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Decomposition analysis of Philippine CO_2 emissions from fuel combustion and electricity generation

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HIGHLIGHTS

- Driving forces of Philippine CO_2 emissions are revealed using LMDI approach.
- About half of the increase in CO_2 emissions are due to economic growth.
- Sudden shifts in energy structure significantly increase CO_2 emissions.
- Policies related to energy planning, self-reliance, and policy execution are recommended.
- We recommend the same methodology be conducted in other ASEAN and developing countries.

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ABSTRACT

In order to address climate change and attain sustainable growth, there is a need to quantify driving factors in CO_2 emissions in the developing countries. While information for accounting of Philippine CO_2 emissions are abound, there is a lack of analytical studies on the driving forces. In this study, the logarithmic mean Divisia index (LMDI) is used to quantify the driving forces of changes in Philippine CO_2 emissions from 1991 to 2014. The top-down approach described from 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines was used to estimate CO_2 emissions from national fuel combustion and electricity generation. Results affirm the negative impacts of economic growth and higher standard of living to CO_2 emissions, and reveal the significant damages inconsistent energy structures deliver to the emissions performance of a country. This has never been highlighted in previous studies in ASEAN and other developing countries. Policies to protect the energy structure from fluctuating oil prices, to improve energy planning capabilities, and to promote industrial symbiosis are recommended. On the other hand, the contribution of economic activity and energy intensity to CO_2 emissions offset each other.

1. Introduction

The Philippines is an archipelagic country located in the Western Pacific Ocean, comprised of three main islands – Luzon, Visayas, and Mindanao. With a total of 7107 islands, it has a total land area of 300,000 square kilometers and an estimate of 97.35 million population at 308 persons per square kilometer as of May 2010 [1]. The Philippines has high vulnerability to risks of climate change specifically due to sea level increase [2], which is also true with Small Island Developing States (SIDS) [3]. In line with this, legislative efforts have been made to mitigate the impacts of climate change to the country. In 1999, the Philippine Clean Air Act (RA 8749) was enacted to provide a comprehensive air pollution control policy. The Renewable Energy Act of 2008 was later on implemented, seeking to promote the development, utilization, and commercialization of renewable energy resources in the country, through feed-in tariffs and other incentives.

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The challenges in implementing feed-in tariff policies in the Philippines were assessed by Bakhtyar et al. [4]. The country has developed its geothermal resources and it is currently the second largest producer of geothermal energy in the world [5]. However, its dependence on hydropower exposes its vulnerabilities on droughts, more specifically in the southern island of Mindanao [6]. Hence, there is a need to improve its performance in harnessing other renewable sources such as biomass, wind, solar and ocean to reduce carbon emissions. The archipelagic geography of the Philippines provides an estimated potential 170,000 MW ocean energy potential that has not been developed yet [5]. Some issues highlighted in literature are the lack of a suitable degression rate and inflation calculation. Shi [7] sheds more light on the gaps of energy and environmental policy in the Philippines, such as lack of effective enforcement of existing Minimum Energy Performance Standards (MEPS) due to the absence of an Energy Efficiency and Conservation (EEC) law. Furthermore, Acosta et al. [8] highlighted potential regional barriers on bioenergy utilization in the country through a survey eliciting the people's preferences on policy issues related to bioenergy. The results showed that the more idealistic population are from northern island of Luzon, while realists are from Mindanao. It was found that the decades-long religious armed conflicts and widespread poverty in Mindanao have been some of the largest barriers to harvesting the huge bioenergy potential of the region.

There have been intensive studies on national CO_2 emissions accounting, especially for the major developed economies [9] and emerging economies [10,11]. Such studies typically employed a top-down approach, which correlated CO_2 emissions to energy consumption. As a representative, the International Energy Agency (IEA) provides country-level CO_2 emissions inventory and driving forces using Kaya identity, covering over 140 countries in its annually released report [12]. However, there is a lack of studies focusing on the CO_2 emissions from ASEAN countries, which have a great potential of CO_2 emissions growth in the future since many manufacturing activities are outsourced in developing countries due to their cheaper labor resources. Also, by 2030, two-thirds of the global middle class consumers are expected to live in the Asia Pacific.

Decomposition analysis is a method that looks into the driving forces behind the changes of an aggregate indicator over time. Two most important techniques of decomposition analysis are index decomposition analysis (IDA) and structural decomposition analysis (SDA). Both IDA and SDA have been widely applied on energy and emission studies [13], with IDA as a more frequently employed technique [14]. By using these techniques, existing studies mostly focus on decomposing energy consumption and emissions from developed economies [15,16], as well as major emerging economies [17]. From the ASEAN region, similar studies have only been done in Indonesia [18], Thailand [19], and Vietnam [20].

The Philippines experienced consistent economic growth in the past decade. Among the ASEAN and Asian countries, the Philippines continues to enjoy positive growth along with Indonesia and South Korea despite the rest suffering from decelerating growth [21]. Several studies have investigated the causal relationship between economic growth and energy consumption [22–24]. These studies present strong causal evidence between the two; hence, increasing carbon emissions as well. For these reasons, it is strategic to investigate the CO_2 emissions of an archipelagic developing country such as the Philippines to ensure that correct policies are responding to the driving factors for sustainable growth.

There is definitely a growing interest in CO_2 emissions mitigation in the Philippines, ASEAN and other developing countries, and this study aims to uncover the driving forces of CO_2 emissions from electricity generation and fuel combustion for the period of 1991 to 2014 by using logarithmic mean Divisia index (LMDI) decomposition analysis. The study will provide a unique analysis derived from an archipelagic, developing country-oriented consumption pattern; such valuable policy insights will prepare decision-makers to craft mitigation policies based upon the Philippines' realities. These research outcomes can serve as benchmark for other ASEAN countries that have similar political and economic structures, growth and consumption patterns. The archipelagic case of the Philippines may even provide useful insights for the sustainable development and climate change mitigation of Small Island Developing States (SIDS). The whole paper is organized as follows: a discussion on research methods including data collection and treatment, and accounting details is provided in Section 2; research findings are presented in Section 3; and Section 4 summarizes the results with conclusions and policy recommendations.

