Pakistan Journal of Commerce and Social Sciences
2020, Vol. 14 (2), 450-483
Pak J Commer Soc Sci

Drivers of Decoupling Economic Growth from Carbon Emission: Empirical Analysis of ASEAN Countries Using Decoupling and Decomposition Model

Sher Khan
School of Economics, Quaid-i-Azam University, Islamabad, Pakistan
Email: sherk2507@gmail.com

Muhammad Tariq Majeed
School of Economics, Quaid-i-Azam University, Islamabad, Pakistan
Email: tariq@qau.edu.pk

Article History

Received: 19 Feb 2020 Revised: 06 May 2020 Accepted: 02 June 2020 Published: 30 June 2020

Abstract

The exponential rise in energy-related carbon emissions poses a severe risk to both human and other species on the earth. The existence of a two-way relationship between economic growth and energy-specific carbon emissions needs to be delinked to achieve a low carbon economy. The current study analyzes the decoupling relationship between economic growth and carbon emissions for the Association of Southeast Asian Nations (ASEAN) countries as a region and at the national level. Moreover, Tapio decoupling indicator accompanied with decomposition techniques are employed to analyze the decoupling status and the drivers of carbon emissions. The findings state that the overall ASEAN region experienced expensive negative decoupling (END) status, followed by weak decoupling (WD) status, however at a national level, Singapore experienced the most significant strong decoupling (SD) status, while other countries mostly experienced END and WD status. The Log Mean Divisia Index (LMDI) decomposition results suggest that population, affluence, and energy structure significantly contributed to the carbon emissions at both regional and national levels. Besides, energy intensity and carbon intensity help to reduce carbon emissions in most of the ASEAN countries. Moreover, the extended decomposition model results state that population, affluence, and energy structure are the major forces that restrict the decoupling process, while energy intensity and carbon intensity help to strengthen the decoupling outcome, thereby driving the ASEAN countries towards the emission-free region. The current study contributes in highlighting key drivers of carbon emissions and gives extensive insights for emission mitigation. In turn, it also helps to foster sustainable economic growth.

Keywords: ASEAN countries, carbon intensity, CO_2 emissions, energy intensity, energy structure, Log Mean Divisia index, Tapio decoupling index.

1. Introduction

The chasing of high economic growth leads the current world towards the severe threat of climatic change that is negatively influencing the socio-economic conditions of human beings. One of the major reasons behind climatic change is global warming caused by greenhouse gas (GHG) emissions that are emitted by the combustion of fossil fuel energy sources (Majeed & Mumtaz, 2017; Leal et al., 2019). These GHG emissions rose from 9385.8 million tonnes (Mt) to 47,599 (Mt) over the past decades depicting 2.6% annual growth rate (USAID, 2016; Shuai et al., 2019). According to the International Panel on Climate Change (IPCC, 2014), the last five decades (1983-2012) were considered as the warmest decades caused by the increasing concentration of GHG emissions in the atmosphere. The GHG emissions are augmenting production volatility and, therefore, hinder stable economic performance of the economies (Majeed & Mazhar, 2019a)

The Association of Southeast Asian Nations (ASEAN) region is considered as the engine of global economic growth after China. However, currently the ASEAN region is also facing a severe challenge of environmental degradation along with increasing regional EG. Many ASEAN countries were experiencing low carbon emissions (CE) in the past, but now emissions have become considerably high because of the dependency on conventional energy. ASEAN countries are shifting their industries from manufacturing to the services sector, enabling them to produce more GDP with fewer emissions. As a result, the GDP of ASEAN member countries have increased 6.7 times than that of the 1990's level, demonstrating 3.2% of growth. Since EG is itself a driver of environmental degradation (Majeed & Luni, 2019; Majeed, 2018; Siddique & Majeed, 2015; Vehmas et al. 2012) it also increased CE, accounted for 3.85% almost 2.3 times more growth in percentage than that of the 1990s.

According to the Global Climate Risk Index published by the German watch, most of the ASEAN countries including Thailand, Cambodia, Vietnam, Myanmar, and the Philippines are the most vulnerable countries to the impact of climate change for past twenty years (Zhang et al., 2020). The ASEAN leaders have declared their commitments for environmental protection in the region following the Bali and Copenhagen (2007 & 2009) UN Conferences on climatic change. The sustainable use and management of natural resources is the prime factor behind social development as well as long-lasting EG of ASEAN countries. The vision 2020 of the ASEAN is "clean and green ASEAN" program to maintain sustainable use of the natural resources, to achieve a high quality of life as well as to ensure environmental protection (Letchumanan, 2010).

The relationship between EG and CE has been debated for a long time among scholars with the outcome of inconclusive results. Recently, this debate has shifted from determining diverse relationships to decouple the relationship between EG and the environment. In 2002, the decoupling phenomenon was familiarised by the "Organization for Economic Co-operation and Development (OECD)" to delink EG from the ecological effect to promote growth without emissions. In addition, Petri Tapio (2005) proposed an elasticity based decoupling indicator, having three-decoupling statuses namely strong decoupling (SD), weak decoupling (WD), and recessive decoupling (RD) between EG and CE. Other than these three main statuses, there are further five decoupling statuses namely, strong negative decoupling (SND), expensive negative decoupling (END), weak negative decoupling (WND), expensive coupling (EC) and recessive coupling (RC) (Tapio, 2005). Due to its usefulness, robustness of results, and ease of understanding, it is widely used in the current literature to determine the decoupling status between EG and CE (Shuai et al., 2019).

