions were performed. They found significant evidence which indicated that CO_2 emissions have converged in industrial countries (and regions).

The carbon emission patterns of different countries (and regions) are crucial in the international climate change negotiations. Since 1992, the so called "common but differentiated responsibilities" have been one of fundamental principles of international environmental agreements. The major sticking point in negotiations between the developing countries (and regions) and the developed countries (and regions) is how to undertake the emission reduction obligations. In different economic development phases, the emission patterns might be very different, so developing countries (and regions) may assume different responsibilities other than developed countries (and regions). The research on carbon emission patterns is also useful to the government policy makers. The identifying of driving forces behind the emission patterns, and discriminating which factors through which ways affect the emission patterns could bring significant policy implications.

In this paper, based on the works of Strazicich and List, we use convergence theory and correlation method to analyze the driving forces of distinguishing emission patterns [26]. The economic level, the process of industrialization, energy consumption structure and population are important factors functioning on emissions and they differ greatly in various countries (and regions). In order to find some more precise insights, in this study we put the world countries (and regions) into different groups.

The rest of the paper is organized as follows: section 2 describes the models and data used in this paper. In section 3, we present a correlation analysis between CO_2 emission levels and other variables. In section 3 and section 4 different convergence models are employed to research the emission patterns of five countries (and regions) groups. Section 5 concludes the paper.

2. Theory, data, and empirical models

2.1 Correlation, σ-convergence and β-convergence

In the traditional Solow–Swan neoclassical growth model [27, 28], the economic grows from a transitional path toward a steady state, and the per capita incomes among nations should converge when some variables are controlled.

The σ-convergence model and β-convergence model were proposed by Barro and Sala-i-Martin [29]. A. Miketa and P. Mulder provided an empirical analysis on the energy-productivity convergence across 56 developed and developing countries (and regions) with 10 manufacturing sectors during the period of 1971 to 1995 [30]. They found that with the exception of the non-ferrous metals sector, cross-country differences in absolute energy-productivity levels tend to decrease, particularly in the less energy-intensive industries. Hua Liao used the economic growth model to analyze China's energy efficiency in provincial scale [31].

Based on former researches, in this paper σ-convergence and β-convergence are defined as follows:

σ-convergence indicates the dispersed patterns of different countries' (and regions') emission patterns, implies the degrees of inequality. If the disparity of per-capita carbon emission patterns among country groups becomes smaller, or the same phenomenon of decreasing cross-country differences in per-capita carbon emission level occurs, then σ-convergence happens. β-convergence indicates the "catch up" effect referring that countries (and regions) of low emission levels usually carry a potential for rapider advancing than high emission level countries. So the emission levels of countries (and regions) with higher emission growth speed might catch up with those of countries (and regions) with lower emission growth speed. If the results are significant without other variables being controlled, it is called absolute

β-convergence. If the results are significant with other variables being controlled such as GDP per-capita and energy consumption, it is called conditional β-convergence.
The correlation statistics are calculated as equation (1):

$$\rho = \frac{E\left[\left(X_i - \mu_{X_i}\right)\left(Y_i - \mu_{Y_i}\right)\right]}{\sigma_{X_i}\sigma_{Y_i}} \tag{1}$$

where X_i is the per capita emissions in country i, Y_i is the control variables(GDP, coal, oil, natural gas, etc.), μ is the expectation value of per capita emissions and σ is the variance of per capita emissions.
The measures on absolute values are different, but in time scale, the trends of those measures should be identical [31]. In this paper, we use the standard deviation and the Theil indicator to represent the variation of cross-country differences in emission patterns.
Suppose there are n countries (and regions), C_{it} is the per capita carbon emission of country i in year t. The standard deviation of C_{it} is:

$$SD_t = \sqrt{\frac{n\sum_{i=1}^{n}(\ln(C_{it}))^2 - \left(\sum_{i=1}^{n}\ln(C_{it})\right)^2}{n(n-1)}} \tag{2}$$

The Theil indicator:

$$Theil_t = \sum_{i=1}^{n}\left(\frac{C_{it}}{\sum_{i-1}^{n}C_{it}}\right)\ln\left(n\times\frac{C_{it}}{\sum_{i-1}^{n}C_{it}}\right) \tag{3}$$

β-convergence was put forward by Baumol [17], Barro and Sala-i-Martin [20]. We calculate the β-convergence as follows:

$$1/(T-1)\sum_{t_0+1}^{T}(\ln C_{it} - \ln C_{it-1}) = \alpha + \beta\ln C_{it_0} + v_i \tag{4}$$

where t_0 is the initial year, T is the number of years, v_i is an independent and identically distributed error term with zero mean and finite variance. α is a constant, β is a parameter testing the null hypothesis of divergence. C_{it} is the initial value of per capita emissions in country i in year t. If $\beta < 0$ and the test is significant, then there is absolute β-convergence in sample countries (and regions)
The economic levels, populations, resources, energy structures are quite different between countries (and regions) around the world. How these factors affect the emission patterns in different country groups? Here we use the conditional β-convergence:

$$1/(T-1)\sum_{t_0+1}^{T}(\ln C_{it} - \ln C_{it-1}) = \alpha + \beta\ln C_{it_0} + \gamma\ln z_i + v_i \tag{5}$$

where the vector of conditional variables z_i indicates the factors which might affect the emission patterns. In this paper, considering the findings in former studies of Strazicich and List [26], we select the per capita GDP in 2000 year U.S. dollars, sum of the populations, consumption amount of oil, gas and coal of the country groups in each year as the proxy indicators. We use geometric mean of each control variables to cover the whole time period. The analysis of conditional convergence gets practical meanings: if some variables are significant, then the government could take policy measures to regulate the certain variables thereby to control the emission trend efficiently.
Based on the research of Miketa and Mulder [30], the convergence speed is calculated as follows:

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$$\lambda = -[(1/T)\log(\beta + 1)] \tag{6}$$

β is calculated from equation (4) and equation (5).

