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KEY TRENDS OF CLIMATE CHANGE IN THE ASEAN COUNTRIES

The IPAT Decomposition Analysis 1980–2005

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1. INTRODUCTION

Decomposition analyses of energy consumption and CO_2 emissions have mainly focused on effects of changes in economic activity, energy intensity and fuel mix, and structural changes in energy consumption in different countries or different sectors of the economy. This e-Book introduces a different perspective by identifying five globally relevant factors affecting CO_2 emissions. Changes in carbon intensity of primary energy, efficiency of the energy system, energy intensity of the economy, level of economic development, and the amount of population have been identified by extending the well-known IPAT identity. Empirical part focuses on CO_2 emissions from fuel combustion in the ASEAN countries between the years 1980 and 2005. CO_2 emissions are considerable low in many ASEAN countries but have increased in recent years due to the rapid economic growth and increased reliance on fossil fuels. Emission and energy intensities have increased during the industrialization process, but with a shift towards a more service-oriented economy and the increase in GDP per capita, the intensities have started to decrease in some ASEAN countries. However, these changes have not been able to slow down the rapid increase in CO_2 emissions due to the growth of both the economy and the population.

With the rapid economic development of the member countries of the Association of South East Asian Nations (ASEAN) and nations such as China and India since the mid-1980s, the Asia-Pacific region has emerged as the growth centre of the global economy. However, many countries in the region have, instead of being successful, faced serious social and environmental problems, particularly with regard to deforestation, land degradation and the loss of biological diversity.

Climate change has been regarded one of the major environmental threats to developing countries. The need to develop theoretical and empirical research in the field of climate and energy policy analysis has been widely recognized. Energy and climate policy planning requires in-depth analyses of current trends and structures of energy production systems and related emission flows. Possibilities to reduce greenhouse gas emissions depend critically on economic growth and on the development of energy efficiency in economy-wide production systems.

The ASEAN Leaders have expressed their concern and commitment for ASEAN to play a proactive role in addressing climate change through their declarations to the 2007 Bali and 2009 Copenhagen UN Conferences on Climate Change. They view the protection of the environment and the sustainable use and management of natural resources as essential to the long-term economic growth and social development of countries in the region. The ASEAN Vision 2020 calls for “a clean and green ASEAN” with fully established mechanisms to ensure the protection of the environment, sustainability of natural resources, and high quality of life of people in the region. (Letchumanan, 2010)

ASEAN Leaders have noted that: “We acknowledged the energy cooperation between ASEAN and Japan in promoting energy efficiency and conservation as well as new and renewable energy, and stressed the need for closer cooperation. The ASEAN Leaders welcomed Japan’s efforts to create a low-carbon society.

We appreciated Thailand's offer for the use of the Practical Energy Management Training Center in Thailand which was established with funding from Japan to other ASEAN Member States interested in energy conservation in factories." (Point 11, Association of South East Asian Nations, 2009)

Thus, low carbon society is key energy policy target of ASEAN countries. Our analysis in this e-book gives analytical background to this strategy. This e-book also indicates that ASEAN countries have very different kind of challenges for low carbon strategy. The e-book provides useful information for ASEAN energy policy formulation and implementation of the Bali Roadmap.

This study presents a comparative analysis of the driving forces behind change in CO_2 emissions from fuel combustion in eight ASEAN member countries: Brunei, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. Analyses for Cambodia and Lao PDR are not provided due to data limitations and unreliability concerning the analysed time period 1980–2005.

The applied decomposition analysis is introduced in section 2. Section 3 gives the essential background information for the analysis, i.e. trends of CO_2 emissions from fuel combustion and gross domestic product (GDP) during the studied period. In section 4, results of the decomposition analysis are presented and preliminary interpretations given for each analysed country. Sections 5, 6 and 7 present the benchmarking results from the decomposition analyses of China and India (section 5), United States, OECD Europe and Japan (section 6), and the World total (section 7). Finally, section 8 presents the conclusions. Special references are made to the policy analyses related to the Bali agreement and zero-carbon strategies of the ASEAN countries.

2. DECOMPOSITION ANALYSIS

The approach presented in this e-book applies decomposition analysis of a change in CO_2 emissions to explain underlying causes of change. The decomposition approach for economic time series was introduced in the 1950s. Since the 1980s, decomposition analysis has been applied especially in the field of energy economics (Ang 2004a). In recent years, decomposition analysis has been increasingly used to explain change in energy-related greenhouse gas emissions such as CO_2 emissions. We cannot provide a review of literature or detailed references here, but the main focus of decomposing CO_2 emissions has been on energy use in different sectors of the economy at the national level, or then decomposition has been restricted to a specific sector such as electricity generation, manufacturing industry, or transport. International comparisons based on decomposition analysis have also been carried out, mainly for industrialised countries. The ASEAN countries have been explicitly analysed earlier by Luukkanen and Kaivo-oja (Luukkanen and Kaivo-oja, 2004), and some of them recently by Shrestha et al (Shrestha et al, 2009). Decomposition analyses focusing on a single ASEAN member country such as Thailand are available as well (Bhattacharyya and Ussanarassamee, 2005; Limmeechokchai and Suksuntornsiri, 2007).

The increasing amount of empirical research and the fact that a widening variety of different decomposition methods have been developed urgently call for methodological discussion. For reviews of different decomposition methods, see e.g. Ang & Zhang (Ang & Zhang, 2000), and Ang et al (Ang et al, 2003). Different decomposition methods may give different results with the same data, and one method may provide a larger residual term than another. “Complete” decomposition without a residual term (or with a procedure to allocate the residual to contributing factors) has also been developed. Ang (Ang, 2004b) has provided criteria and suggestions for preferred decomposition methods. The method applied here is based on a method developed by Sun (Sun, 1996; 1998) which is among the recommended methods by Ang (Ang, 2004b). It has been also pointed out that Sun’s method is equal to a method based on the Shapley index (Ang et al, 2003; cf. Albrecht et al, 2002). Thus, the actual decomposition method applied in the approach of this e-book, can be called as the Sun/Shapley method.

The objective of decomposition analysis in this e-Book is to divide observed change in CO_2 emissions from fuel combustion into contributions from different factors of interest identified in Equation (1). The method is based on a simple two-factor decomposition, which provides results to be used as a starting point for second decomposition, and this “chaining” will be repeated until the contributions of all factors identified in Equation (1) have been calculated. This kind of chained decomposition has been recently used by Vehmas (Vehmas, 2009) for decomposing CO_2 emissions from fuel combustion in selected countries (EU-25 countries, the USA, Japan, China, India, and Brazil).

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP \qquad (1)$$

In Equation (1), CO2 refers to carbon dioxide emissions from fuel combustion, TPES is total primary energy supply, FEC is final energy consumption, GDP is real gross domestic product adjusted by purchasing power parities, and POP is the amount of population. The contributions of the factors on the right hand side of Equation (1) will be calculated as shown in Equations (2a–2e), where the explaining factors are chained on the basis of assumed causality: Change in CO_2 emissions from fuel combustion is a result of change in using primary energy (TPES) which is affected by change in final energy consumption (FEC) which, in turn, is affected by change in economic growth (GDP) due to changes in population (POP). It is possible to chain these explaining variables in a different order which may provide different results and requires a different assumed causality.

$$\frac{CO2}{TPES} = (TPES_0 + \lambda_1 \Delta TPES_{t0}) \times \Delta\left(\frac{CO2}{TPES}\right)_{t0} \qquad (2a)$$

$$\frac{TPES}{FEC} = \left(\left(\frac{CO2}{TPES}\right)_0 + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES}\right)_{t0}\right) \times (FEC_0 + \lambda_2 \Delta FEC_{t0}) \times \Delta\left(\frac{TPES}{FEC}\right)_{t0} \qquad (2b)$$

$$\frac{FEC}{GDP} = \left(\left(\frac{CO2}{TPES}\right)_0 + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES}\right)_{t0}\right) \times \left(\left(\frac{TPES}{FEC}\right)_0 + (1-\lambda_2)\Delta\left(\frac{TPES}{FEC}\right)_{t0}\right) \times$$
$$(GDP_0 + \lambda_3 \Delta GDP_{t0}) \times \Delta\left(\frac{FEC}{GDP}\right)_{t0} \qquad (2c)$$

$$\frac{GDP}{POP} = \left(\left(\frac{CO2}{TPES}\right)_0 + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES}\right)_{t0}\right) \times \left(\left(\frac{TPES}{FEC}\right)_0 + (1-\lambda_2)\Delta\left(\frac{TPES}{FEC}\right)_{t0}\right) \times$$
$$\left(\left(\frac{FEC}{GDP}\right)_0 + (1-\lambda_3)\Delta\left(\frac{FEC}{GDP}\right)_{t0}\right) \times (POP_0 + \lambda_4 \Delta POP_{t0}) \times \Delta\left(\frac{GDP}{POP}\right)_{t0} \qquad (2d)$$

$$POP = \left(\left(\frac{CO2}{TPES}\right)_0 + (1-\lambda_1)\Delta\left(\frac{CO2}{TPES}\right)_{t0}\right) \times \left(\left(\frac{TPES}{FEC}\right)_0 + (1-\lambda_2)\Delta\left(\frac{TPES}{FEC}\right)_{t0}\right) \times$$
$$\left(\left(\frac{FEC}{GDP}\right)_0 + (1-\lambda_3)\Delta\left(\frac{FEC}{GDP}\right)_{t0}\right) \times \left(\left(\frac{GDP}{POP}\right)_0 + (1-\lambda_4)\Delta\left(\frac{POP}{EMP}\right)_{t0}\right) \times \Delta POP_{t0} \qquad (2e)$$

In Equations (2a–2e), parameters λ_1, λ_2, λ_3 and λ_4 refer to shares of corresponding joint effects (residuals) allocated to factors in each of the chained two-factor decompositions. Subscript 0 refers to the base year (1980) value and subscript t0 refers to a deduction of the base year value from the value at year t (2005).