The feasibility and importance of Tapio decoupling assessment can be projected by its use on different level of analysis such as at global and regional level (Shuai et al., 2019; Chen et al., 2018; Li et al., 2017; Zhou et al., 2017; Xu et al., 2016), at national level (Khan & Majeed, 2019; Naminse & Zhuang, 2018; Li et al., 2017; Wang & Li, 2016; Lin et al., 2015; Zhang & Lahr, 2014; Wang et al., 2005; Lu et al., 2007), at provincial level (Jiang et al., 2019; Siping et al., 2019; Luo et al., 2017), at sectoral level such as the building sector (Zhang et al., 2019; Ma & Cai, 2018; Ma et al., 2018; Zhao et al., 2017; Qi et al., 2016; Wang et al., 2011), the agriculture sector (Han et al., 2018), the transportation sector (Tapio, 2005), the construction industry (Wu et al., 2018b) and sectors in general (Yang et al., 2018; Zhou et al., 2017; Zhao et al., 2017; Fan et al., 2015; Tang et al., 2014; Liu et al., 2007). The intensive use of decoupling phenomena on different levels of the analysis revealed its usefulness and robustness for the examination of the economic growth-environment relationship in the current literature.

The decoupling analysis, however, overlooks external effects of the environment. The LMDI decomposition technique gathered with Tapio decoupling indicator to examine the change in CE more efficiently in order to have a complete analysis (Zhao et al., 2017). The literature offers three main decomposition techniques namely Structure Decomposition Analysis (SDA), Production Decomposition Analysis (PDA), and Index Decomposition Analysis (IDA). The IDA technique is most commonly used in the literature (Zhou et al., 2017). It aims to decompose the total CE with a governing function into some predefined factors of interest (Ang, 2004). It is further divided into the Divisia index and Laspeyres index that are the commonly used techniques of the IDA, along with both additive and multiplicative forms.

Among many of index decomposition techniques, Ang (2004) proposed LMDI as the most ideal technique, because of its adaptableness, ease of use, ease of interpretations, handling of zero values, no residuals in the output thus providing complete decomposition. This technique demonstrates that CE is the product of the pre-determined factors that include population, EG, energy intensity (EI), and carbon intensity (CI) (Khoung et al., 2019). The factors used in the analysis were firstly introduced by Yoichi Kaya (1990) in the International Panel on Climate change (IPCC), and according to him total CE is the product of population, affluence, energy intensity (EI) and CI, and is also known as kaya identity. However, certain studies also included energy structure (ES) factor because of its significant impact on environmental quality and EG.

The importance of decoupling technique can be realised from the prior discussion, however, some of the researchers also criticize it such as Bithas and Kalimeris (2013) stated that conventional energy/EG indicator has been found more positive than the decoupling indicator in the existing literature. Similarly, Ward et al. (2016) by comparing the historical data stated that the decoupling of EG from energy and resource consumption does not occur, moreover breaking the coupling relationship of EG from primary energy consumption and its induced CE can only be envisioned. Although, several researchers acknowledged that decoupling is far better than the prior techniques in the field of environment-energy economics. Most of the researchers such as Van Canehgam et al. (2010) used the decoupling techniques to analyze the decoupling status of the Flemish industry, results suggest the existence of absolute and relative decoupling. Similarly, absolute decoupling between EG and energy-related CE was founded by De Freitas and Kaneko (2011) for Brazil between 2004-2009. In addition, the efficacy of decoupling techniques was also acknowledged by former United States (U.S) President Mr. Barrack Obama, in his article "The Irreversible Momentum of Clean Energy" (Obama, 2017). Furthermore, during his presidential period in the U.S, energy sector-related CE reduced by 9.5% while the U.S economy experienced 10% EG, demonstrating relative decoupling of EG from CE (Deutch, 2017).

Due to rapid increase in EG, ASEAN region emerge as an integral part of world economic development. The prior statistics confirm that ASEAN is emerging as a driver of global economic development in the intra-regional as well as at the global level. ASEAN Integration report (2019) says that overall EG of the region remains robust, along with a collective GDP of 3.0 trillion U.S dollar in 2018, which was about 2.5 trillion U.S dollars in 2015. Besides, ASEAN is also the fifth-largest global economy. Its regional trade increased from 2.3 trillion U.S dollar in 2015 to 2.8 trillion U.S dollar in 2018, with the overall growth of 23.9%. Furthermore, the region also experienced the highest investment in the history of ASEAN worth of 154.7 billion U.S dollar, along with the increase in total foreign direct inflows reaching up to 118.7 billion U.S dollar in 2015 (ASEAN Integration Report, 2019).

Apart from these strengths, the region is also confronted with various environmental challenges (Vehmas et al., 2012). Due to high vulnerability to climate change, the ASEAN region is faced with the severe threats of forest and land fire that mainly occurred in Indonesia. The forest/land fire of 2015 occurred between June-October ends up with 19 deaths, about 43 million people became exposed to the smoke caused by fire, while the economic losses accounted for $33.5 billion and $515.3 billion in case of Indonesia and Singapore (Tay et al., 2017). Besides, the region has over 600 million population, along with this, ASEAN is located on the busiest trade routes from which thousands of ships pass annually through Malacca and South China sea, which further enhance the regional vulnerability to climate change (Francisco, 2008). Moreover, ASEAN member countries are heavily dependent on the industry and agriculture to support their economic growth, while at the same time region is going through huge deforestation, which makes the region more exposed to the impacts of climate change (Hoad, 2015).