2. Methods and data

2.1. Accounting CO_2 emissions

The CO_2 emissions from fuel combustion and electricity generation were estimated following the top-down approach outlined in Vol. 2, Ch. 6 of the "2006 IPCC National Greenhouse Gas Inventory Guidelines" (Intergovernmental Panel on Climate Change [25]). The two were estimated from separate data sets, which are described in Section 2.3.

CO_2 emissions from fuel combustion were estimated directly from national material flow analysis (MFA) data, which contains information on domestically extracted, imported, and exported products. Net fuel consumption is then calculated using Eq. (1).

$$\text{Net consumption} = \text{Domestically Extracted} + \text{Import} - \text{Export} \tag{1}$$

The annual fuel consumption mix from 2000 to 2010 is summarized in Fig. 1. There are no domestically extracted oil-based fuels during the period of 2000 to 2010, eliminating the possibility of double counting. The emission factors used based on each type of fuel are summarized in Table 1. Annual CO_2 emissions from fuel combustion based on each fuel type are then calculated using Eq. (2).

$$C_i^j = M_i^j EF_i \tag{2}$$

where C is CO_2 emissions; the subscript i refers to fuel type and j refers to year; M refers to mass or volume of fuel i consumed in year j; and EF refers to the emission factor of fuel type i, expressed in tCO_2 per kg fuel or tCO_2 per gallon fuel.

CO_2 emissions from electricity generation were estimated from national power statistics data, considering the energy sources used by electric power plants. The annual energy structures used for electricity generation from 1991 to 2014 are summarized in Fig. 2. Other renewable sources include hydro, wind and solar power. Emission factors used are summarized in Table 1. CO_2 emissions from electricity generation are then calculated using Eq. (3).

$$C_i^j = E^j S_i^j EF_i \tag{3}$$

where C is CO_2 emissions; i and j refer to fuel type and year, respectively; E refers to the total energy generation in year j; S refers to energy share of fuel type i in year j; and EF refers to the emission factor of fuel type i, expressed in tCO_2 per GW h.

2.2. Index decomposition analysis

IDA, specifically the LMDI method, is used in this study to uncover the driving forces on Philippine CO_2 emissions from fuel combustion and electricity generation. A similar study by Guo

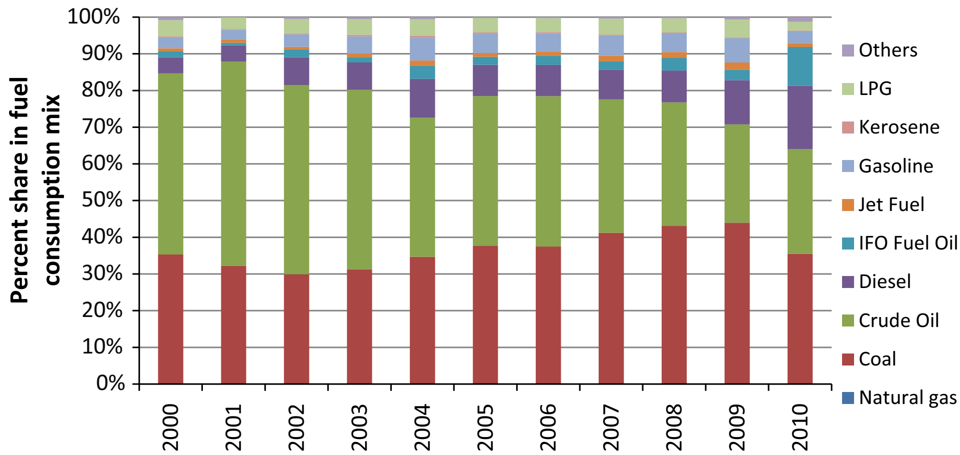

Fig. 1. National fuel consumption mix (2000–2010). (Source: [33].)

Table 1
Summary of emission factors used in the study.

Energy source	For fuel combustion Emission factor (*kg CO_2/gallon or **lb CO_2/short ton)	For electricity generation Emission factor (tCO_2/GW h)
Crude oil	10.28*[a]	N/A
Diesel	10.21*[a]	715.00[b]
IFO fuel oil	11.27*[a]	N/A
Jet fuel	9.03*[a]	N/A
Gasoline	8.78*[a]	N/A
Kerosene	9.75*[a]	N/A
LPG	5.68*[a]	N/A
Others	9.29*[a]	N/A
Natural gas	53.10**[a]	400.00[b]
Coal	4631.00**[a]	965.00[b]
Geothermal	N/A	80.55[c]
Other renewable (hydro, wind or solar)	N/A	0
Biomass	N/A	1084.79[a]

[a] Sources: [41].
[b] Sources: [39].
[c] Sources: [40].

et al. [26] used the same method to derive the driving forces of the Chinese transport industry's CO_2 emissions, and commended it for its ease of use and results interpretation. Furthermore, the same method was used in recent studies to determine the driving forces of energy use, industrial wastewater discharges and carbon emissions [27–31]. A detailed tutorial on the formulation of the LMDI was presented in Ang [32].