The effect of CO_2/TPES refers to the contribution of the change in CO_2 intensity of primary energy use to CO_2 emissions. In practice, change in CO_2 intensity is a result of several things. One of the most obvious issues is fuel switch, i.e. change from the use of one energy form to another with different carbon content (if any). Examples of significant switches include changes from fuels with a high carbon content – such as coal or oil – to energy sources with a lower or zero carbon content such as nuclear power, renewables, or natural gas, or vice versa. It is important to study this effect further by using data including the shares of different primary energy sources. In this e-book, data on primary energy sources is used only to interpret the decomposition results, especially the CO_2/TPES effect.

The effect of TPES/FEC refers to the efficiency of the energy transformation system, i.e. efficiency in transforming primary energy into different energy carriers such as electricity or heat. This can be influenced by e.g. a switch from fuel use to electricity use, or vice versa, or technological changes in fuel combustion such as a shift from separate heat and electricity production to combined heat and power production (CHP) or vice versa.

The effect of FEC/GDP refers to the energy intensity of the whole economy. This can be influenced by several factors, such as changes in the industrial structure from energy intensive to less energy intensive industrial branches, a shift from industrial production towards services in terms of GDP shares, or technological development inside energy-consuming fields of the economy. If the shares of different sectors of the economy in GDP and FEC are available, it is possible to analyse the structural effect in more detail. This kind of analysis is, however, not provided in this e-book.

The effect of GDP/POP refers to the amount of economic activity per capita which is influenced by economic growth and changes in the amount of population.

The effect of POP refers to changes in the amount of population brought about by changing birth and death rates as well as changes in international migration. We have not considered population growth the most important factor explaining CO_2 emissions as the original IPAT equation suggests. Instead, we prefer the causality explained above.

The decomposition analysis performed in this e-book has been derived on the basis of the so-called IPAT identity, later also referred to as Kaya equation. Our decomposition approach includes the basic components of the IPAT identity: population, affluence, and technological development (Fischer-Kowalski & Amann, 2001; Cole & Neumayer, 2004). This kind of application is useful. For example, the Intergovernmental Panel on Climate Change (IPCC, 2001) has applied IPAT equation in their studies of CO_2 emission levels.

3. CO_2 EMISSIONS FROM FUEL COMBUSTION AND GDP IN THE ASEAN COUNTRIES

Figure 1 gives an overview of the differences in the changing patterns of CO_2 emissions from fuel combustion in the ASEAN countries and some reference countries during the time period 1980‒2005. Globally, CO_2 emissions in 2005 were 1.5 times higher than in 1980. The growth of CO_2 emissions has been extremely rapid in Thailand, Malaysia, Vietnam and Indonesia, where CO_2 emissions from fuel combustion in 2005 were 5‒6 times higher than in 1980. In the industrial countries, represented here by OECD Europe, Japan and the U.S., CO_2 emission growth has been modest – in Europe, the economic collapse of the East European countries has slightly decreased emissions during the studied period. The decomposition analysis provided in the next section gives more information about the factors behind the change in CO_2 emissions from fuel combustion between the years 1980 and 2005 in the ASEAN countries.

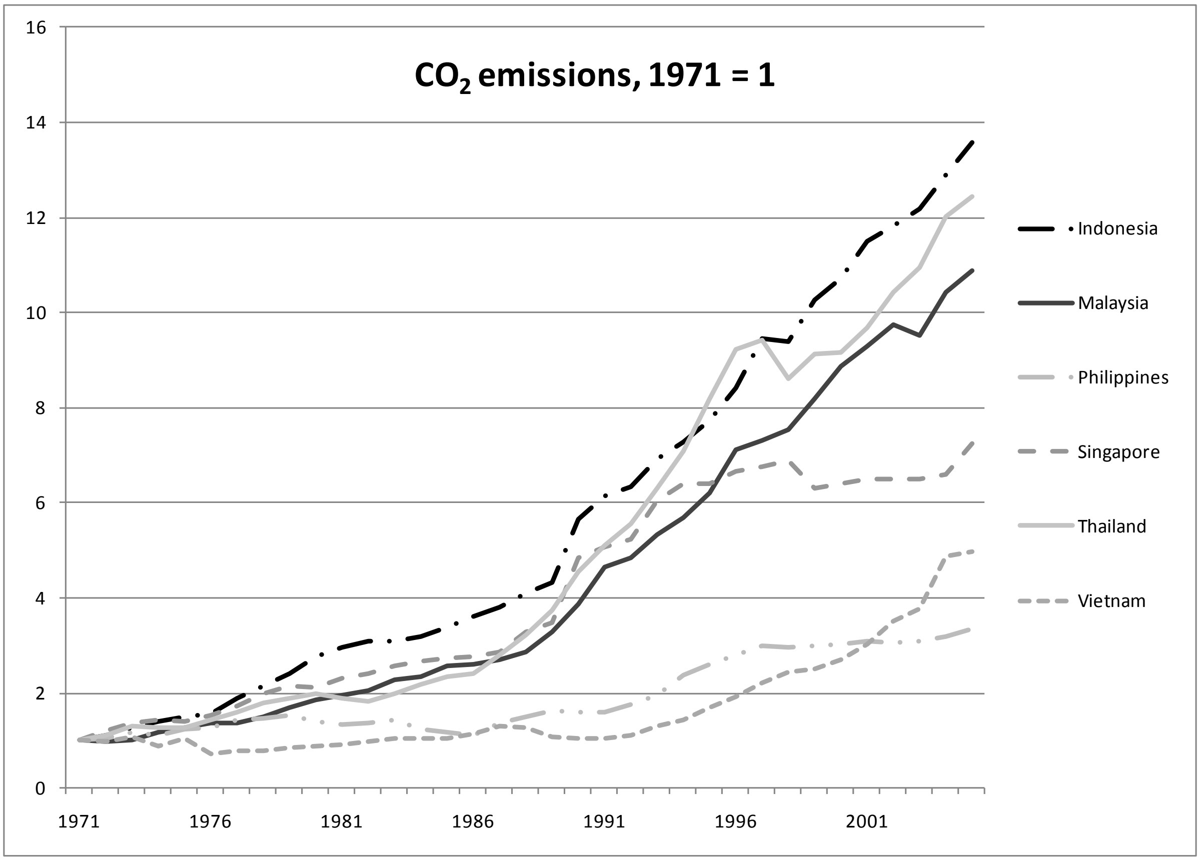

Figure 1. CO_2 emissions from fuel combustion in the ASEAN countries 1980‒2005 as an index, 1980=100. Source: IEA 2007a.

Figure 2 shows the changing pattern of economic development (GDP adjusted by purchasing power parities) in the ASEAN countries and some reference countries in 1980–2005. Economic growth in Singapore and Vietnam has exceeded other ASEAN countries but remained far behind the extremely rapid growth of GDP in China where GDP in 2005 was over ten times higher than in 1980. Other "ASEAN tigers" include Malaysia and Thailand where economic growth has been similar to India, with economic growth faster than in the United States, Japan, and OECD Europe. Only Philippines and Brunei have remained at modest "western" level in terms of economic growth. For Lao PDR and Cambodia, the least developed ASEAN countries, International Energy Agency (IEA 2007a) has not provided any data.