The above factual discussion about the ASEAN region leads our interest to conduct the decomposition and decoupling analysis between EG and CE for ASEAN countries on regional as well as at the national level. Due to the unavailability of energy-specific CE data for specific countries, six ASEAN countries namely Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam are selected in the current paper. The regional analysis has also been carried out as the ASEAN is considered one of the most vulnerable region to climate change, therefore it is necessary to scrutinize the main drivers of CE, in order to formulate and implement carbon mitigation policies. However, as per our known information, no prior study provided decoupling and decomposition analysis for ASEAN countries. Delinking EG from the environmental impact is necessary to achieve the goal of green development in the region. Therefore, this study aims to decouple EG from the environmental impact of the ASEAN region. Moreover, this study also decomposes the regional CE into pre-determined factors that are population, affluence, EI, ES, and CI. Tapio decoupling elasticity is used to evaluate the decoupling status and the LMDI decomposition technique is used to decompose the total regional CE into its factors. Furthermore, the extended decomposition model also helps to trace the reaction of each decoupling driver on the progress of the region and of the selected each member country.

The aim of this paper is to present the analysis in a systematic manner, providing findings of the relevant data. The remaining study is organized in the following manner. In "literature review" section, a deep analysis of the former literature on the nexus between EG and environmental impact is offered. The “empirical and theoretical” background along with data sources of the current paper is provided in "methodology and data sources" section. The outcome of the study is demonstrated in "results and discussion" section, computed by employing novel methodologies. In the end, the whole study is summed up in "conclusion and policy recommendation" section.

2. Literature Review

Achieving the highest EG rate, along with the lowest CE is the objective of every economy across the world. However, most of the countries experienced high growth as well as high CE, perhaps the environment is not as prioritized as growth. The loss of environmental balance is a severe threat to the whole world, as it leads to climate change that has a disastrous impact on the socio-economic conditions of the global economy (Majeed & Mazhar, 2019). The global economy experienced an annual growth of 7.6% during 1960-2016, accounted for economic worth of 1.367 trillion dollars in 1960 up to 75.845 trillion dollars in 2016, however, this EG is triggered due to high energy intensity that put severe pressure on the environmental quality (Majeed et al., 2020; Deutch, 2017). Besides, the global CE also increased from 9385.8 Mt in 1960 to 36138.3 (Mt) in 2014, demonstrating the total growth rate of 2.6%. EG induced climate change, led to the death of 600,000 people together with 4.1 billion wounded and also resulted in 1.9 trillion global monetary loss during the past two decades (Shuai et al., 2019).

The continuous degradation of global environmental quality possesses a severe threat to the sustainability of the ASEAN region, according to the Climate Risk Index, five among twenty most exposed countries to the impact of climate change are from ASEAN region. Due to the severe use of primary energy sources such as coal (in Philippines, Malaysia, and Indonesia) and natural gas and oil (in Singapore, Thailand and Vietnam) tend to increase CE in the region, which further leads to the worsening of regional climate change profile (Marquardt, 2016). The energy sector is considered the highest contributor to global GHG emissions, moreover, due to high dependency on conventional energy sources, the ASEAN region became the highest contributor to global warming (Silitonga et al., 2018; Mofijur et al., 2019). The dependency and continuous increase in the conventional energy consumption without any decarbonization policies will lead the region to have doubled its energy induced CE till 2040, reaching up to 2.3 billion tonnes (IEA, 2017). Furthermore, Indonesia being a populous country in South East Asia and fourth at a global level, similarly, Singapore is the most urbanized country of ASEAN region with no rural area in the whole country, these demographic facts further worsen the sustainability of environmental quality in the ASEAN region.

It can be inferred from the above discussions that CE has a paramount relationship with EG. Therefore, an urgent response is required to break this relationship, in turn to achieve green growth (Shi et al., 2017; Pan et al., 2018; Chen et al., 2018). To achieve this objective a comprehensive analysis of decoupling growth from emissions is required. However, in the recent literature decoupling techniques are widely used (Dong et al., 2018; Wu et al., 2018b; Shen et al., 2018).

According to the United Nations Environmental Protection (UNEP), decoupling can be defined as "Breaking the link between economic growth and carbon emissions" (UNEP, 2011). The term decoupling was firstly originated from physics, the prior meaning of the decoupling is to delink EG from CE, however, decoupling phenomena was firstly proposed by the OECD (Wu et al., 2018b). The OECD decoupling method has widely been used in literature because it contains fewer calculations (De Freitas & Kaneko, 2011; Yu et al., 2013). However, this method is highly sensitive to the selection of the base year (Zhou et al., 2017). Alternatively, Tapio (2005) introduced the decoupling model, which is based on the elasticities, and it provides more accurate results as compared to the OECD method. Moreover, it decomposes the decoupling status between EG from CE into eight categories (Tapio, 2005). Tapio decoupling is more credible than other decoupling techniques (Wu et al., 2018c).