2.2 Data source and data process

The emission data used in this paper are per-capita emission (tons CO2 equivalent per-capita). The per capita GDP in 2000 year U.S. dollars, populations and emission per-capita are from World Development Indicator 2008 [32]. The oil consumptions (Thousand barrels per day), natural gas consumptions (Billion cubic metres per year) and coal consumptions (Million tons oil equivalent per year) are from BP Statistical Review of World Energy 2008 [33].

The reasons we use per-capita CO_2 data rely on that the per-capita CO_2 data have low sensitive to national territory difference and they are comparable in big and small countries (and regions). Also the political meanings of per-capita CO_2 data are easy to be understood.

The data from many developing countries (and regions) are incomplete. There are also many new countries (and regions) (such as some places in Africa and Balkan). We exclude these countries (and regions). The CO_2 data in developing countries (and regions) before 1965 are few, and only some countries' (and regions') CO_2 data after 2005 were published, so the selected period is from 1965 to 2004. The GDP data of some developing countries (and regions) in 1960s are missing, so we use the earliest GDP data we can found in these countries (and regions) including Yemen, Ethiopia and Gambian. In 1960s, these countries (and regions) had not entered the fast growing period, so the starting time selection does not significantly affect the conclusions. Besides, in BP Statistical Review of World Energy 2008 [33], Belgium and Luxembourg's energy data were summed and counted as one. The population and energy consumption in Luxembourg are relatively small, so we approximately use the sum of Belgium and Luxembourg as Belgium itself. Some old data are missing form BP statistical review, so we use the newest data which are available from BP to calculate instead. The energy consumption data are incomplete in more than half of the developing countries (and regions). The explanatory power will be weakened a lot if these countries (and regions) are excluded. So the energy consumption structure affects analyses are only carried on developed countries (and regions).

After data processing, the data from 128 countries (and regions) in 40 years enter our research.

According to the United Nations, the countries are categorized into 5 groups based on the income level: 23 high income OECD countries (and regions), 16 high income Non-OECD countries (and regions), 31 upper middle income countries (and regions), 35 lower middle income countries (and regions) and 23 low income countries (and regions). The income levels did not change a lot in recent 50 years, so we do not consider the group changing.

3. The correlation-ship between per capita emission patterns and economic growth

In this section, we will discuss the relationship between per capita emission patterns and economic growth divided by countries income levels.

3.1 High income OCED countries (and regions)

High income countries (and regions) are the most powerful and influential on both policies and developments around the world. They are very active in the international issues of coping climate change and related negotiations. These countries (and regions) have been discharging pollution gases since the industrial revolution. Their cumulative emissions are the biggest in all five groups. The high income OCED countries hold the greatest responsibility in coping climate change. Since 1960s, these countries' per capita emissions have been rising except a few countries such as Australia, Ireland and France. The per capita emission of USA ranked the first in the past 40 years (Figure 1).

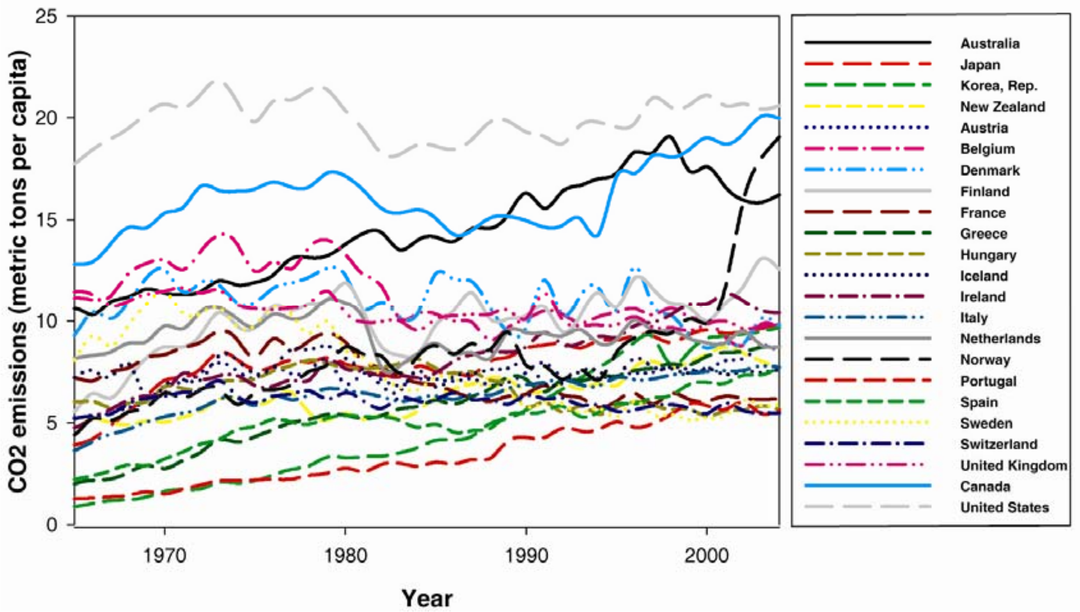

Figure 1. Per capita emissions in high income OECD countries (and regions)

Based on the calculation of equation (1), we found that:

(1) In 1965, the per capita emissions showed strong positive correlation with coal consumptions. In 1960s, coal hold big percentage in energy consumption structure. Compared with oil and gas, the CO_2 emission from coal is 36% higher than that from oil, 61% higher than that from gas. In 1965, the correlation indicator between coal consumptions and CO_2 emissions is 0.6698 (Table 1).