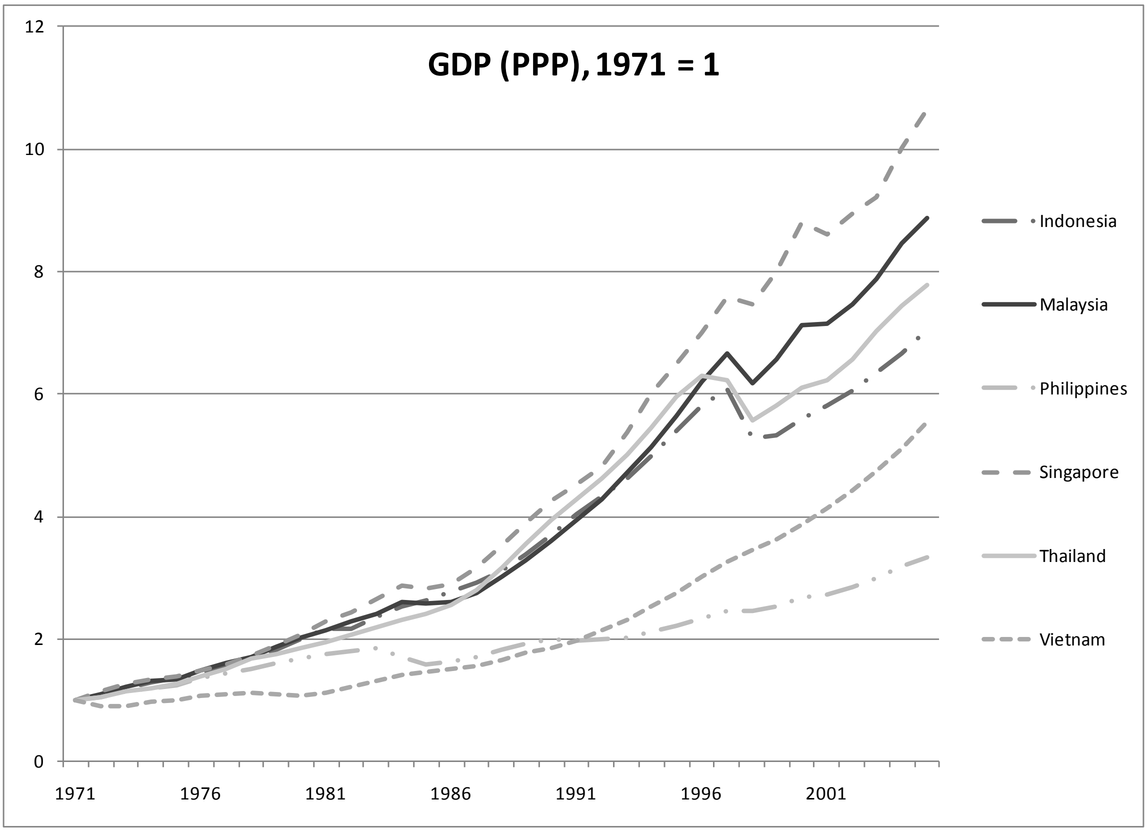

Figure 2. GDP index (using purchasing power parities PPP) in the ASEAN countries and in some reference countries 1980–2005 (1980=100). Source: IEA 2007a.

4. DRIVING FORCES BEHIND CHANGING CO_2 EMISSIONS IN THE ASEAN COUNTRIES, 1980–2005

In the following, results from the decomposition analysis described in the previous section will be presented. Results are provided for those ASEAN countries where data is available for the years 1980–2005 in the International Energy Agency database (IEA 2007a; 2007b). Data for Lao PDR is not available at all and data for Cambodia is available only for the years 1995–2005, so these countries have been excluded from the analysis. Moreover, according to the results, data for Brunei and Myanmar seems not to be very reliable. A correction concerning final energy consumption (FEC) time series and statistical difference in the IEA database have been carried out for Vietnam.

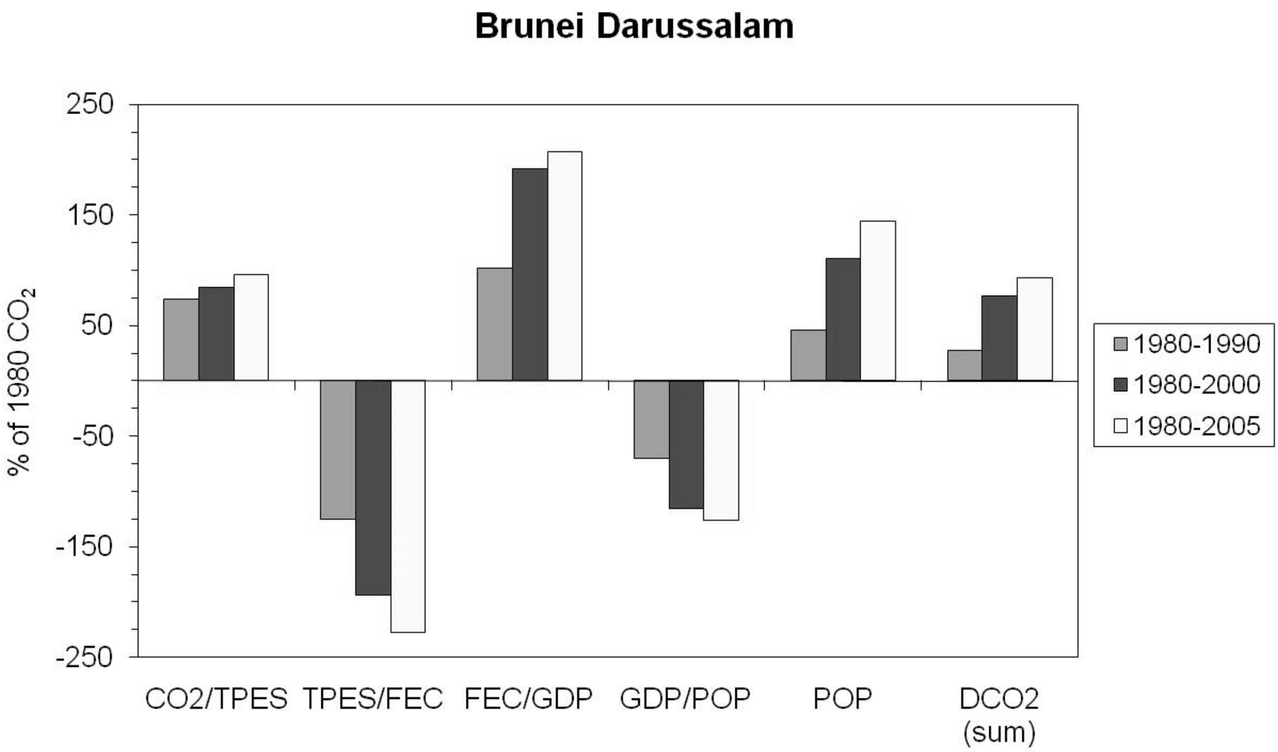

Figure 3. Decomposition of CO_2 emissions from fuel combustion in Brunei 1980–2005, contributions of five factors in percentage of 1980 CO_2 emission level. Source: Authors.

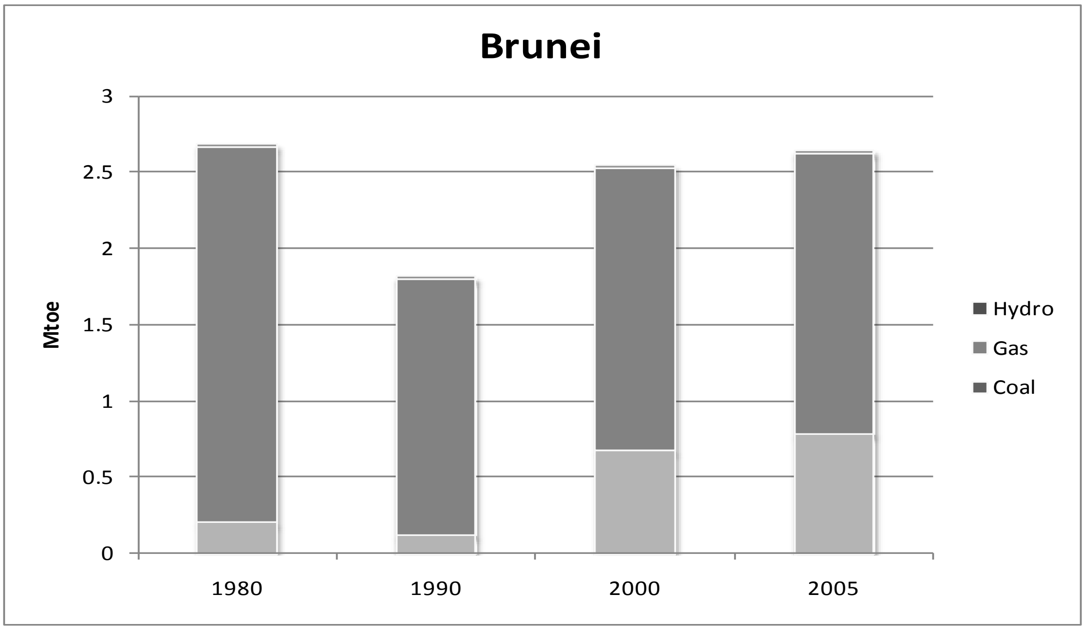

Figure 4. Total Primary Energy Supply (TPES) by energy source in Brunei 1980–2005. Source: IEA 2007b.

In Brunei (see Figure 3), the decomposition analysis indicates that factors TPES/FEC and GDP/POP have decreased CO_2 emissions from fuel combustion. This change is very surprising when compared with other ASEAN countries. Figure 4 shows that primary energy supply in Brunei has slightly decreased in 1980-2005, which explains a minor part of the result. Furthermore, economic model of Brunei is exceptional because the government has not implemented personal or company taxation and also promotes other measures of development than the traditional GDP. This significant change has occurred in the observed time period. Economic structure in Brunei is not traditional because the GDP share of services is 50 % and industry 45 %. However, data uncertainties may have a significant role in the surprising Brunei results. On the other hand, increased energy intensity of the economy (factor FEC/GDP) and population growth have increased CO_2 emissions in Brunei as expected.