In this study, period-wise and time series LMDI are employed to show the driving forces on the changes in CO_2 emissions per year interval, and the aggregated effects, respectively. Four explanatory factors were quantified in this study: population effect, activity effect, intensity effect and structure effect. Furthermore, the structure effect was broken down into the different fuel types, to estimate the impact of each fuel to the change. A positive value for an effect means that it increased the emissions for that year, and vice versa. The sum of all the effects, positive and negative, should equate to the emission change for that year interval. Otherwise, it would mean that an unaccounted factor in the LMDI exists, i.e. change in emission factors. It is important to take note that emission factors were assumed to be constant in this study, thus the emission factor effect can be regarded as zero.

Population effect (ΔC_{pop}) quantifies the contribution of the increase or decrease in population. Activity effect (ΔC_{act}) quantifies the effect of the increase or decrease in economic activity, measured in GDP per person. Intensity effect (ΔC_{int}) quantifies the effect of the increase or decrease in the required energy to produce the same amount of product, measured in energy per GDP (GW h per million pesos). A decrease in energy intensity usually refers to an improvement in energy efficiency or a shift in the nature of work. For example, considering only direct consumption, the ser-

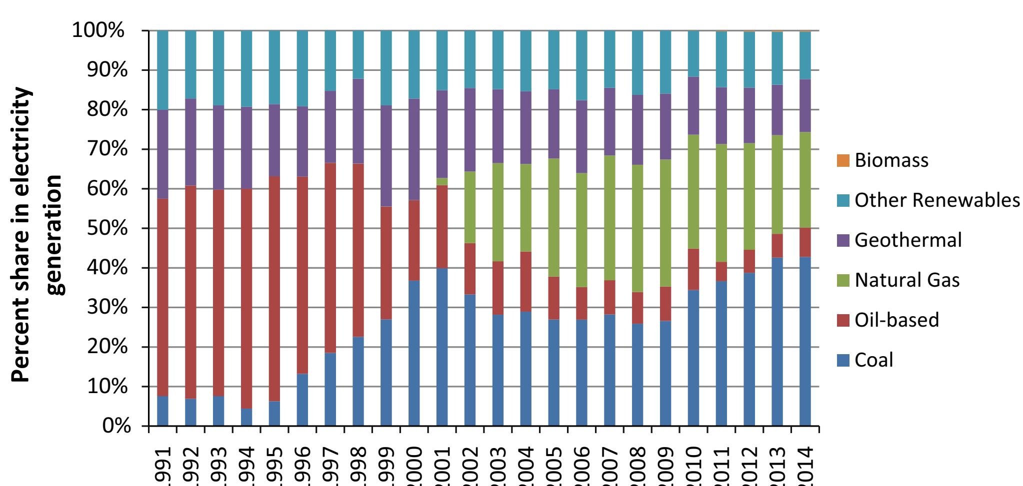

Fig. 2. Power structure for electricity generation (1991–2014). Other renewables compose of hydro, wind and solar. (Source: [34] and [35].)

vice sector requires less amount of energy from fuels to provide the same value of product as compared to the manufacturing industry. Finally, the structure effect (ΔC_{str}) quantifies the effect of the change in fuel or power mix adopted by the country in the year interval.

The IDA identity used in this study is shown in Eq. (4) below. This identity shows how each of the driving factors considered in this study contribute to the calculation of the changes in CO_2 emissions. The magnitude of each individual effect per year interval is further calculated using Eqs. (5)–(8) below.

$$C = \sum_i C_i = \sum_i P \times \frac{Q}{P} \times \frac{E}{Q} \times \frac{E_i}{E} \times \frac{C_i}{E_i} = \sum_i P \times G \times I \times S_i \times F_i \tag{4}$$

where C refers to CO_2 emissions, P is population, Q is gross domestic product (GDP), E is energy consumption, and i is fuel type. G is economic activity in GDP per capita, I is energy intensity in GW h per GDP, S_i is share in energy mix for fuel type i, and F_i is emission factor for fuel type i.

$$\Delta C^T_{pop} = \sum_i \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \ln\left(\frac{P^T}{P^0}\right) \tag{5}$$

$$\Delta C^T_{act} = \sum_i \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \ln\left(\frac{G^T}{G^0}\right) \tag{6}$$

$$\Delta C^T_{int} = \sum_i \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \ln\left(\frac{I^T}{I^0}\right) \tag{7}$$

$$\Delta C^T_{str} = \sum_i \frac{C_i^T - C_i^0}{\ln C_i^T - \ln C_i^0} \ln\left(\frac{S^T}{S^0}\right) \tag{8}$$

The superscripts T and 0 refer to the final and baseline year in that interval, respectively. C refers to CO_2 emissions, while ΔC refers to the change in emission levels between the final and baseline year in the time period. The subscript i indicates fuel type. Lastly, the subscripts pop, act, int and str refer to population effect, activity effect, intensity effect and structure effect, respectively. As mentioned above, the sum of all the quantified effects in each time period should equate to the difference in emissions for the time period.

2.3. Data sources

Data for this analysis were taken from multiple sources. The annual net fuel consumption was taken from material flow analysis (MFA) data consolidated in a previous study of the author [33] in cooperation with United Nations Environment Programme (UNEP). The MFA data quantifies all the products domestically produced, imported and extracted, and are expressed either in units of weight (kg or lb) or volume (liters or gallons). Available MFA data is from 2000 to 2010. Annual electricity consumption was taken from power statistics data published by the DOE in 2012 and 2014 [34] and [35]. This data set provides electricity generation statistics broken down per major island and fuel type. Equivalent emission factors are then calculated based on the fuel mix of a particular island. Available power statistics data is from 1991 to 2014. Population and gross domestic product (GDP) data were retrieved from the Philippine Institute for Development Studies (PIDS) [36] and PSA [37] and [38], respectively. The latest population census data available are for the years of 2000, 2007 and 2010. Population for the years in between were extrapolated assuming linear trend. Specific emission factors of different fuels were assumed constant and lifted from multiple sources: IPCC Guidelines for National Greenhouse Gas Inventories [39], DiPippo [40], and Environmental Protection Agency [41]. Electricity and fuels purchased by industry type per region were obtained from Annual Survey of Philippine Business and Industry (ASPBI) [42,43].