(2) In 2004, the correlation between emissions and other variables are weaker than in previous years. This phenomenon was partly caused by the energy structure reconstruction in many countries. Energy efficiency improvement was also very important. Besides, the coming into force of the international climate change agreements and the application of low carbon technologies kept downing the emissions in these countries (and regions).

Table 1. The correlation analysis of high income OECD countries (and regions)

			1965			
Correlation	Emission per capita	GDP per capita	Populations	Oil consumptions	Natural gas consumptions	Coal consumptions
Emission per capita	1					
GDP per capita	0.5431	1				
Populations	0.4589	0.2154	1			
Oil consumptions	0.6294	0.3367	0.9204	1		
Natural gas consumptions	0.6041	0.3109	0.8433	0.9812	1	
Coal consumptions	0.6698	0.3163	0.9069	0.9577	0.9149	1
			2004			
Emission per capita	1					
GDP per capita	0.4244	1				
Populations	0.435	0.3006	1			
Oil consumptions	0.5017	0.3108	0.974	1		
Natural gas consumptions	0.5415	0.2893	0.9422	0.9833	1	
Coal consumptions	0.5313	0.3108	0.9525	0.9898	0.9779	1

3.2 High income non OCED countries (and regions)

Most high income non OCED countries (and regions) are islands countries (and regions), such as French Polynesia, New Caledonia, Singapore, Cyprus, and Bahamas. Some Middle East countries (and regions) also belong to high income non OCED countries (and regions), including Israel, Saudi Arabia and United Arab Emirates. The high income non OCED countries (and regions) are usually small with low percentage of heavy industry and their tourism industry is well developed. So, most of these countries' (and regions') emission patterns are relatively steady (except United Arab Emirates, Brunei and Bahamas) (Figure 2).

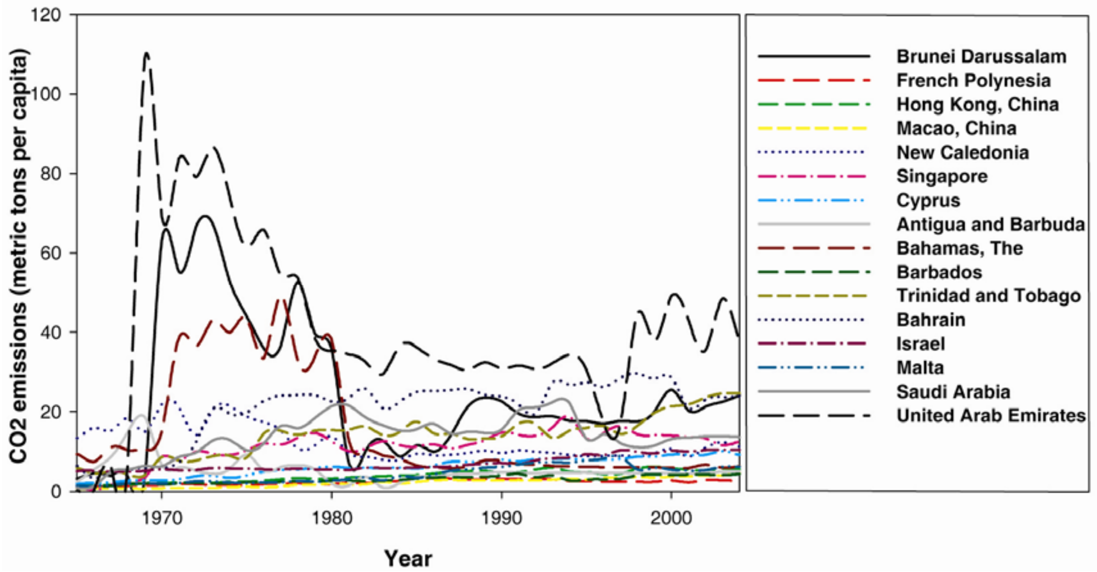

Figure 2. Per capita emissions in high income Non-OECD countries (and regions)

Because of the accessibility of the data, the energy consumption structure is not taken into the correlation analysis as in other four country groups, but only emission per capita, GDP per capita and population.

(1) In 1965, the per capita emissions showed weak negative correlation with GDP and population. For the countries (and regions) whose tourism industry and entrepot trade are well developed, the emissions were relatively small and had less correlations with economic growth.

(2) In 2004, the per capita emissions showed weak positive correlation with GDP. The indicators were still small when the economy grew (Table 2).