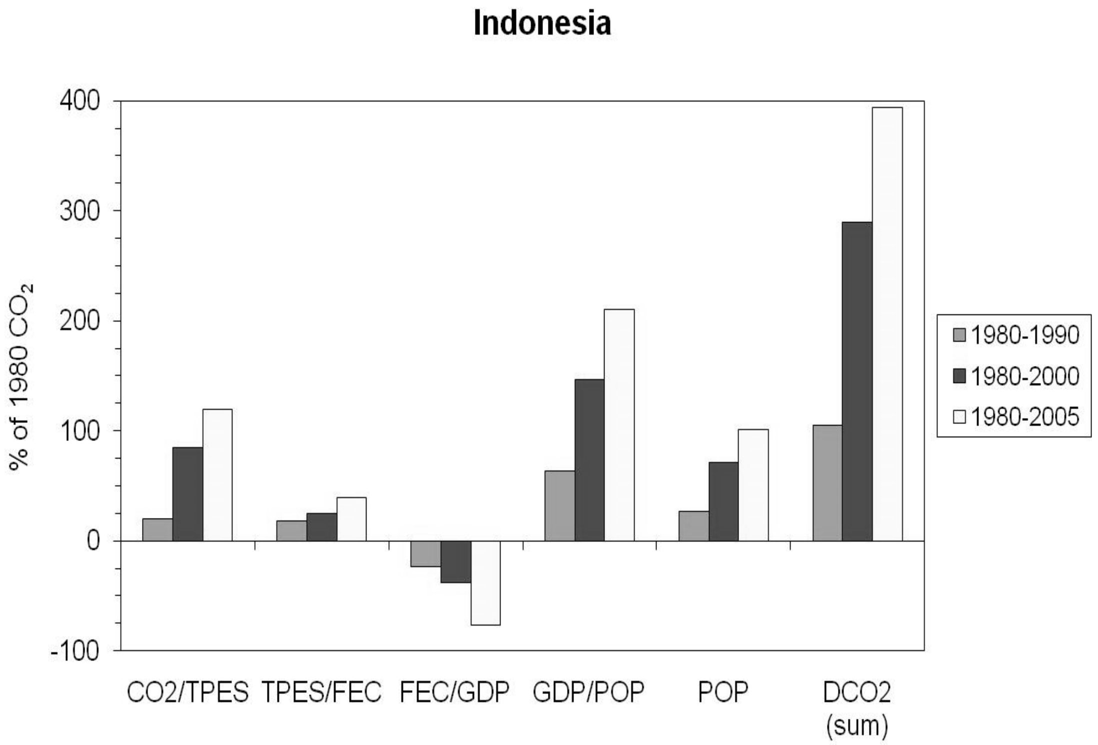

Figure 5. Decomposition of CO2 emissions from fuel combustion in Indonesia 1980–2005, contributions of five factors in percentage of 1980 CO2 emission level. Source: Authors.

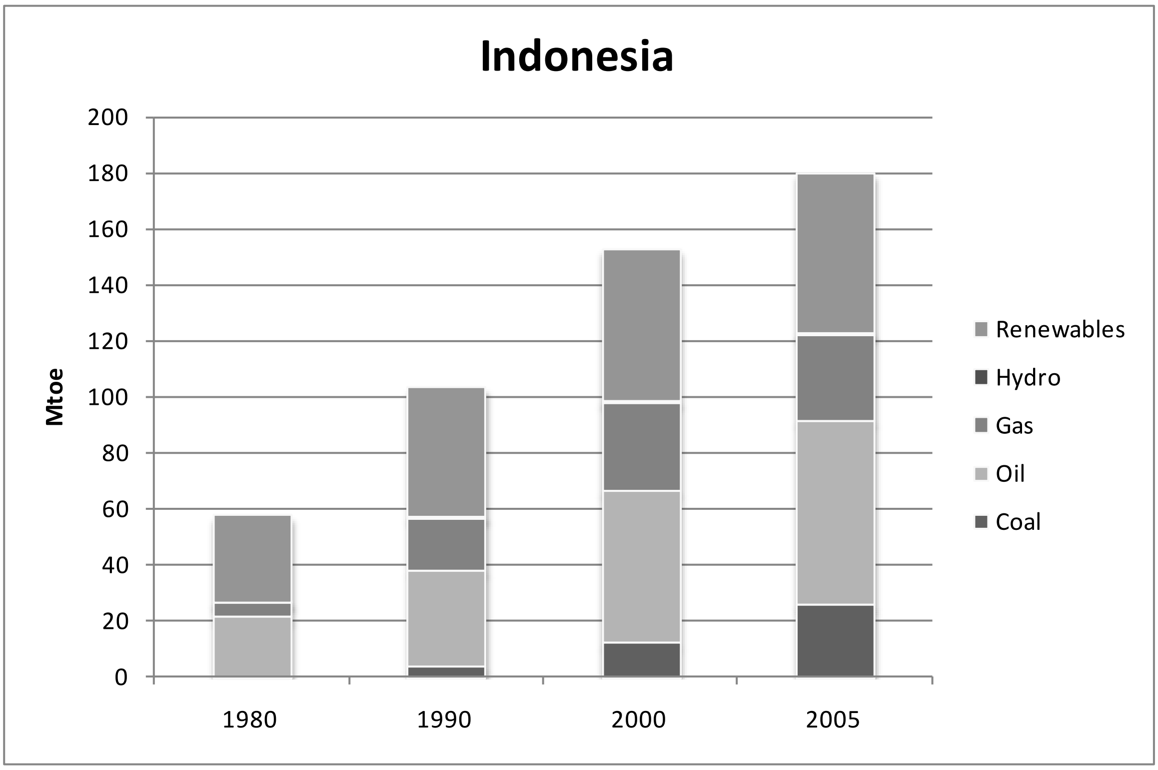

Figure 6. Total Primary Energy Supply (TPES) by energy source in Indonesia 1980–2005. Source: IEA 2007b.

In Indonesia (see Figure 5), the considerable increase in the use of coal, oil and, to some extent, gas (Figure 6) can be seen in the decomposition results as an increase in the CO_2/TPES component. The decrease in the efficiency of the energy transformation sector (TPES/FEC) has also contributed to the increase in CO_2 emissions. The energy intensity of the production system has decreased considerably, thereby lowering the emissions, but the increase in GDP per capita has more than outweighed the effect. Population growth in Indonesia has also increased the emissions leading to a total increase of almost 400 % in the observation period 1980–2005.

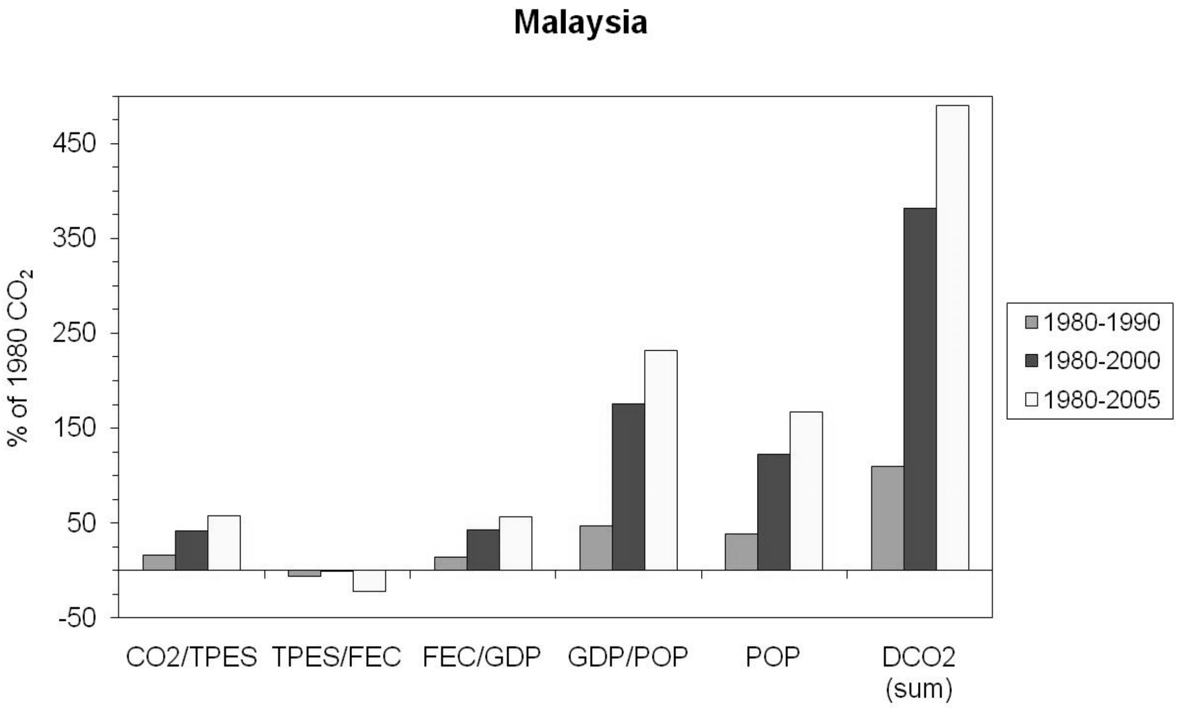

Figure 7. Decomposition of CO_2 emissions from fuel combustion in Malaysia 1980–2005, contributions of five factors in percentage of 1980 CO_2 emission level. Source: Authors.