3. Results and discussion

3.1. Determination of driving forces of CO_2 emissions using LMDI

Electricity generation

The effects of different factors to changes in national CO_2 emissions due to electricity generation are summarized in Figs. 3 and 4. Looking at the aggregated effects in Fig. 3, the trend of CO_2 emissions is increasing at a rate of approximately 1500 ktons CO_2 per year in general.

The population effect (ΔC_{pop}) is consistently positive, despite the steady decline of population growth rate [44]. On average, population growth in the Philippines contributes an additional of 488 ktons of CO_2 emissions per year. In addition, the effect of economic activity (ΔC_{act}) is consistently positive. Fig. 3 shows that economic growth is the largest contributor to the increase in CO_2 emissions from 1991 to 2014, and contributes 684 ktons of additional CO_2 emissions per year. On the other hand, the effect of energy intensity (ΔC_{int}) is quite interesting. The annual effects presented in Fig. 4 shows the year 2003 as an inflection point for the effect of energy intensity. That is, beyond 2003, the effect of energy intensity changed from positive to negative, which could mean that the country has been using more energy efficient technologies or switching to less energy-intensive industries year after year. From 1991 to 2003, changes in energy intensity contribute an additional of 479 ktons CO_2 per year, while from 2003 onwards, improvements in energy intensity are responsible for displacing an average of 611 ktons of CO_2 emissions per year.

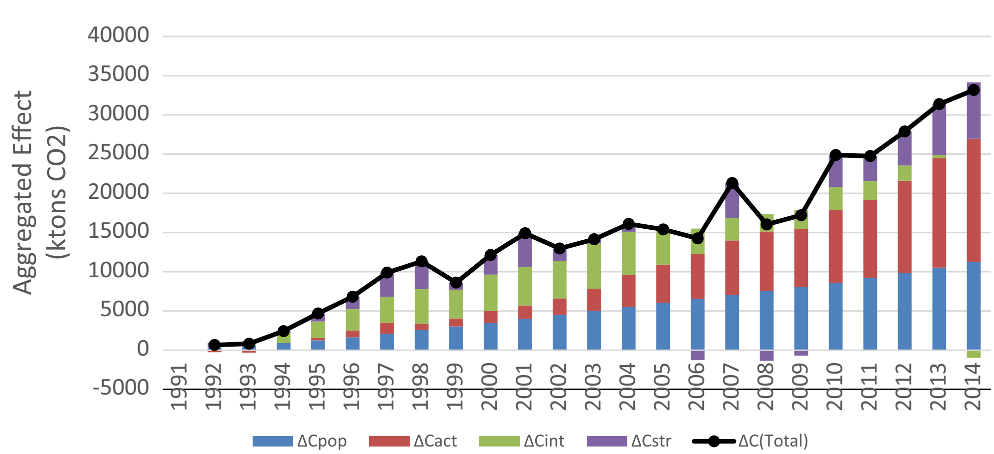

Fig. 3. Aggregated effects from various driving forces to electricity generation CO_2 emission increments from 1991 to 2014.

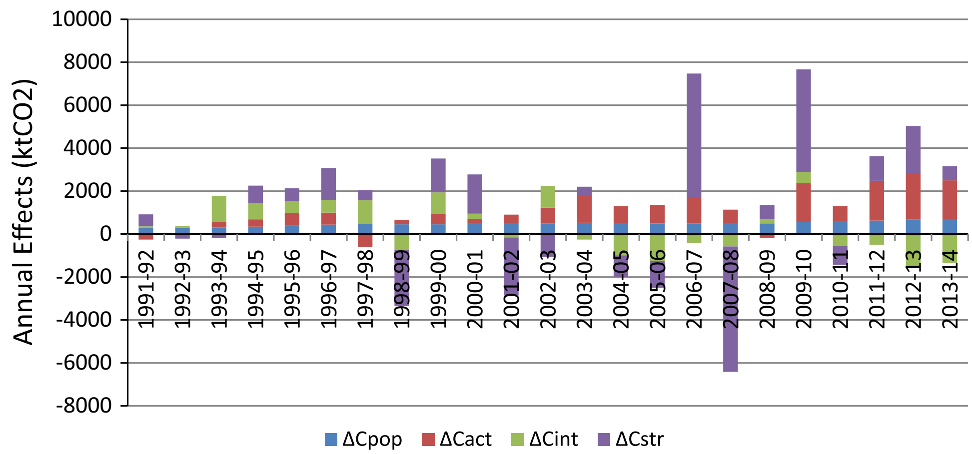

Fig. 4. Annual effects from various driving forces to electricity generation CO_2 emission increments from 1991 to 2014.

Lastly, there is a randomness in the effect of changes to energy structure (ΔC_{str}). Fig. 4 demonstrates that the country has been using an inconsistent energy mix to generate electricity, which may be driven by the substantial dependence on imported coal and oil. The effects of changes in energy structure vary from displacing 2700 ktons CO_2 to adding 5700 ktons CO_2 in a particular year. Ultimately, changes in energy structure are responsible for an additional of 312 ktons CO_2 per year.

Fuel combustion

The effects of different factors to changes in national CO_2 emissions due to fuels combustion are summarized in Figs. 5 and 6. The aggregated effects in Fig. 5 presents that the general trend of CO_2 emissions is increasing at approximately 8900 ktons CO_2 per year.