Table 2. The correlation analysis of high income Non-OECD countries (and regions)

Correlation 1965	Emission per capita	GDP per capita	Populations	Correlation 2004	Emission per capita	GDP per capita	Populations
Emission per capita	1			Emission per capita	1		
GDP per capita	-0.1096	1		GDP per capita	0.17	1	
Populations	-0.2345	-0.2332	1	Populations	0.0837	0.0424	1

3.3 Upper middle income countries (and regions)

The countries (and regions) in this group bear huge differences. Most countries' (and regions') emissions were low. Libya got the peak of carbon emission before 1970. From qualitative perspectives, the higher percentage of manufacturing in the whole industry, the higher per capita emissions these countries (and regions) got (Figure 3).

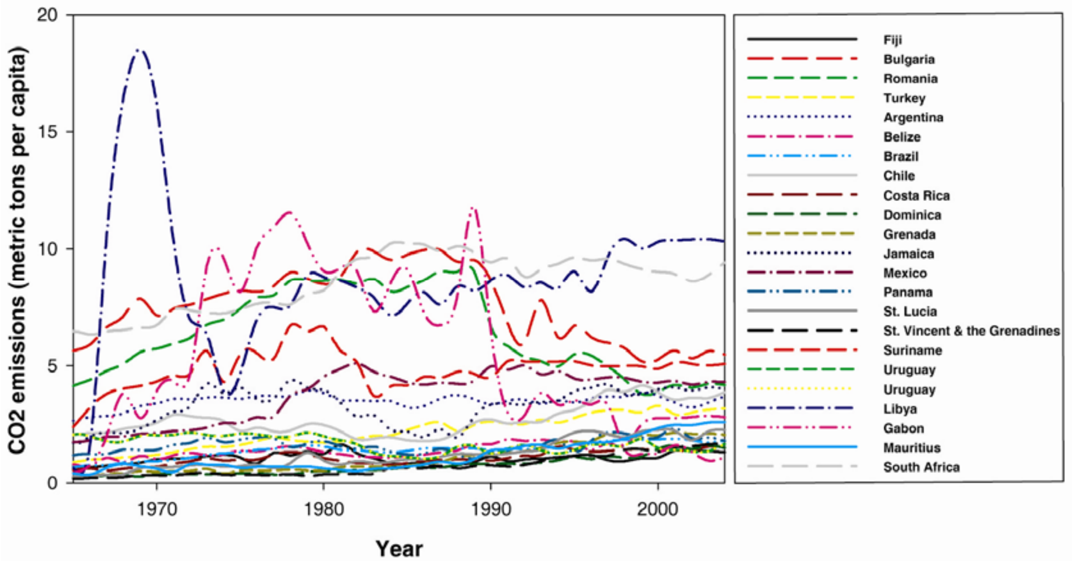

Figure 3. Per capita emissions in upper middle income countries (and regions)

(1) In 1965, the per capita emissions showed positive correlation with GDP. In 1960s and 1970s, the concept of emission reduction was not popular. The emissions increased along with economics growth (0.4404, Table 3).
(2) In 2004, the per capita emissions showed very weak correlation with population. Forty years after 1965, the population was no longer a major driving force of economy. The population has very weak correlations with emissions (0.0506).

Table 3. The correlation analysis of upper middle income countries (and regions)

Correlation 1965	Emission per capita	GDP per capita	Populations	Correlation 2004	Emission per capita	GDP per capita	Populations
Emission per capita	1			Emission per capita	1		
GDP per capita	0.4404	1		GDP per capita	0.1067	1	
Populations	0.0992	0.0653	1	Populations	0.0506	0.1544	1

3.4 Lower middle income countries (and regions)
The economy growth patterns are very different in this group. The emission patterns also vary widely (Figure 4).

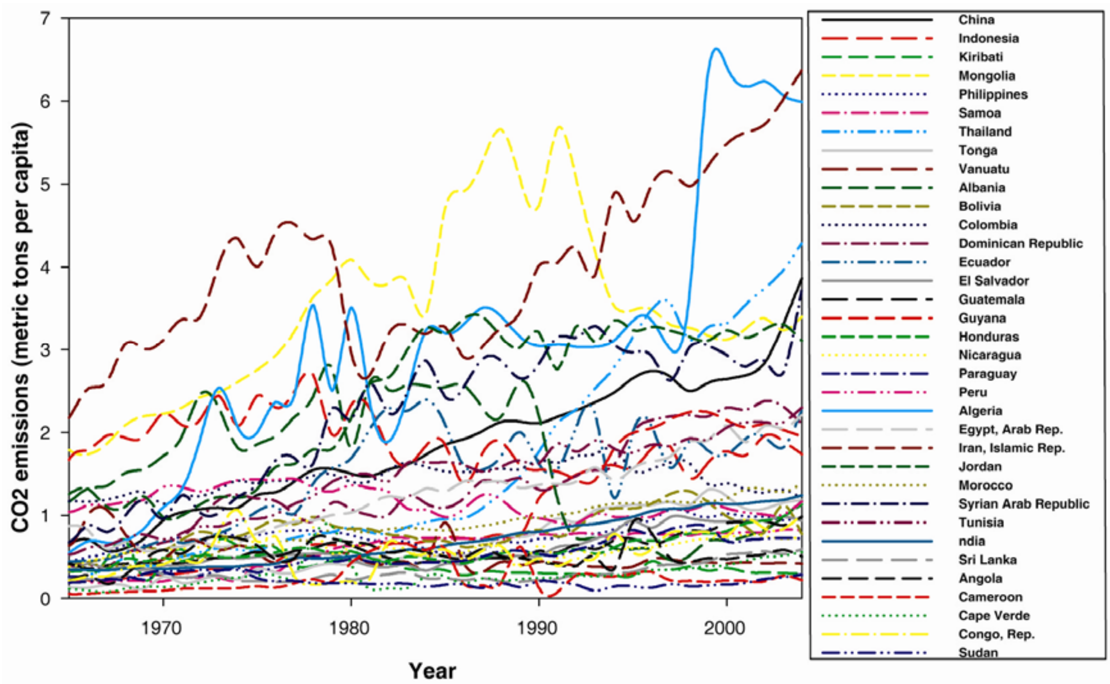

Figure 4. Per capita emissions in lower middle income countries (and regions)