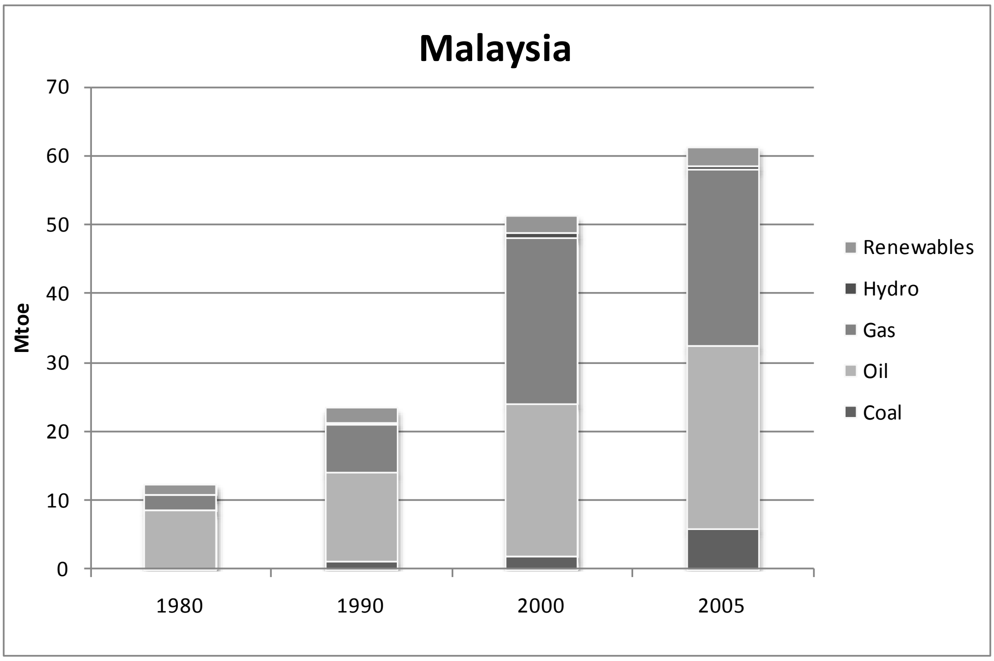

Figure 8. Total Primary Energy Supply (TPES) by energy source in Malaysia 1980–2005. Source: IEA 2007b.

In Malaysia (see Figure 7), the industrialization process can be seen in the decomposition results. Shift to fossil fuels (CO_2/TPES, see Figure 8), increase in energy intensity of production (FEC/GDP), increase in GDP per capita and increasing population all contribute to the increase of CO_2 emissions.

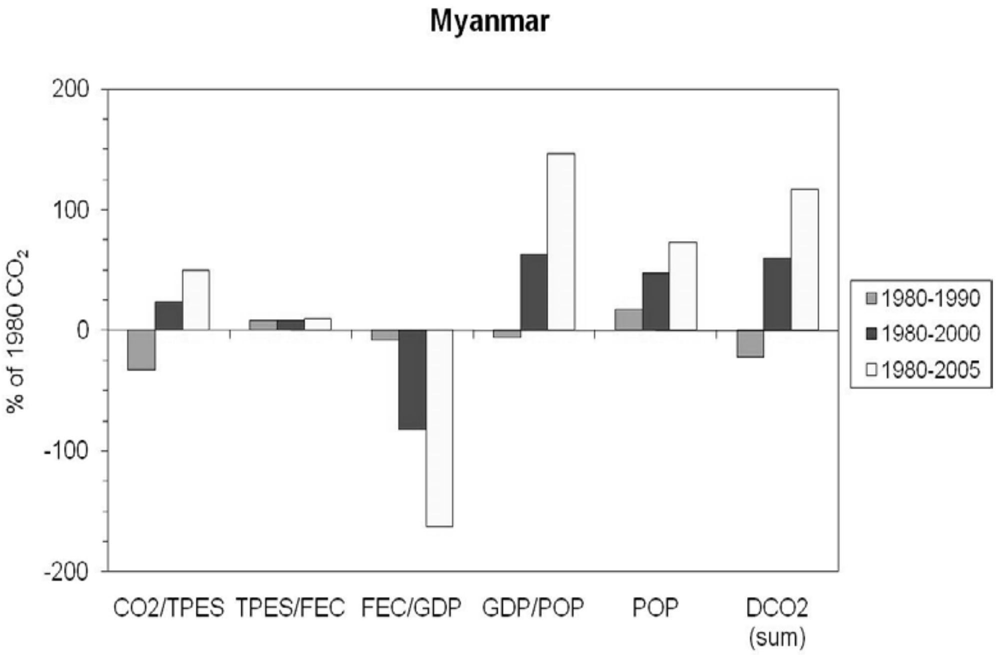

Figure 9. Decomposition of CO_2 emissions from fuel combustion in Myanmar 1980–2005, contributions of five factors in percentage of 1980 CO_2 emission level. Source: Authors.

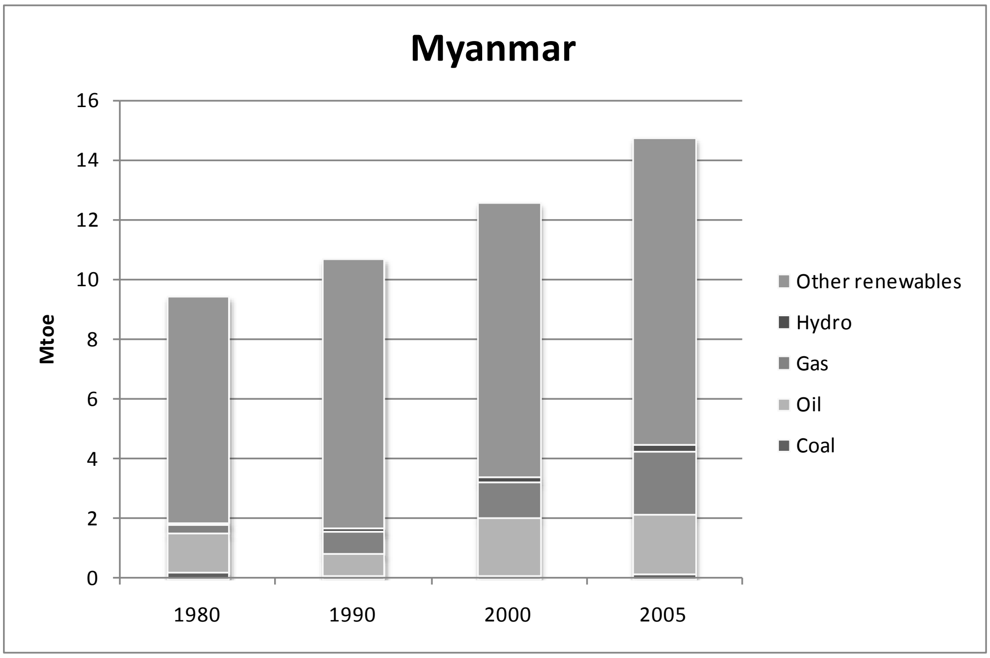

Figure 10. Total Primary Energy Supply (TPES) by energy source in Myanmar 1980–2005. Source: IEA 2007b.

In Myanmar (see Figure 9), the energy intensity of the economy (factor FEC/GDP) has been the major factor decreasing CO_2 emissions. During the period 1980-1990, CO_2 emissions decreased, which is exceptional among the ASEAN countries. Myanmar uses large amounts of renewable energy, and economic growth has been faster than growth in the use of fossil fuels (cf. Figures 2 and 10). The structure of Myanmar's economy is still dominated by agriculture and primary production, and the industrialization process is in the very beginning. Increased tourism is one reason for relatively fast economic development and thus explains the observed change in energy intensity (FEC/GDP).