Similar to electricity generation, the contributions of population increase (ΔC_{pop}) and economic activity (ΔC_{act}) are

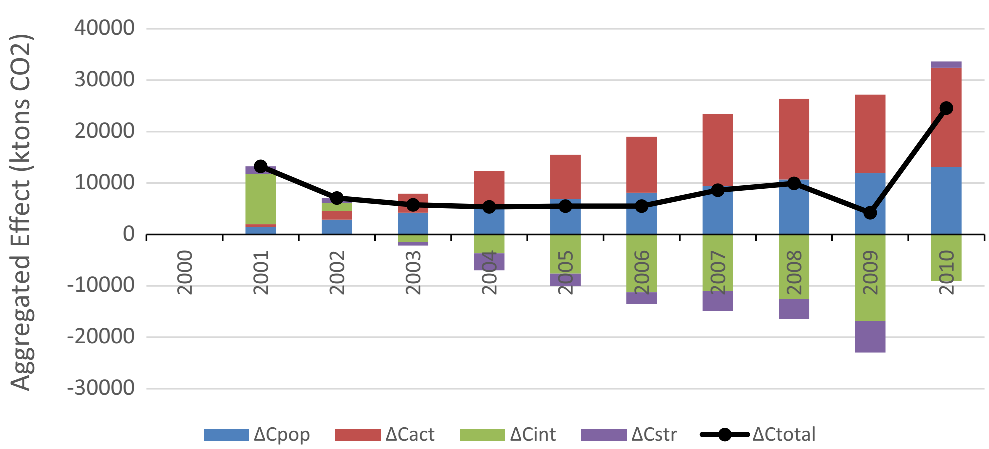

Fig. 5. Aggregated effects from various driving forces to fuel combustion CO_2 emission increments from 2000 to 2010.

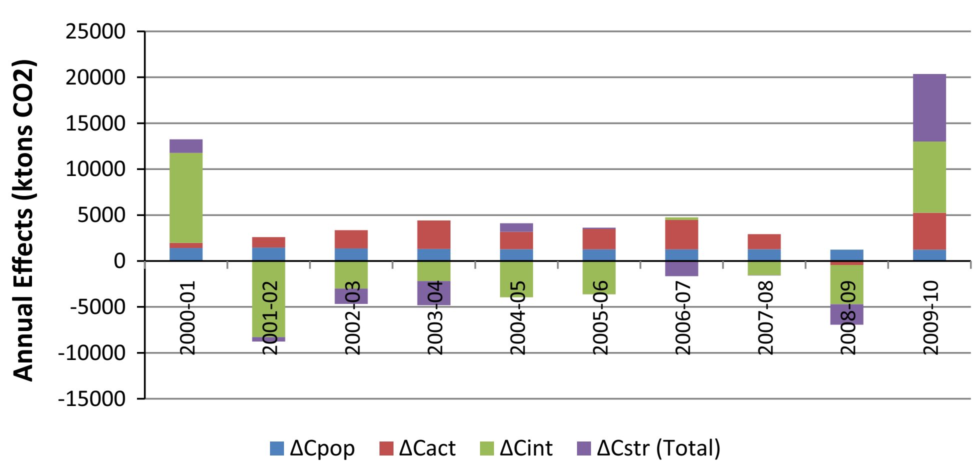

Fig. 6. Annual effects from various driving forces to fuel combustion CO_2 emission increments from 2000 to 2010.

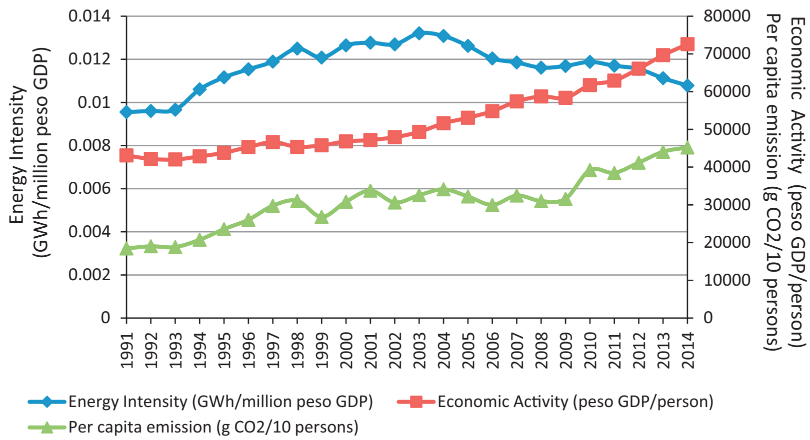

Fig. 7. Co-plots of various indicators that contribute to CO_2 emissions.

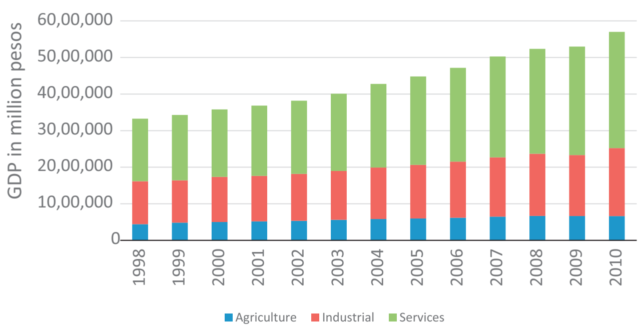

Fig. 8. Gross domestic product at constant year 2000 prices. (Source: 37,38.)

consistently positive and is accountable for an additional 1300 and 1900 ktons CO_2 per year.

On the other hand, the effect of emission intensity (ΔC_{int}) is almost consistently negative from 2003 to 2010. Improvements in energy intensity have been responsible for displacing approximately 900 ktons CO_2 per year.