(1) In 1965, the per capita emissions showed weak positive correlation with GDP. The subsistence emissions were the major emission sources in these countries (and regions). Owing to the relative low economic development level, the correlation between emission and economy is relatively small. There were few heavy industries in lower middle income countries (and regions).
(2) In 2004, the per capita emissions showed strong positive correlation with GDP. The developmental emissions took a larger share in 2004. The correlation indicator rose from 0.1706 in 1965 to 0.4256 in 2004, which means that the economy had stronger impacts to emissions (Table 4).

Table 4. The correlation analysis of lower middle income countries (and regions)

Correlation 1965	Emission per capita	GDP per capita	Populations	Correlation 2004	Emission per capita	GDP per capita	Populations
Emission per capita	1			Emission per capita	1		
GDP per capita	0.1706	1		GDP per capita	0.4256	1	
Populations	-0.0262	-0.4337	1	Populations	0.1772	-0.1768	1

3.5 Low income countries (and regions)

The low income countries (and regions) are the least developed countries (and regions) in the world. The amounts of emissions in this group are lower than in other four groups. The per capita emissions are less than 1 ton in most of the countries (and regions), which is only one fifth or even one tenth of the developed countries (and regions). The subsistence emissions are dominant emission sources (Figure 5).

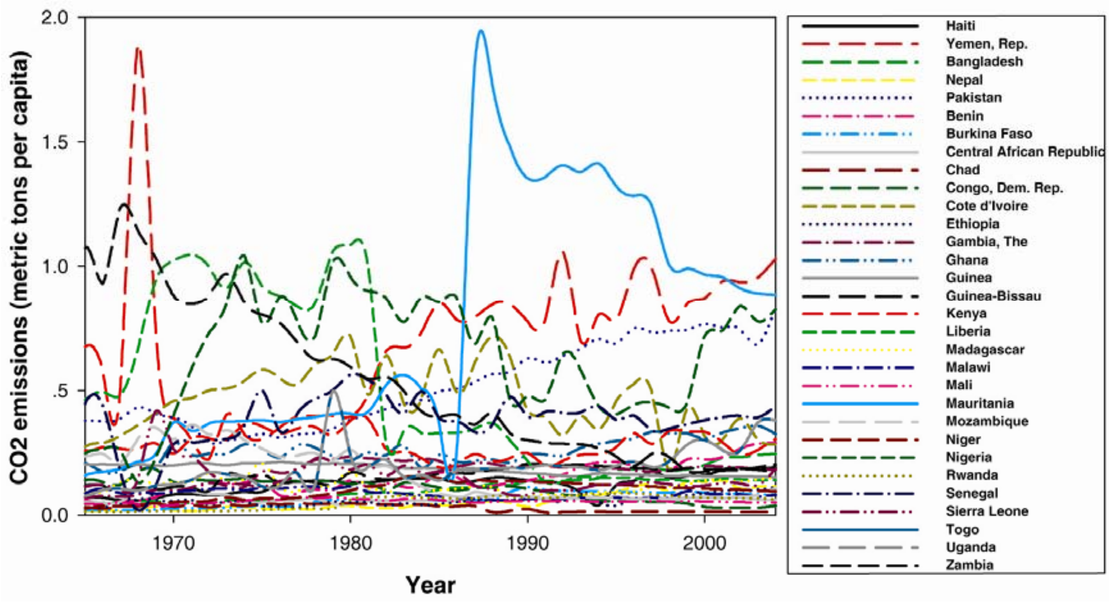

Figure 5. Per capita emissions in low income countries (and regions)

(1) In 1965, the per capita emissions showed strong positive correlation with GDP. The characteristics of economy styles, energy efficiency and technology in these countries (and regions) induced the emissions being sensitive to economic levels(r = 0.5612,Table 5). The population had little influence on emissions (r = 0.0022, Table 5).

(2) In 1965, the per capita emissions showed stronger positive correlation with GDP. In 2004, the influence of economy to emissions was stronger than before. But the war against poverty in these countries (and regions) still had a long journey to win. The population also had a positive affects (0.3112, Table 5).

Table 5. The correlation analysis of low income countries (and regions)

Correlation 1965	Emission per capita	GDP per capita	Populations	Correlation 2004	Emission per capita	GDP per capita	Populations
Emission per capita	1			Emission per capita	1		
GDP per capita	0.5612	1		GDP per capita	0.7007	1	
Populations	0.0022	-0.1802	1	Populations	0.3811	0.3112	1

4. Emission patterns analysis based on σ -convergence

The correlation could only reflect linear relationship from statistical characteristic angle. If we want to discuss the emission patterns from time series perspective, more methodologies are needed. We use σ -convergence to analyze the 40 years emission trends. The σ -convergence model is calculated here based on equation (2), (3). The results are shown in Figure 6.