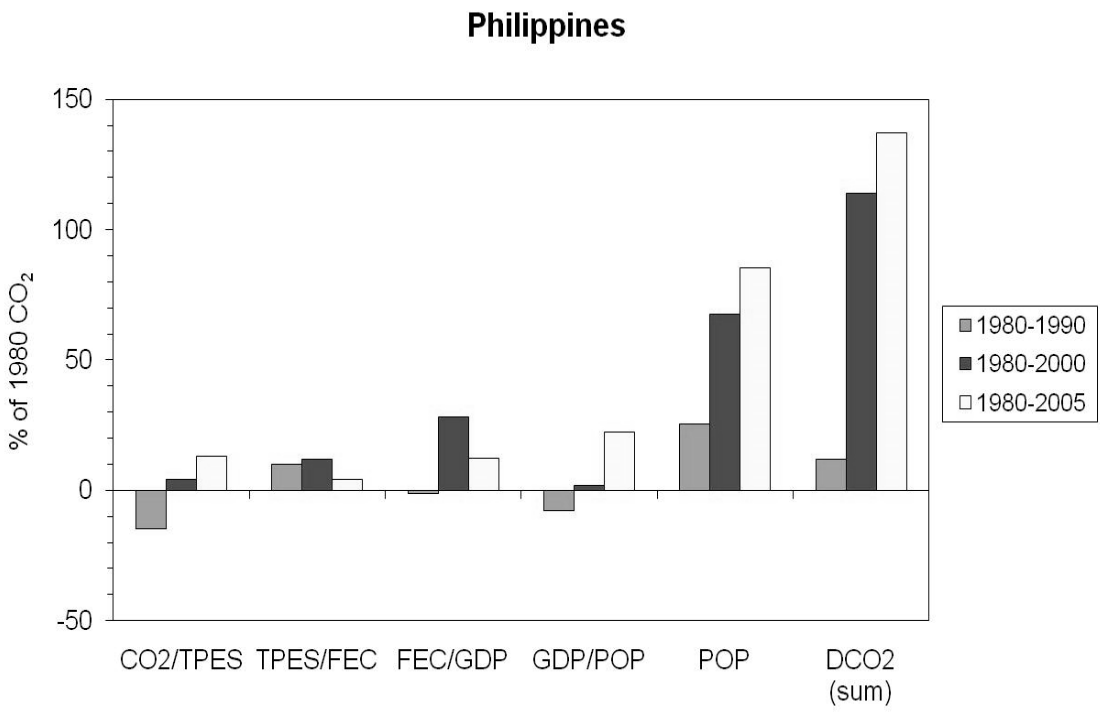

Figure 11. Decomposition of CO_2 emissions from fuel combustion in the Philippines 1980–2005, contributions of five factors in percentage of 1980 CO_2 emission level. Source: Authors.

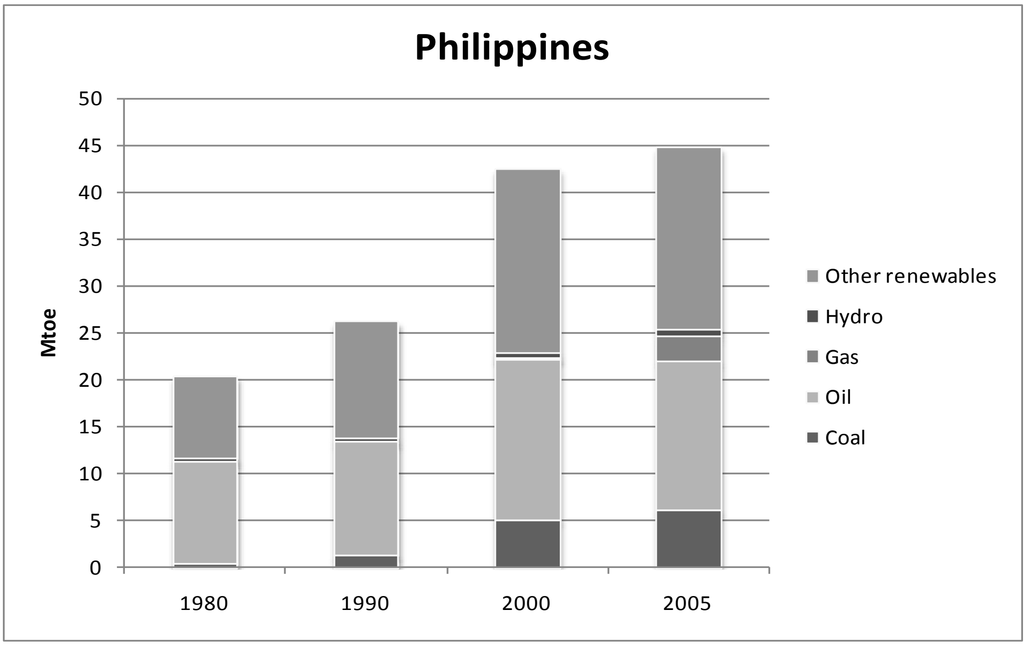

Figure 12. Total Primary Energy Supply (TPES) by energy source in the Philippines 1980–2005. Source: IEA 2007b.

In the Philippines (see Figure 11), the fast growth of population is the most important factor contributing to CO_2 emission growth. The economy has been growing only at the same speed as the population and there are only slight changes in relative shares of different energy sources (Figure 12) and energy intensity of production.

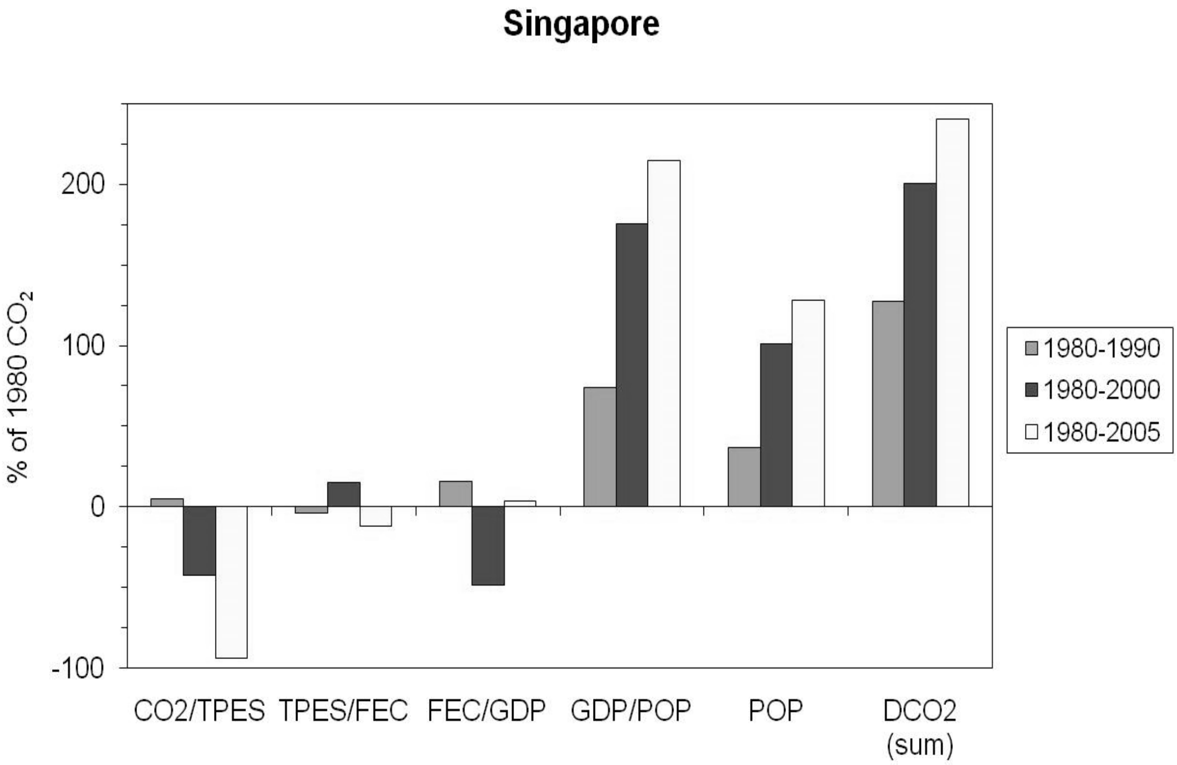

Figure 13. Decomposition of CO_2 emissions from fuel combustion in Singapore 1980–2005, contributions of five factors in percentage of 1980 CO_2 emission level. Source: Authors.

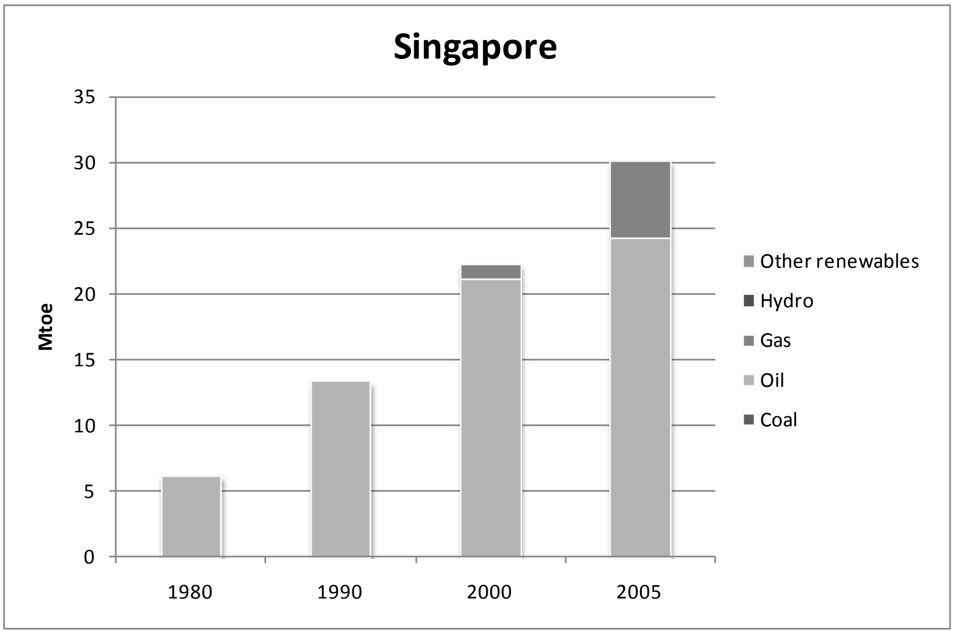

Figure 14. Total Primary Energy Supply (TPES) by energy source in Singapore 1980–2005. Source: IEA 2007b.