Randomness is also observed in the effect of energy structure (ΔC_{str}) to CO_2 emissions due to fuel combustion. Contributions of changes to energy structure vary from displacing 2300 ktons CO_2 to adding 7300 ktons of CO_2 in a particular year. Ultimately, the changes in energy structure are responsible for an additional of 120 ktons CO_2 per year.

The aggregated effects in Fig. 5 shows that changes in CO_2 emissions from 2003 to 2010 are relatively negligible. This is because the additional emissions due to population and economic growth are cancelled out by improvements in energy intensity. However, in 2010, changes in energy structure generated an additional of 7700 ktons CO_2, which caused the emissions for that year to increase.

3.2. Critical analysis of results

This section performs a critical analysis of the trends highlighted in the previous section. Evidences, implications, potential triggers and causes of such trends will be discussed. Primarily, trends in CO_2 emissions reflect the negative effect of economic growth and higher standard of living to the environment, which are also evident in developed countries such as China and the United States. The Philippine economy has been performing well in the past few years, as shown by the consistent increase in GDP per capita in Fig. 7. As a result, about half of the increase in CO_2 emissions is due to the increase in economic activity. Events such as the Mt. Pinatubo eruption in 1991, the 1997 Asian Financial Crisis, and the 2008 Global Financial Crisis have contributed to the economic performance of the Philippines. These are reflected in the LMDI analysis in Fig. 4 (as negative annual ΔC_{act} in the respective years) and economic activity in Fig. 7. The effects of the aforementioned effects though to overall CO_2 emissions are very small.

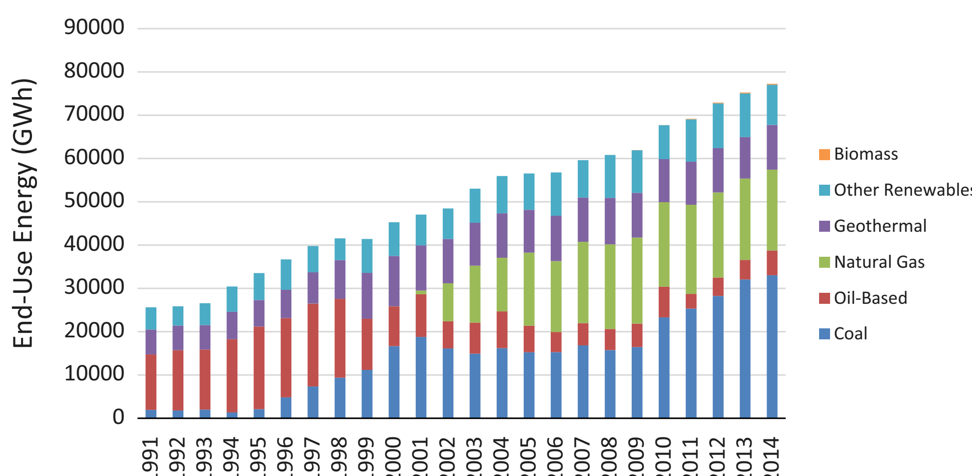

Fig. 9. Annual end-use electrical energy from 1991 to 2014 broken down per fuel type.

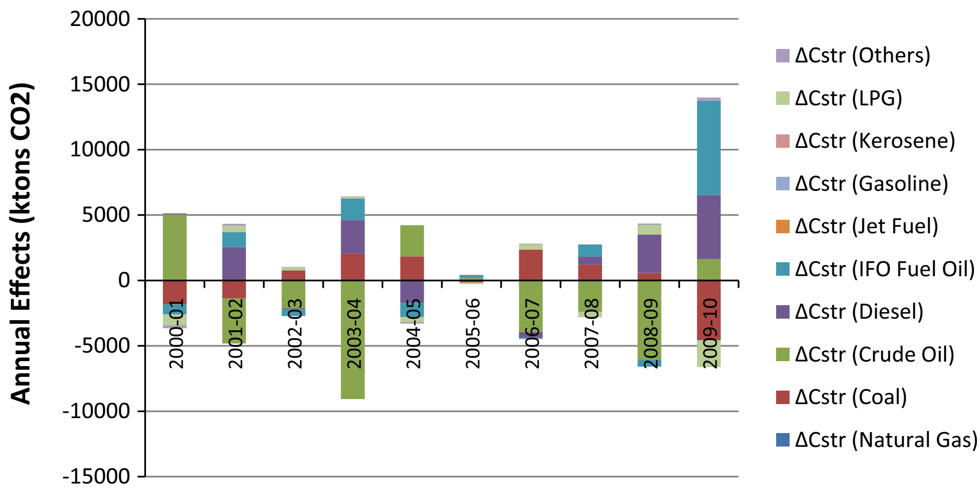

Fig. 10. Breakdown of annual energy structure effects (ΔC_{str}) to fuel combustion CO_2 emission increments into various fuel types from 2000 to 2010.

Also, Fig. 7 suggests that increase in income of Filipinos contribute significantly to the increase in CO_2 emissions, as reflected by the increasing trend of GDP per capita and CO_2 emissions per capita. Emissions increase attributed to population are approximately 34%. Policies to ensure sustainable growth will be provided in Section 4.

Conversely, improvements in energy intensity have been commendable. As already mentioned above, 2003 appears to be an inflection point for energy intensity as it began a decreasing trend beyond this year. This may be attributed to the advent of the service sector, which is less energy intensive compared to the industrial sector. After the 1997 Asian Financial Crisis, the Philippines developed its services sector tapping into its human capital resources. There has been significant growth in the service-oriented sectors in the Philippines. The breakdown of annual GDP from different sectors are presented in Fig. 8. The Bangko Sentral ng Pilipinas [45] identifies the business process outsourcing industry as a priority area for the growth and job creation. Economic activity and energy intensity are co-plotted in Fig. 7 to demonstrate that the Philippines has been consistently growing its economy while consuming less energy every year. Further discussion on the economic structure are provided in Section 3.3.