2.1 Literature on Decoupling Analysis

The decoupling phenomenon has become the most heated/debated topic of energy and environment literature in recent decades (Pao & Chen, 2019). The association between energy consumption and income of residents of the Shandong province has been analyzed by Zhang and Bai (2018) using the decoupling technique. The results demonstrated a WD status between urban and rural people's energy consumption and income level. Similarly, China's manufacturing industry decoupling status has been analyzed by Ren et al. (2014) by employing the decoupling method and founded that there exist four decoupling status namely, WD status, SND status, END status, and EC status. Wang and Yang (2015) examined the decoupling status of the industrial sector of the Beijing-Tianjin-Hebei district of China over the period 1996-2010 and results exhibited that WD status is the most dominant decoupling status during the study period. Similar results are also obtained by Zhao et al. (2017) for the five major sectors of China namely agriculture, transport, service, industrial, and construction for the time span of 1992-2012. All the sectors exhibit the coupling status between EG and environmental impact during the analysis period. The panel decoupling analysis of transport sector induced environmental impact from EG has been examined by Loo and Banister (2016) during 1990-2012. The results demonstrated that decoupling exists in most of the examined countries at a heterogeneous level. Tapio decoupling analysis was used by Chen and Chen (2017) for Macao, the results demonstrated variation in decoupling status during the study period. Wang and Su (2020) analyzed the decoupling relationship between CE and EG using Tapio decoupling index at global as well as regional level. The results exhibit that most of the developed countries experienced WD status, while constantly improving it and shifting from weak-SD status. While the developing countries do not exhibit any clear decoupling status. Furthermore, affluence in both developed and developing, while EG in developing countries restricts the decoupling process, while EI is the main factor strengthening the decoupling of EG from CE. The decoupling relationship of China's transportation sector GDP and its induced CE has been analyzed by Wu et al. (2018a) during 1994-2012 and experienced poor decoupling status. Similarly, Zhou et al. (2017) found WD status between EG and industrial sector CE in eight different regions of China. Furthermore, Jiang et al. (2016) found that there exist relative decoupling and coupling status for U.S EG and CE during 1990-2014.

2.2 Literature on Decomposition Analysis

The implication of the Tapio decoupling indicator is sufficient to examine the decoupling status between EG and CE, however, it failed to provide factor specific contribution to the total CE. Therefore, Ang and Choi (1997) proposed the Log Mean Divisia Index (LMDI) decomposition technique to identify the main drivers of CE. Many scholars have applied LMDI decomposition technique to analyze the main drivers of CE, such as Du and Lin (2018) decompose CE of China's metallurgical industry from 1991-2014 using LMDI, and they have found that labor productivity, EI, and industry size are the main influencing factors of CE. Jiang et al. (2017) analyzed China's provincial CE drivers and emissions reduction strategies, and they have found that provincial economic expansion and EI reduction plays a significant role in enhancing and reducing CE. There are several studies at national and provincial level on decoupling and decomposition, however regional analysis is limited on such topics, though there are some studies that have examine decoupling and decomposition of CE at regional level such as (Zhang & Lin, 2012; He et al., 2017; Wen & Li, 2019; Wang & Yang, 2020; Madaleno & Moutinho, 2018; Zhang et al., 2020). Zhang and Lin (2012) and He et al. (2017) employed Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model to assess the relationship between urbanization, energy, and CE in Eastern, Western and Central region for a span of 1995-2010 and 1990-2013.

Zhang and Lin (2020) experienced that urbanization significantly increases CE and energy consumption. Moreover, He *et al*. (2017) stated that there exists an inverted U-shape relationship between urbanization and CE. Wen and Li (2019) examine national and regional level drivers of CE for China using Influence, Population, Affluence, and Energy (IPAT-E) model from 2001-2016. The results demonstrated that affluence, energy, and technology increase CE at the national level, while regional analysis confirmed that population, affluence, and energy significantly increase CE, while technology has a minor impact on CE. Wang and Yang (2020) explored the decoupling and decomposition for China's regional CE and EG employing the "Tapio decoupling" technique and LMDI decomposition technique. The results demonstrated that overall China has stable decoupling between EG and CE, while decomposition results stated that GDP significantly increases CE, while EI helps to curb it. ASEAN region and China's EG-environment relationship has been examined by Zhang et al. (2020) over the period of 1990-2014 using the LMDI decomposition technique along with the Tapio decoupling indicator. The results supported that population, affluence, and CI are the main drivers of CE, while EI significantly decreases CE in both ASEAN and China. Moreover, the ASEAN region exhibits WD status, EC status, and END status, while China mainly observed WD status throughout the study period.

To achieve the ASEAN vision of "clean and green ASEAN" it is necessary to delink EG from environmental harms. The decoupling and decomposition analysis for ASEAN region and countries is not yet explored. The comparative studies are needed to be adopted on an urgent basis, to develop the co-operation among the countries that will help to promote the decoupling progress of the region. Therefore, the present study fills this research lacuna and contributes to the decoupling literature in the following ways. First, this study extends the empirical literature using novel methods like "Tapio decoupling elasticity analysis" and LMDI decomposition technique in the environment-economic growth research area for the ASEAN region and its member countries. Second, the current study will also be helpful in mitigating CE in the specific region as well as in the member countries as it highlighted the main drivers of CE. Third, the study can serve as a milestone for policymakers to propose and implement carbon mitigation policies at the region/country level to attain sustainable EG. Fourth, this research will open an avenue for future research in the context of ASEAN nations.

3. Data and Methodology

3.1 Theoretical Framework

The association between EG and CE has been debated among researchers for several decades (Siddique & Majeed, 2016; Majeed & Ayub, 2018). Based on the Simon Kuznets theory, there occurs an inverted U-shaped relation between EG and CE, which elaborates that in the beginning CE increases with the increase in EG (short term phenomena), while after the certain point EG leads to decrease CE (long term phenomena). Though in the current environmental literature, EKC has been criticized by many researchers such as Stern (2004) argued that that EKC is rejected when suitable techniques and diagnostics statistics are concerned, similarly, EKC also fails to give suitable results on a global level (Majeed & Mazhar, 2020; Borghesi & Vercelli, 2003). Majeed and Mazhar (2020) provide comprehensive analysis of EKC using a long panel time series data from 1961 to 2018. They conclude that the global evidence on EKC is inconclusive. Further, EKC does not give annual decoupling status between EG and CE, and it did not specify the time period of the turning point of the EKC, from where EG tends to decrease CE.