The increasing share of gas in Singapore (Figure 14) has decreased the emission intensity of fuel use (CO_2/TPES). There is not much change in energy transformation efficiency (TPES/FEC) or the energy intensity of production (FEC/GDP), but the fast growth of economy (GDP/POP) and population growth add up to a considerable increase in CO_2 emissions (see Figure 13).

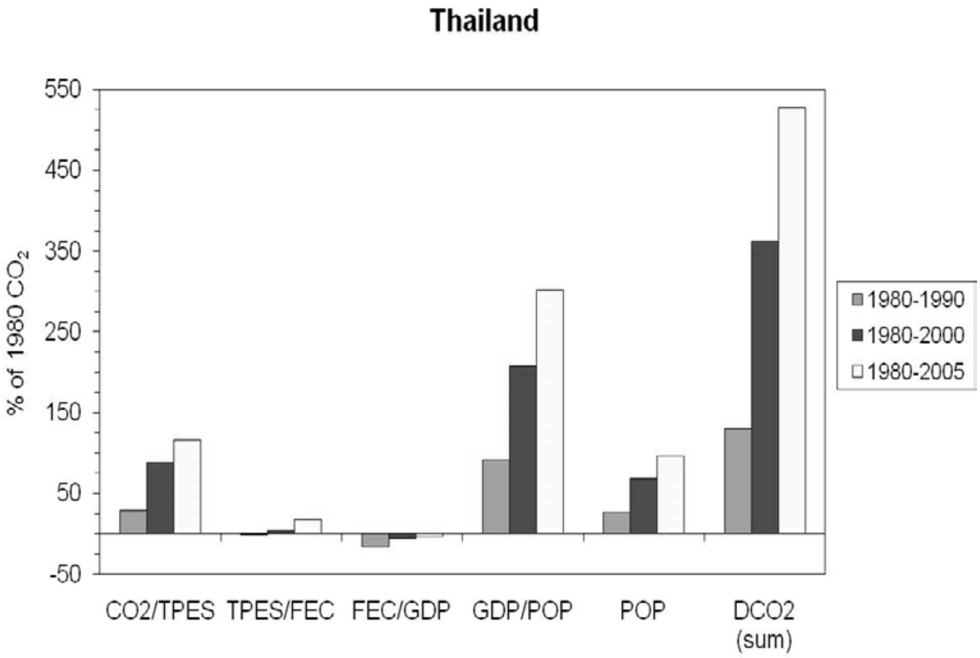

Figure 15. Decomposition of CO2 emissions from fuel combustion in Thailand 1980–2005, contributions of five factors in percentage of 1980 CO_2 emission level. Source: Authors.

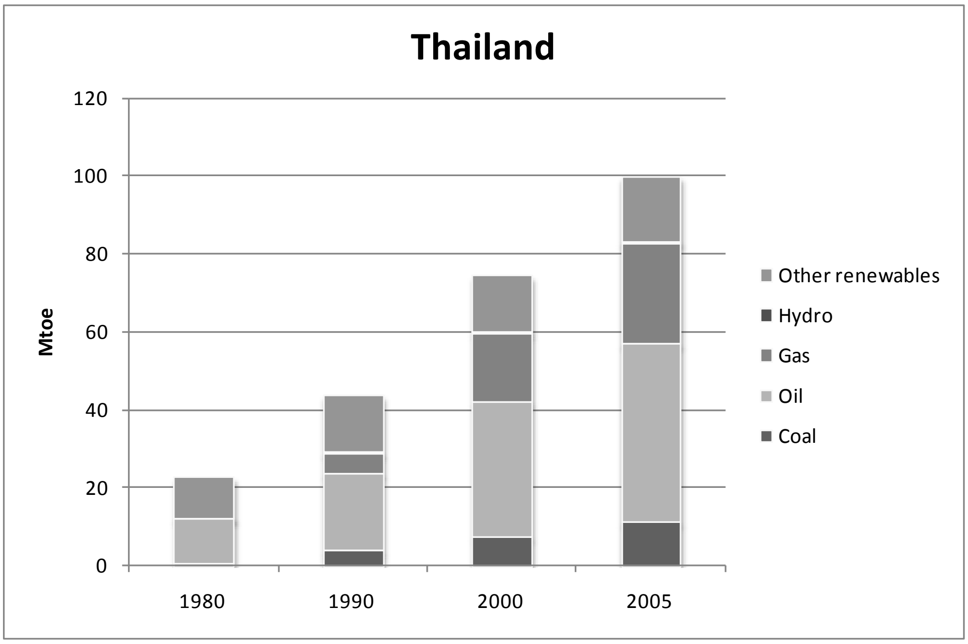

Figure 16. Total Primary Energy Supply (TPES) by energy source in Thailand 1980–2005. Source: IEA 2007b.

In Thailand (see Figure 15), the shift to fossil fuels (Figure 16) has increased emissions considerably. In addition, the fast economic growth and considerable population growth have contributed to an increase of over 500 % in CO_2 emissions from 1980 to 2005. The industrialization of the economy can be seen in the stable energy intensity factor (FEC/GDP).

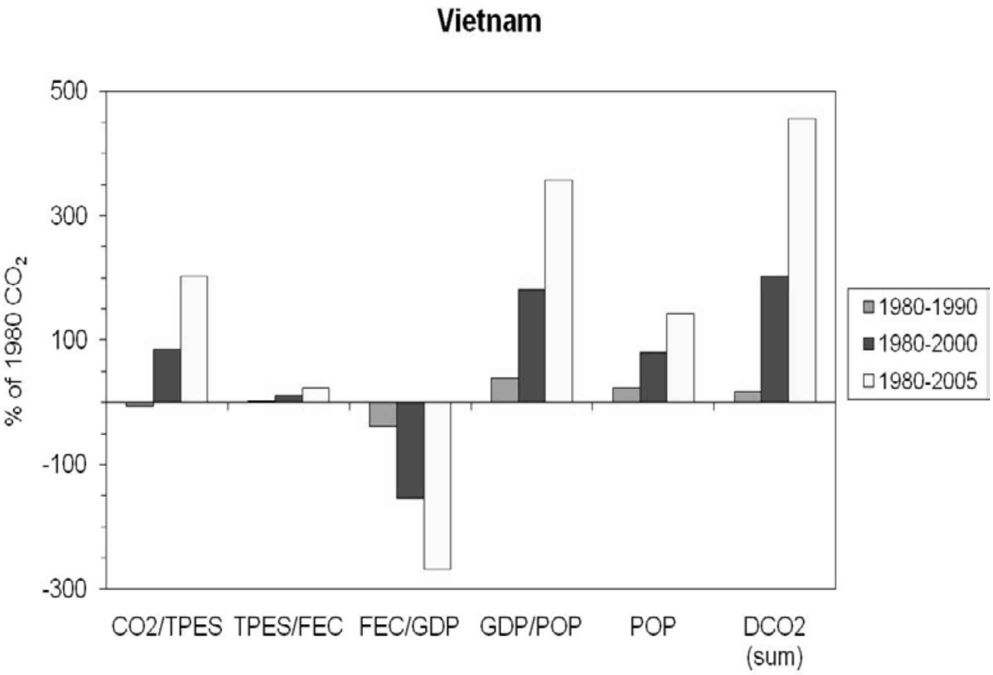

Figure 17. Decomposition of CO_2 emissions from fuel combustion in Vietnam 1980–2005, contributions of five factors in percentage of 1980 CO_2 emission level. Source: Authors.