Unlike the emissions attributed to economic growth and lifestyle change, increases in emissions due to sudden changes in energy structure are unnecessary, and reflect poor management of the energy sector.

Annual power generation by fuel type is shown in Fig. 9. In relation to the energy structure effect provided by LMDI decomposition analysis in Fig. 4, efforts to promote and commercialize cleaner and renewable energy sources successfully displace significant CO_2 emissions. However, inconsistent follow through and weak management of the energy industry negate the rewards of these efforts. Cleaner and renewable energy sources appear as single-period shocks. Since 1991, most of the renewable power generation are from hydroelectric facilities. The Malampaya natural gas facility was inaugurated in late 2001. In 2005 and 2008, Phases 1 and 2 of the Bangui wind farm was completed, respectively. The impacts of these projects support the results of the decomposition analysis (see annual ΔC_{str} for years 2002, 2005

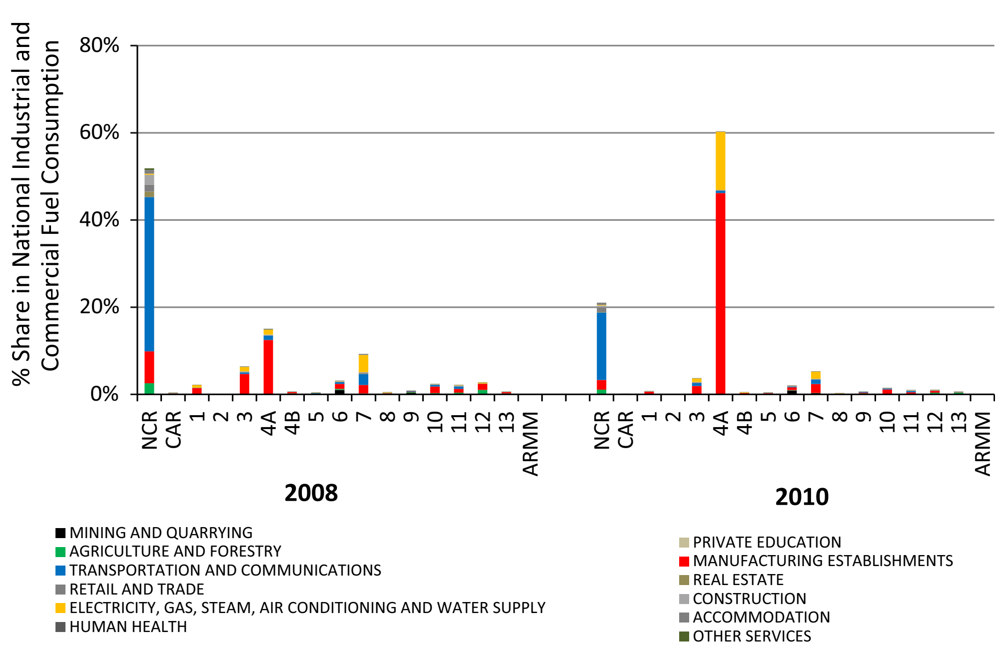

Fig. 11a. Percent share in national industrial and commercial fuel consumption per region and industry type. (Source: [42,43].)

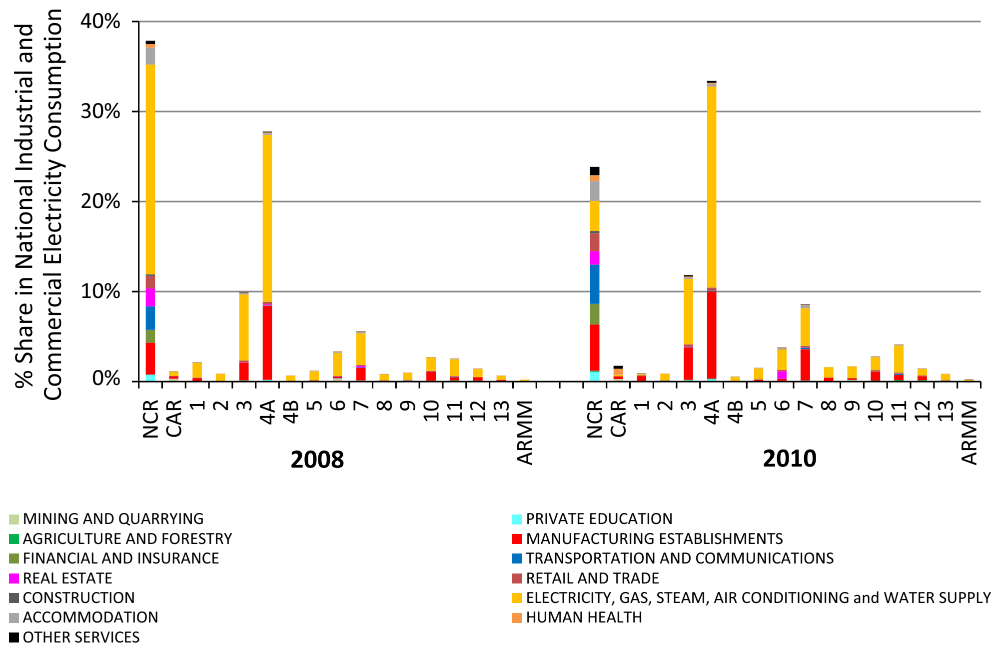

Fig. 11b. Percent share in national industrial and commercial electricity consumption per region and industry type. (Source: [42,43].)

and 2008 in Fig. 4). After these, the next significant renewable energy investments did not come until 2014, even with the passing of the Renewable Energy Act in 2008 [46], which provides guaranteed payments per kilowatt hour to renewable energy producers. The energy industry is slow to follow through on successful clean technology projects. As a result, it is forced to turn back into the traditional fossil-based fuels as the power demand increases. This is evidenced by the emergence of coal-based power plants from 2010 onwards, when energy demand increased by 10%. This is high compared to the average annual increase of 2%. The country's strong dependence on imported fuels and previous issues regarding weak energy planning should provide a more complete context.