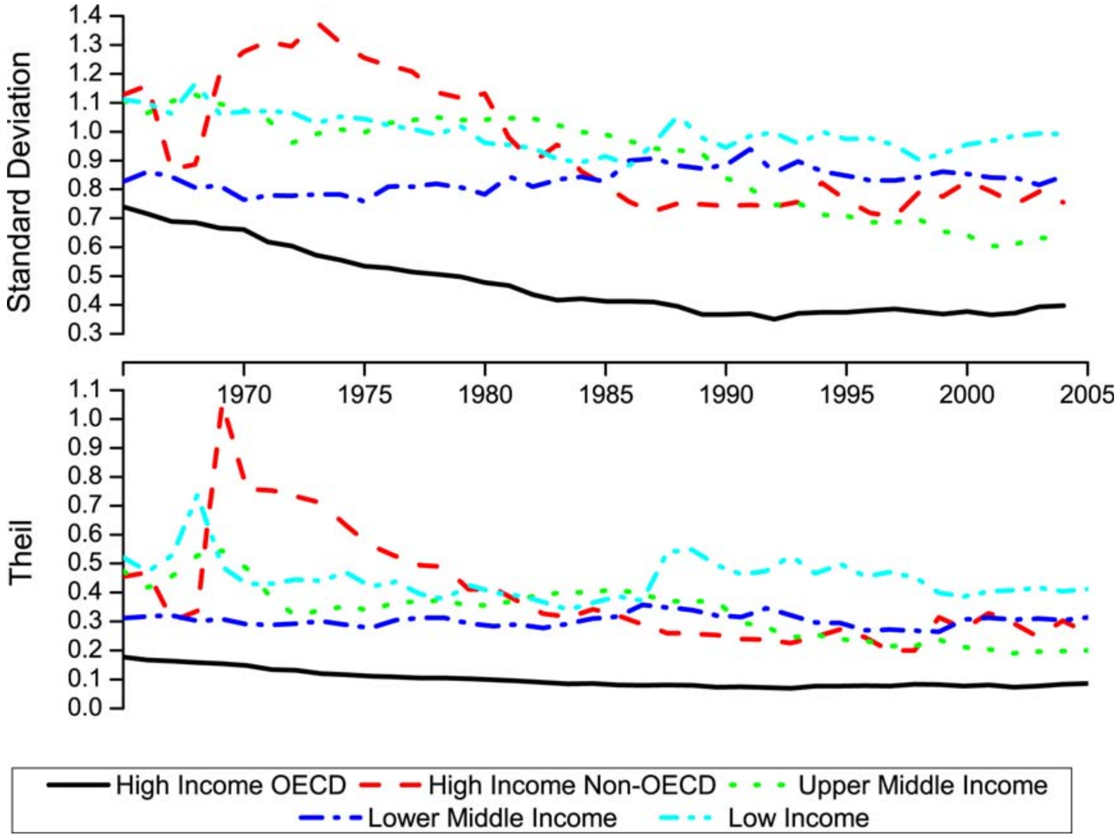

Figure 6. The standard deviation and the Theil indicators of different country groups from 1970 to 2005

From Figure 6, the standard deviations and the Theil indicators of high income OECD, high income Non-OECD, upper middle income, low income countries (and regions) all show decreasing trends. The indicators of lower middle countries (and regions) show slight difference. The economy implications are:
(1) High income OECD countries (and regions) showed a pattern of significant σ-convergence. The cross-country differences in emission per capita kept declining in last 40 years. The SD indicator declines from 0.9489 in 1960 to 0.4370 in 2004, and the Theil indicator declines from 0.3491 in 1960 to 0.0629 in 2004. The cross-country differences in emission levels increased a little after 2002.
(2) High income Non-OECD showed a pattern of σ-convergence after 1970s. The emission from United Arab Emirates decreased sharply in 1960s and 1970s. The differences among these countries (and regions) also decreased.
(3) Upper middle countries (and regions) showed a pattern of σ-convergence. These trends became more significant after 1990s.
(4) The cross-country differences of emission in lower income countries (and regions) increased from 1970s to 1980s. The typical countries (and regions) in this group such as China were entering the industrialized stage, which made the emissions from those countries (and regions) rising rapidly. Meanwhile, some other countries (and regions) in this group were steadily in emitting levels. So the inner-differences are increasing in lower income countries (and regions). The SD and Theil indicators rose from 0.7589 and 0.2781 in 1975 to 0.9075 and 0.3490 in 1987, respectively. After then, convergence occurred again. The SD and Theil indicators declined to 0.8447 and 0.3141 in 2004, respectively.
(5) The variation of low income countries (and regions) decreased slightly overall. The SD and Theil indicators decreased from 1.3292 and 1.1202 in 1960, to 0.9925 and 0.4119 in 2004, respectively. The low income countries (and regions) are still in the state of poverty. The disparity degrees of this country group are the biggest in all the 5 country groups.
(6) The results indicate that the richer countries (and regions) show more significant convergence. The poor countries (and regions) have different energy structures and economic growth speeds, the diversity of these countries (and regions) will keep stable in most years. The differences among poor countries (and regions) are greater than rich countries (and regions).