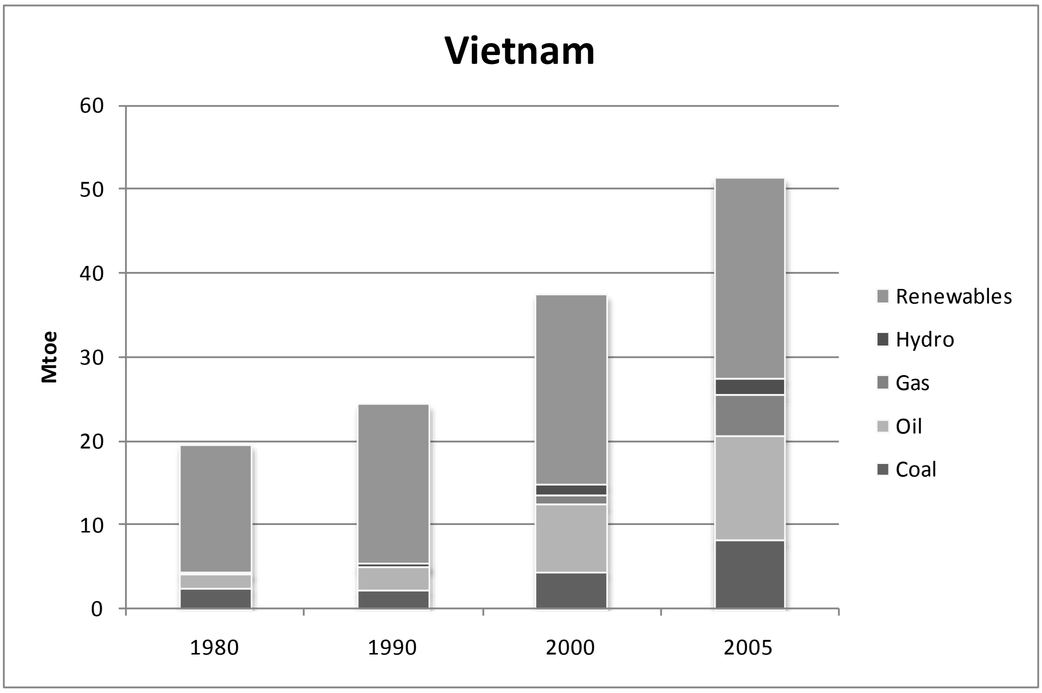

Figure 18. Total Primary Energy Supply (TPES) by energy source in Vietnam 1980–2005. Source: IEA 2007b.

In Vietnam (see Figure 17), the increasing share of fossil fuels in primary energy supply (Figure 18) has contributed to fast growth in the emission intensity of fuel use (CO_2/TPES). The economic process of industrialization is, however, characterized by fast decreasing energy intensity of production (FEC/GDP). This is mainly due to the increase in light industry and fast growth of the service sector. Fast economic growth and population growth have resulted in a growth of over 400 % in CO_2 emissions.

5. BENCHMARKING CO_2 EMISSIONS IN THE ASEAN COUNTRIES WITH CHINA AND INDIA: THE IPAT METHODOLOGY DEMOSTRATION

The decomposition results of change in CO_2 emissions from fuel combustion in the ASEAN countries in 1980-2005 are summarized below (Table 1). Also the results from similar decomposition analysis for two important benchmarking countries, China and India, and the World as a whole are included. The similarities and differences between the results from all studied countries are brought out here (Table 1). This Table 1 summarises the key energy economy trends in the ASEAN countries.

Table 1. Decomposition results of change in CO_2 emissions from fuel combustion in the ASEAN and important benchmarking countries and the world total in 1980–2005, as percentage of the CO_2 emission level in 1980.

Country	CO_2/ TPES	TPES/ FEC	FEC/ GDP	GDP/ POP	POP	CO_2 (sum)
Brunei	96	-227	207	-126	144	94
Indonesia	120	40	-77	210	101	394
Malaysia	57	-22	56	232	167	490
Myanmar	50	10	-163	147	73	117
Philippines	13	4	12	22	86	137
Singapore	-94	-12	3	215	128	240
Thailand	116	17	-4	301	97	527
Vietnam	203	23	-269	357	142	457
China	50	-50	-378	540	99	261
India	94	55	-197	226	115	293
World	-7	-2	-42	52	48	50

China and India provide an interesting framework for benchmarking the ASEAN countries, because these countries are linked to the ASEAN economies in several different ways. For example, trade relations are active with China and many ASEAN countries. The Mekong River with a large potential of hydro power is a shared interest between China and countries such as Thailand, Vietnam, Laos, and Cambodia. China and India are the most populated countries in the continent of Asia, and thus comparison of the ASEAN results to them is very relevant and important. When the IPCC and key global policymakers will analyse global climate policy situation in Asia, this benchmarking table 1 is good to keep in mind.

Rapidly increasing efficiency of the energy transformation system (factor TPES/FEC) is a predominant characteristic in China. Thus it can be said that countries with this kind of result where TPES/FEC have significantly decreased CO_2 emissions from fuel combustion such as Malaysia and Singapore, more or less follow the "Chinese model". The most typical feature of the "Indian model" is that change in energy intensity of the economy (factor FEC/GDP) is the only factor which has decreased CO_2 emissions. Among the ASEAN countries, Indonesia, Myanmar, Thailand and Vietnam more or less follow the Indian model. The most rapid increase in CO_2 emissions can be found in Thailand, Malaysia and Vietnam. An easy conclusion is that both the Chinese model and the Indian model are very problematic because CO_2 emissions have strongly increased during the studied time period. Increasing energy efficiency and decreasing energy intensity of the economy in the Chinese model have been overdriven by factors increasing CO_2 emissions such as economic growth per capita (GDP/POP), increasing use of coal and other fossil fuels (CO2/TPES) and population growth (factor POP).

To sum up, one key finding of the ASEAN benchmarking Table 1, the Indian model of development is very alarming because all the identified factors have actually increased CO_2 emissions from fuel combustion.

Rest of the analysed ASEAN countries, i.e. Brunei and the Philippines are different from China or India. As discussed earlier, Brunei is an exception among the ASEAN countries with economic growth (factor GDP/POP) decreasing CO_2 emissions. The Philippines has quite modest changes in relative terms, but none of the identified factors has actually decreased CO_2 emissions.

As a general benchmarking result, Table 1 presents also the contributions of different factors to change in CO_2 emissions from fuel combustion at global level. It clearly identifies the basic components of the IPAT equation (Fischer-Kowalski & Amann 2001; Cole & Neumayer 2004).

The IPAT identity describes the multiplicative contribution of population, affluence, and technology to environmental impact. Table 1 shows that the effects of population (P, factor POP) and affluence (A, factor GDP/POP) are very similar in direction and size, and technology (T, factors FEC/GDP, CO2/TPES and TPES/FEC) has the same size but opposite direction. This means that, at global level, technological development is not enough to compensate the effects of population and affluence. Roughly speaking, both factors should be halved to reach a balanced state between the IPAT factors globally. This global analysis clearly indicates that issues in relation of population such as education, gender aspects, and poverty reduction should be integrated as an elementary part of global climate change policy.

Thus, in this study we have made methodological extension of the conventional IPAT model, which is providing new policy relevant insights to global climate change policies. In the future studies of global energy economy, it is possible to provide this kind of interesting benchmarking analysis for all the key regions of the world.

From this perspective, this e-book is providing new methodological innovation to decomposition research literature and global climate change analysis.

6. CONCLUSIONS

In this e-book, we have empirically analysed the reasons behind change in CO_2 emissions from fuel combustion in the ASEAN countries using data from International Energy Agency (IEA). Instead of an ordinary three-factor (activity, intensity and structural effects) decomposition analysis, a new method, capable of taking more explaining factors into account, has been used.

The CO_2 emissions per capita are considerably low in many ASEAN countries (except Singapore), but the emissions are increasing fast due to the rapid economic growth and increased reliance on fossil fuels. The emission intensities in the countries have been increasing in the industrialization process, but with a shift towards a more service-oriented economy and the increase in GDP per capita, the intensities have started to decrease. However, the trend of increasing CO_2 emissions is difficult to cut due to the growing economy and increasing amount of population.

Empirical results from eight ASEAN countries show that each country has its own structure of driving factors behind changing CO_2 emissions. This means that each ASEAN country needs a specific and nationally tailored climate policy, where technology policy, energy policy, population policy and economic policy have different weights and contents. Each country needs a more problem-oriented approach in their climate-related policies. In the worst case, overtly unified policy frameworks can have countervailing and even negative effects on economy, environment and the whole society and thus jeopardise all dimensions of sustainability.

The findings of this e-book imply that all policies aimed at decreasing emissions of carbon dioxide (and other greenhouse gases listed in Annex A of the UNFCC Kyoto Protocol) in the ASEAN countries, are very challenging because of the rapid growth in CO_2 emissions during last decades. The results very clearly represent the difficulty of developing countries' involvement into any targets related to CO_2 emissions from fuel combustion.

Thus, in this study we have made a new methodological extension of the conventional IPAT model and analysis. This new methodological approach is providing new policy relevant insights to global climate change policies. In the future studies of global energy economy, it is possible to provide this kind of interesting benchmarking analysis for all the key regions of the world. From this methodological perspective, this e-book is providing new methodological innovation to decomposition research literature and global climate change analysis. It is also a scientific landmark of IPAT research tradition.

However, the approach of this study brings new insights to classical discussion on the IPAT equation. At global level, technological development is not enough to compensate the effects of population growth and increasing affluence. Roughly speaking, both factors should be halved to reach a balanced state between the IPAT factors globally. This global analysis clearly implies that despite of being politically unpopular, economic growth and population growth in developing countries cannot be left outside the elementary parts of global climate change policy.

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