In response to the flaws in the prior techniques, the need for some concrete methodology was realized to properly analyse the connection between EG and CE. In response, Tapio (2005) proposed a more appropriate technique based on the elasticities of the response factors, which gives the annual decoupling status of EG from CE, and it is applicable on different levels of the economy. Besides, the LMDI decomposition technique is thought to be complementary with the Tapio decoupling technique, which gives a complete decomposition of CE into its pre-determined factors such as population, affluence, energy, and CI (Kaya identity). The current section comprises a detailed explanation of the above-said techniques.

3.2 Tapio Decoupling Elasticity

Tapio (2005) suggested the decoupling elasticity to decouple EG from the environmental impact. The Tapio decoupling elasticity has three main categories that are SD status, WD status, and RC status, while these are further divided into five sub-categories, such as END, expansive coupling, RD, WND, and SND. Tapio (2005) defines the decoupling elasticity as follows,

$$\mathrm{DE} = \frac{(CE_t - CE_o)/(CE_o)}{(GDP_t - GDP_o)/(GDP_o)} = \frac{\Delta \mathrm{C}E_t/CE_o}{\Delta \mathrm{GDP}/GDP_o} = \frac{\%\Delta CE}{\%\Delta GDP} \qquad (1)$$

In the above expression, the CE_0 and GDP_0 represents the initial year of CE and EG, while ∆CE and ∆GDP represents the change in CE and EG, based on a non-continuous chaining method. The %∆CE and %∆GDP represents the growth rate of CE and EG. Figure (1) demonstrate the “decoupling status” using the decoupling elasticity (DE).

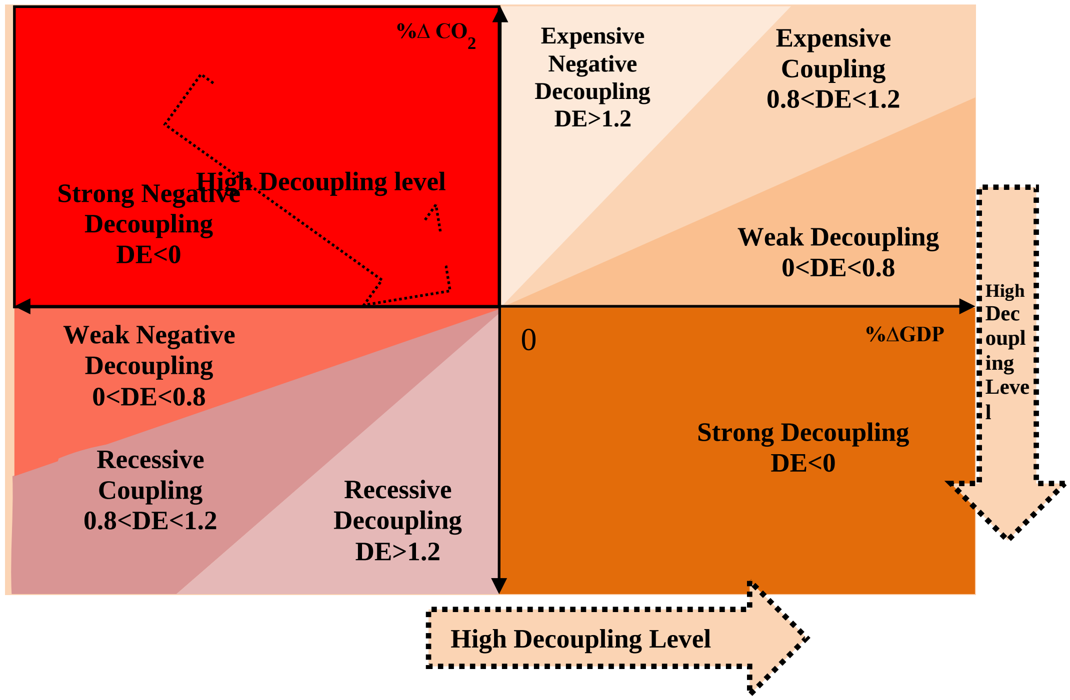

Figure 1: The Framework of Decoupling States

3.3 Decomposition Model

Several decomposition methods are employed to evaluate the changes in CE at global as well as national level, however LMDI is the mostly used technique, built on the Kaya identity. The model was first proposed by Yoichi Kaya (1990) at the International Panel on Climate Change (IPCC) decomposing CE in its pre-determined factors which are demonstrated in eq (2),

$$\mathrm{CE} = \sum_{i=1}^{3} CEi = \sum_{i=1}^{3} \mathrm{P} \times \frac{G}{P} \times \frac{E}{G} \times \frac{Ei}{E} \times \frac{Ci}{Ei} = \sum_{i=1}^{3} Pop \times Aff \times EI \times ES \times CI \quad (2)$$

In equation 2, *Pop* shows population (total); GDP ("constant 2010 US$") is represented by *G i.e.* economic growth, total energy consumption in a "metric tonne of oil equivalent" (Mtoe) is represented by *E*, consumption of *i* fuel energy is demonstrated by *Ei* (Mtoe), and energy-induced CE of *i* fuel is shown by C*i* (Mtoe). Further, *Aff* represents economic growth per capita termed as affluence, *EI* demonstrates energy intensity (energy consumption per unit of GDP), energy structure is showed as *ES* (share of *i* fuel energy in total energy consumption) and carbon intensity as *CI* (CE "per unit of energy use"). The string *i*=1, 2, and 3 represent coal, petrol, and natural gas, respectively.