5. Emission patterns analysis based on β-convergence

We will further explore the mechanisms behind the differences in the process of development disclosed in previous sections. The β-convergence is used here.

5.1 Emission patterns analysis based on absolute β-convergence

As we defined above, the absolute β-convergence of cross-country emissions expressed a tendency of converging toward a uniform level. According to equation (4), the values of β are calculated. The smaller the β values, the more obvious behavior of "catch up" effects are. The results of absolute β-convergence are shown in Table 6.

Table 6. Absolute β-convergence for emission patterns

	coefficients	**standard deviation**	**t**	**P>|t|**	**95% confidential intervals**		**R-squared**
high income OECD countries (and regions)							
β	-.0029404	0.0006995	-4.20	0	-.0043951	-.0014857	0.4569
Intercepts	0.0337849	0.0054569	6.19	0	0.0224366	0.0451332	
high income Non-OECD countries (and regions)							
β	-.0058522	0.0018157	-3.22	0.006	-.0097466	-.0019579	0.4260
Intercepts	0.0603235	0.0090298	6.68	0	0.0409564	0.0796906	
upper middle income countries (and regions)							
β	-.0073212	0.0017033	-4.30	0	-.0108635	-.0037789	0.4680
Intercepts	0.0394434	0.0045932	8.59	0	0.0298912	0.0489955	
lower middle income countries (and regions)							
β	-.0143292	0.0058392	-2.45	0.020	-.0262091	-.0024492	0.1543
Intercepts	0.0364715	0.0044976	8.11	0	0.027321	0.045622	
low income countries (and regions)							
β	-.0572362	0.0173684	-3.30	0.003	-.0927586	-.0217137	0.2724
Intercepts	0.0224343	0.0050649	4.43	0	0.0120755	0.0327932	

From Table 6 We can draw a conclusion that if we take the whole period of 40 years into consideration, all the countries (and regions) show a pattern of absolute β-convergence. In short, the results of our test for β-convergence provide evidences that lagging countries (and regions) are catching up with developed countries in emission levels.

The results of absolute β-convergence confirm the conclusions in section 4. A country with a relatively low initial emission level tends to carry a faster growth of emissions. In any case, it should be noted that the low R-squared indicates that the explanatory value of equation (4) is very limited (In all five country groups, the R-squared values are less than 0.5. The R-squared value of lower middle income countries are only 0.1543), which suggests the existence of factors impacting cross-country differences in emission patterns other than those in equation (4). In the next section we deal with these issues by exploring patterns of conditional β-convergence.

5.2 Emission patterns analysis based on conditional β-convergence

In this section, we concern on convergence of CO_2 emissions in different countries (and regions) toward different levels, to verify that convergence is conditional determined by the similarities of countries' (and regions') characteristics. According equation (5), the results of high income OECD countries (and regions) are shown as Table 7:

Table 7. Conditional β-convergence for emission patterns in high income OECD countries (and regions)

	coefficients	standard deviation	t	P>|t|	95% confidential intervals		R-squared
β	-.0015349	.0006346	-2.42	0.028	-.0028803	-.0001895	0.8250
GDP per capita	.0051857	.0096754	0.54	0.599	-.0153253	.0256966	
Populations	.005599	.0180623	0.31	0.761	-.0326913	.0438894	
Oil	.006472	.0052661	1.23	0.237	-.0046917	.0176357	
Natural gas	.0005504	.001342	0.41	0.687	-.0022945	.0033954	
Coal	.0048274	.0020543	2.35	0.032	.0004725	.0091824	
Intercepts	.0085809	.0106353	0.81	0.432	-.013965	.0311269	

We put all the conditional variables (GDP per capita, populations, oil, natural gas, coal) into the model to analyze the pattern of convergence (the value of β is -.0015349). But from statistical perspective, the results are insignificant. Further parameter adjustment is needed.

The stepwise method is used in the adjustment process, and the biggest significant level is set to be $p = 0.2$. The statistical adjusted results are shown in Table 8. Other 4 groups' results which have been amended are also shown. The convergence speed is calculated according to equation (6).

Table 8. Adjusted conditional β-convergence for emission patterns

	coefficients	standard deviation	t	P>|t|	95% confidential intervals		R-squared	Speed
high income OECD countries (and regions)								
β	-0.0014829	0.0005029	-2.95	0.008	-0.0025354	-0.0004304	0.8207	0.00161%
Oil	0.0090409	0.0025686	3.52	0.002	0.0036648	0.014417		
Coal	0.0049665	0.0018271	2.72	0.014	0.0011422	0.0087907		
Intercepts	0.014196	0.0052434	2.71	0.014	0.0032214	0.0251706		
high income Non-OECD countries (and regions)								
β	-0.0052097	0.0009548	-5.46	0.000	-0.0072725	-0.0031469	0.8543	0.00567%
Populations	0.0273123	0.0044172	6.18	0.000	0.0177694	0.0368551		
Intercepts	0.0326598	0.0065038	5.02	0.000	0.0186091	0.0467104		
upper middle income countries (and regions)								
β	-0.0073212	0.0017033	-4.30	0.000	-0.0108635	-0.0037789	0.4680	0.00798%
Intercepts	0.0394434	0.0045932	8.59	0.000	0.0298912	0.0489955		
lower middle income countries (and regions)								
β	-.0135927	0.0046894	-2.90	0.007	-0.0231446	-0.0040408	0.4718	0.01486%
GDP per capita	0.0178225	0.0040639	4.39	0.000	0.0095445	0.0261004		
Intercepts	0.0251481	0.004438	5.67	0.000	0.0161081	0.0341881		
low income countries (and regions)								
β	-0.0500319	0.0166047	-3.01	0.005	-0.084045	-0.0160187	0.3822	0.05573%
GDP per capita	0.0153643	0.0068873	2.23	0.034	0.0012563	0.0294724		
Intercepts	0.0217982	0.0047583	4.58	0.000	0.0120514	0.0315451		

The results in Table 8 are all statistical significant. We could find that all the five groups show patterns of convergence, similar to the previous conclusions.