From 1999 to 2009, the Philippines imported an average of 54.3% of its primary energy supply [47]. Dependence on imported fuels make the country vulnerable to fluctuations in the global market. For example, the Philippines' oil consumption significantly rose in 2009 (see ΔC_{str} (Diesel) in Fig. 10). This may be attributed to the sudden dip in oil prices from approximately 95 USD per barrel in 2008 to 60 USD per barrel in 2009 [48]. This resulted to an additional of 12 Mtons CO_2 from year 2009 to 2010. Annual ΔC_{str} for national fuel consumption is broken down into different fuel types in Fig. 10.

Also, effective energy planning should be able to schedule the necessary clean and renewable energy power plants as the demand comes. The exploration and commissioning process for these options are more rigorous compared to traditional fossil-based plants. In addition, the weak energy planning is a possible consequence of the full privatization of the energy industry. Due to the Electric Power Industry Reform Act (EPIRA Law) enacted in 2001, the government is no longer allowed to own any energy assets, even for security purposes. Competitive bidding of energy projects and sound energy planning have been significantly affected and amendments to the law are being planned as of writing [49].

3.3. Regional analysis and economic structure

Regional analysis is performed using economic data published by the Philippine National Statistics Office (NSO) for the years 2008 and 2010 [42,43]. Data show regional disparity in electricity and fuel consumption. Share of fuel and electricity consumption by industry per region are shown in Figs. 11a and 11b, respectively. From Figs. 11a and 11b, it can be noted that high levels of electricity consumption come from three regions namely, National Capital Region, Region 3 and Region 4A. The three regions compose roughly 70% of the entire country's consumption and most of the economic activity is also concentrated in these regions. Therefore, provisions for regional incentives may be considered. Between 2008 and 2010, remarkable shifts were indicated such that there was a dramatic reduction in electricity consumption of NCR, and at the same time, electricity and manufacturing increased for Regions 3, 4A, 7 and 11. This is attributable to the lower minimum wage imposed in areas outside the NCR, and the recovery effect from the 2008 Global Financial Crisis. The presence of economic processing zones amplifies the increase due to economic recovery, since firms enjoy benefits such as reduced tariffs and tax exemptions. Furthermore, application of industrial symbiosis in the zoned industrial areas is recommended for up-scaled integration to minimize transportation-related emissions and optimal use of energy [50]. Industrial symbiosis in economic and industrial zones facilitates optimized flow of resource exchanges [51]. By doing so, many firms can avoid consuming more virgin materials extracted from the earth so that the overall emissions can be mitigated since most extraction processes are energy-intensive [52].

4. Summary of policy implications and conclusions

This section summarizes the policy implications and concludes based on the key insights from the study. Below are the policy options which are key for sustainable growth of developing countries like the Philippines:

1. Strengthen energy planning capabilities to effectively schedule the exploration and commissioning of clean and renewable energy power plants in the horizon.
2. In relation to number 1, consider to amend the privatization of energy sector for energy security under government monitoring.

3. Improve execution of clean energy policies, such as the Renewable Energy Act of 2008, and follow through of its successful projects.
4. Promote both resource and energy efficiency through eco-industrial development, energy saving activities and capacity building efforts.
5. Promote sustainable consumption and production to address the unsustainable consumption patterns of the growing population with higher purchasing power. Programs such as sustainable public procurement, and life cycle costing can be introduced to collective and individual consumers.
6. Internalizing of externalities through appropriate energy pricing, while provide incentives to support renewable energy.

It is expected that economic growth would lead to increases in CO_2 emissions, as demonstrated by developed countries such as China and the United States. The LMDI decomposition analysis performed in this study showed that majority of the increases in CO_2 emissions may be attributed to economic growth and lifestyle change of the population. In comparison to developed economies, the contribution of the Philippines, other ASEAN countries and SIDS to global CO_2 emissions are small. Therefore, practical measures for the Philippines and similar economies should be more execution-related to effectively promote sustainable growth. Furthermore, the Philippines has shown consistent improvements in energy intensity. This is driven largely by the shift in nature of work of the primary sector from manufacturing- to service-oriented. Finally, decomposition analysis revealed that sudden shifts in energy structure provide unnecessary significant damages to the emissions performance of a developing country. Appropriate protective policies to strengthen energy planning, energy self-reliance and policy execution are important for sustainable growth.

From an international perspective, as ASEAN countries together were responsible for about 3.7% of global energy-related CO_2 emissions in 2012 (IEA, 2014), it is critical to further understand the driving factors of CO_2 emissions in these countries. As ASEAN countries share many common patterns in terms of resource endowment, economic structure, energy trade, supply and consumption, the research findings in this study are of high relevance to other ASEAN countries.

In conclusion, since energy structure has been proven to be a substantial driving factor behind the changes of CO_2 emissions in Philippines, a similar approach using LMDI is recommended to be carried out in other ASEAN countries, with special consideration on energy structure. Latest studies in Indonesia, Thailand and Vietnam, as cited in Section 1, have not factored changes in energy structure.

Economic growth, combined with population growth has repercussions on the environmental and natural resources of the country. Effective forecasting, planning and policy design should be emphasized to achieve sustainable progress.

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