According to Ang (2005), equation 3 depicts a change in energy-related CE from the initial year (t) to base year (0), resulting from the change in its predetermined factors such as population, affluence, EI, ES, and CI based on Kaya (1990) identity.

$$\Delta \mathrm{C} = C_t - C_o = \Delta C_{Pop} + \Delta C_{Aff} + \Delta C_{EI} + \Delta C_{ES} + \Delta C_{CI} \quad (3)$$

The equation 3 variables are calculated by using equations from (4)-(8) mentioned as follows,

$\Delta Pop = \sum_{i=1}^{3} ln(C_{it}, C_{io})\ ln(\frac{Pop_t}{Pop_o})$ (4)

$\Delta Aff = \sum_{i=1}^{3} ln(C_{it}, C_{io})\ ln(\frac{Aff_t}{Aff_o})$ (5)

$\Delta iI = \sum_{i=1}^{3} ln(C_{it}, C_{io})\ ln(\frac{EI_t}{EI_o})$ (6)

$\Delta ES = \sum_{i=1}^{3} ln(C_{it}, C_{io})\ ln(\frac{ES_t}{ES_o})$ (7)

$\Delta CI = \sum_{i=1}^{3} ln(C_{it}, C_{io})\ ln(\frac{CI_t}{CI_o})$ (8)

The proof of the perfect decomposition of the LMDI technique can be obtained by combining equations 4, 5, 6, 7, and 8 into equation 3.

$$= \sum_{i=1}^{3} ln(C_{it}, C_{io}) ln\ (\frac{Pop_t}{Pop_o}) + \sum_{i=1}^{3} ln(C_{it}, C_{i0}) ln\left(\frac{A_{fft}}{Aff_o}\right) + \sum_{i=1}^{3} ln(C_{it}, C_{io}) ln\left(\frac{EI_t}{EI_o}\right) + \sum_{i=1}^{3} ln(C_{it}, C_{i0}) ln\left(\frac{ES_t}{ES_o}\right) + \sum_{i=1}^{3} ln(C_{it}, C_{io}) ln\left(\frac{CI_t}{CI_o}\right)$$

$$= \sum_{i=1}^{3} ln(C_{it}, C_{io}) \left[ln\left(\frac{Pop_t}{Pop_o}\right) + ln\left(\frac{Aff_t}{Aff_o}\right) + ln\left(\frac{EI_t}{EI_o}\right) + ln\left(\frac{ES_t}{ES_o}\right) + ln\left(\frac{CI_t}{CI_o}\right)\right]$$

$$= \sum_{i=1}^{3} ln(C_{it}, C_{io}) \left[ln\left(\frac{Pop_t Aff_t EI_t CI_t ES_t}{Pop_o Aff_o EI_o CI_o ES_o}\right)\right]$$

$$= \sum_{i=1}^{3} ln(C_{it}, C_{io}) \left[ln\left(\frac{Ei_t}{Ei_o}\right)\right]$$

$$= \sum_{i=1}^{3} (E_t - E_o)$$

$$\Delta \mathrm{C} = \Delta \mathrm{E} \qquad (9)$$

However, the term $ln(C_t, C_o) = ln\left(\frac{C_t - C_o}{lnC_t - lnC_o}\right)$

The above equation (9) demonstrated the perfect decomposition of the LMDI, therefore it is ideal among other decomposition methods.

3.4 Extended Decomposition Model

The decomposition model of section 3.2 demonstrates the decomposition of CE intro pre-determined factors of Kaya identity. However, decomposition analysis does not capture the response of the factors towards the decoupling of EG from environmental impact. Therefore, this section combines the decoupling and decomposition model (extended decomposition model) to elaborate factor specific response towards the decoupling progress. The results of the extended decomposition model can be obtained by incorporating equation (3) into (1):

$$= \frac{\Delta \mathrm{C_{Pop}} + \Delta \mathrm{C_{Aff}} + \Delta \mathrm{C_{EI}} + \Delta \mathrm{C_{ES}} + \Delta \mathrm{C_{CI}} / \mathrm{CE_o}}{\Delta \mathrm{G} / \mathrm{GDP_o}}$$

$$= \frac{\Delta \mathrm{C_{Pop}}/\mathrm{CE_o}}{\Delta \mathrm{G}/\mathrm{GDP_o}} + \frac{\Delta \mathrm{CE_{Aff}}/\mathrm{CO_o}}{\Delta \mathrm{G}/\mathrm{GDP_o}} + \frac{\Delta \mathrm{C_{EI}}/\mathrm{CE_o}}{\Delta \mathrm{G}/\mathrm{GDP_o}} + \frac{\Delta\, \mathrm{C_{ES}}/\mathrm{CE_o}}{\Delta \mathrm{G}/\mathrm{GDP_o}} + \frac{\Delta \mathrm{C_{CI}}/\mathrm{CE_o}}{\Delta \mathrm{G}/\mathrm{GDP_o}}$$

$$= \mathrm{D_{Pop}} + \mathrm{D_{Aff}} + \mathrm{D_{EI}} + \mathrm{D_{ES}} + \mathrm{D_{CI}} \qquad (10)$$

The factors of equation (10) i.e. $\mathrm{D_{Pop}}, \mathrm{D_{Aff}}, \mathrm{D_{EI}}, \mathrm{D_{ES}},$ and $\mathrm{D_{CI}}$ are the five sub-indicators of the decoupling elasticity, exhibiting the response of population, EG, EI, ES and CI to the decoupling progress in the ASEAN region and for the respective member countries.