(1) Oil and coal consumptions are the main driving forces in high income OECD countries (and regions). From Table 8, the coefficient of oil is 0.0090409[0.0025686], the coefficient of coal consumption is 0.0049665[0.0018271]. These outcomes are statistical significant. Compared with economic growth, population and natural gas consumption, oil and coal consumptions have more effects on emission

patterns. Oil has stronger effects than coal. Both oil and coal are carbon-intensity energies. The developing phases make these two resources having more impact power than other variables we selected. From the policy making perspective, adjusting energy structure and improving low carbon technology will be helpful in reducing the emission levels.

(2) Population is the main factor affecting high income Non-OECD countries (and regions) emission levels. The regression coefficient of population is 0.0273123[0.0044172], the t-statistic value is 6.18, and the p value is 0.000. That outcome is very significant. Those results indicate the big influences of population on carbon emissions. The reason might be the economy structures of these countries (and regions). These countries (and regions) are rich and with low proportion of heavy industry, so the residents' consumption emissions contribute much more than those in other countries (and regions). Besides, the tourism industries are well developed in many high income Non-OECD countries (and regions). The emissions from people's daily living affect the emission trends a lot.

(3) Nether GDP and population are not the main factors affecting upper middle income countries' (and regions') emission levels. The p values of GDP and population are 0.525 and 0.648, respectively. So these two variables are eliminated after the adjusting process. This conclusion is same as in high income OECD countries (and regions). It should be noted that because of the lack of data, we do not analyze the energy structure effects in upper middle income countries (and regions). Therefore when the growth of economy is not the direct reason of emission level changing, usage of high carbon intensity energy resources or lag in technology development might be the reasons of various emission patterns. The R-squared is only 0.4680 also implies the above speculation.

(4) GDP per capita is the main driving force for lower middle income and low income countries' (and regions') emission levels. The GDP Coefficients of these two groups are 0.0178225[0.0040639] and 0.0153643[0.0068873] respectively. These numbers imply that when economy grows, the difference between countries (and regions) of carbon emission levels might decrease. But the R-squared values are relative small, so further works are still needed to be done to analyze the mechanism in depth.

(5) The poorer countries (and regions) have a higher convergence speed. From the rightmost series of Table 8 we can conclude that the convergence speed slows down from the last row to the first row. This speed of convergence is the time needed for the emission levels to move its initial level halfway [30].

(6) The increase of GDP, population, oil and coal consumptions in different country groups positively affect the convergence indicators. For all the 5 groups, their conditional variables are all positive. Such as in the low income countries (and regions), the development of economy change along with emission convergence.

6. Conclusion

This paper analyzed the main driving factors of carbon emission levels in 128 countries (and regions) from 1965 to 2004.

The pattern of convergence was shown in five country groups. From the results of σ-convergence we found that in most countries (and regions), cross-country differences in absolute emission levels tend to decline. The lower middle countries (and regions) showed diversity in some years, but they became converging after 1987. Both the absolute β-convergence and conditional β-convergence were consistent.

In terms of emission levels, lagging countries (and regions) tend to catch up with advanced nations, with convergence tending to be conditional on country-specific characteristics. To different countries (and regions), the main factors affecting their emission patterns were quite different. Oil and coal consumptions were the main driving force for high income OECD countries (and regions). Populations were the main reason affecting high income Non-OECD countries (and regions) emission levels. Neither GDP no population were not the main reasons affecting upper middle income countries' (and regions') emission levels. GDP per capita was the main driving force for both lower middle income and low income countries' (and regions') emission levels. Referred to the converge speed, the poorer countries (and regions) have a higher convergence speed.

From our analysis we could conclude that, different economic levels have different emission patterns driving factors. The finding of natural gas has weak influence on emissions in all the countries might because that natural gas was a energy resource with relative low carbon intensity compared to oil and coal, and gas had lower percentage usage in all the energy structures.

The history of developed countries' emission patterns could be divided into two phases. The first phase is the early industrialization period. Coal was the major energy resources in that phase. The second phase began from the transition from solid energy to fluid energy. Oil was widely used and natural gas was more and more popular. The concept of environmental protection has gradually filtered into people's recognization. The world is taking active steps to handle with climate change problem. The results of conditional β-convergence shows that promote the use of low carbon-intensity energy such as natural gas will slow down the increase speed of emissions. Therefore, for the developed countries, they should improve their energy efficiency, encourage and support the development of low carbon-intensity energies.

The international climate change negotiations should consider the different income levels of all the countries (and regions). Because the income levels varied a lot, the main driving forces of emission patterns also changes. It is unfair to addressing all countries (and regions) to the same responsibility.

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