3.5 Data and Variable

The current study is conducted for a panel of six ASEAN countries (Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam) as well as the regional analysis of ASEAN is also conducted between 2000 and 2014. The period for the current study has been divided into three phases, comprised of a five-year time interval, to better capture the share of factors into the CE as well as the response of factors towards the decoupling process. Due to the unavailability of data, the time period is restricted from 2000-2014 and six ASEAN countries are selected for the current paper, however, regional analysis is also conducted. The data of GDP ("constant 2010 $U.S), population (total) carbon emissions (kt), carbon emissions (kt) from i fuel (coal, oil, and natural gas"), per person GDP also termed as affluence (constant 2010 $U.S) is sourced from World Bank (2020), while the energy-related data such as energy consumption (Mtoe) of i fuel (coal, oil, and natural gas) is obtained from the British Petroleum (2019). The variables from different data sites are further used to construct index variables i.e. energy intensity (consumption of energy per unit of GDP), energy structure (ratio of i fuel consumption in total energy consumption), and CI (carbon emissions per unit of energy consumption).

The response variables are taken in different measurement because of data limitations, however, the variables are transformed into percentage form after implication of LMDI decomposition technique, because the "Divisia index methods evaluate the results of each unit by statistics, using the weighted logarithmic mean variations of the relevant factors" (Khan & Majeed; Lin & Raza, 2019).

4. Results and Discussions

The current section is organized as, first trend analysis of CE at the global, regional, and national levels is discussed, followed by the decoupling status of the ASEAN region as well as country-specific are discussed. After that decomposition of CE into its factors is provided at regional and at the national level. At last, results of extended decomposition model is given for both regional as well as national level.

The global CE trend has been shown in figure 2, which elaborates that the world CE grew continuously during the study period, except in the global financial crises of 2009. The decrease in CE in 2009 exhibits the prime relationship between environmental impact and EG. The fossil fuel energy consumption has the dominant role in promoting CE all over the world, according to Chen et al. (2019), coal consumption induced CE has increased rapidly from 36.02% to 44.65%, while oil consumption induced CE gradually decreased from 44.03% to 35.5% and the natural gas consumption induced CE remains constant at 19% during the study period. The fossil fuel energy has a dominant role in the global ES. However, natural gas is less carbon-intensive than other forms of fossil fuels. Hence, its consumption should be promoted for green EG.

The individual country analysis of the CE trend for the selected ASEAN countries is shown in figure 3. Due to the completion of Initiative of ASEAN Integration (IAI) phase 1 (2002-2008) and initiating of phase 2 (2009-2015) comprised of 232 and 182 projects, ASEAN CE increased during study period except 2011 and 2012 (Sok, 2019).

In the selected ASEAN countries, Indonesia shows the highest CE, followed up by Malaysia, Philippines, Singapore, Thailand, and Vietnam. The respective countries CE increases rapidly throughput analysis period that is Indonesia's CE raised from 268.2 to 476.5 (Mt), while Malaysia's CE grew from 131.3 to 241.0 (Mt). The Philippines has the lowest rate of CE i.e. 66.8-97.6 (Mt), Singapore's CE grew significantly from 107.7 to192.6 (Mt) during the analysis period. Thailand and Vietnam depict rapid growth in CE from 169.8-282.8 (Mt) and 47.0-157.5 (Mt), respectively.

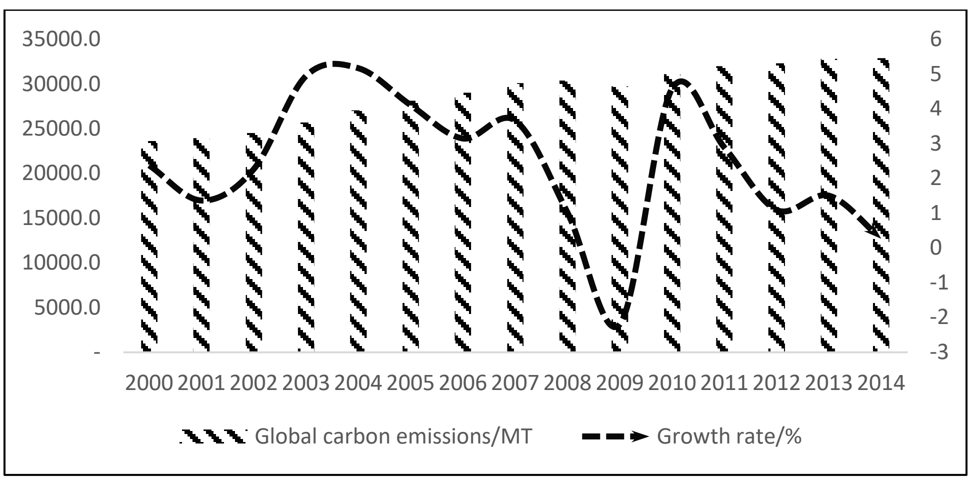

Figure 2: Global Carbon Emissions from 2000-2014 (Authors Own Calculations)

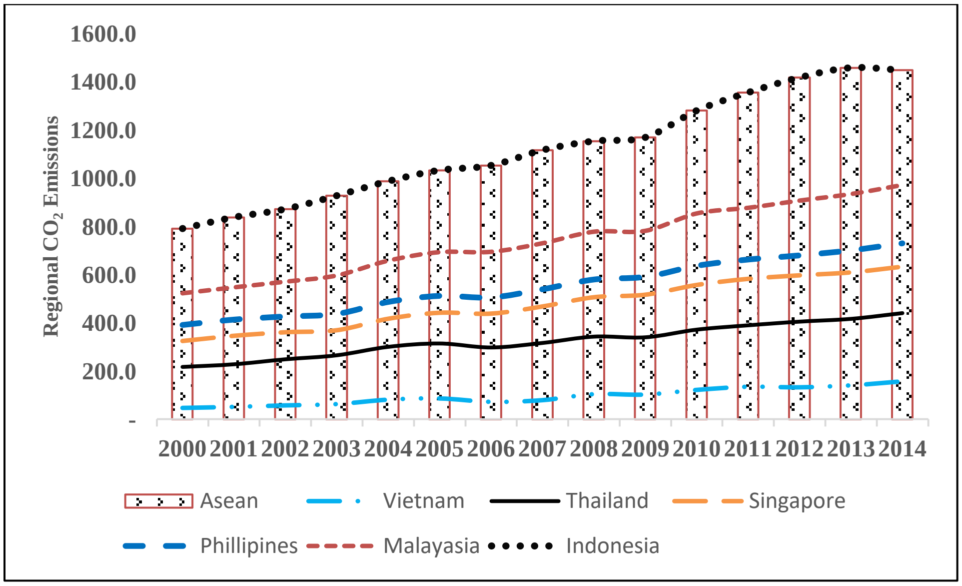

Figure 3: ASEAN Carbon Emissions Trend From 2000-2014.

Source: Authors Own Calculations

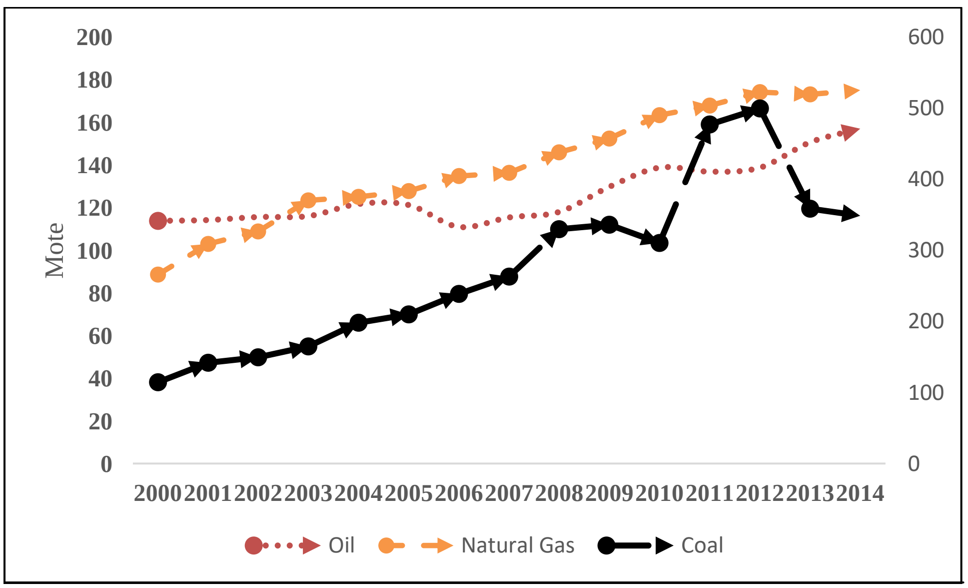

Figure 4: ASEAN Energy Induced CO_2 Emissions

Source: Authors Own Calculations

The energy consumption induced CE of the ASEAN region has been shown in figure 4. Natural gas and oil-induced CE in the ASEAN region grew significantly with an increasing trend, while coal-related CE depicts a mixed trend. The decrease in oil-related CE in 2008 demonstrates the oil supply shortage of 2008, which in turn increases the consumption of coal and its relevant CE. According to British Petroleum (2019) statistics, the coal consumption in 2010 suddenly increased from 310 (Mtoe) to 476 (Mtoe) in 2011, which leads to an increase in CE. This increase in coal consumption is due to temporary oil supply shortage, while post oil supply shortage, coal consumption decreases to 358 (Mtoe) and coal induced CE also decreases in 2013 (BP, 2019).

4.1 Decoupling Analysis of Economic growth from Carbon emissions

4.1.1 Regional Decoupling Analysis

This section demonstrates the decoupling analysis of EG from environmental impact based on Tapio's decoupling elasticity analysis for the ASEAN region during 2000-2014. The vertical axis of figure 5 shows the percentage change of CE and the horizontal axis depicts the percentage change in GDP, while the dots shows the decoupling status of the ASEAN region. The results demonstrate that ASEAN region experienced WD status *i.e.* EG is relatively higher than CE in most of the years, due to substitution of emission-intensive fuels with less emission-intensive fuels, such as renewable energy and natural gas, however, such fuel substitution is not on a higher note that's why in most of the analysis period ASEAN experienced higher rates of CE, demonstrated by the END status *i.e.* CE is higher than EG (Sandu et al., 2019). Moreover, END status in ASEAN is consistent with the Zhang et al., (2020) which states that ASEAN experienced an average annual economic growth rate of 5.08%, while 5.26% growth rate in CE due to excessive combustion of fossil fuel in past two decades. Besides, EC status is also observed, demonstrating that in the respective years, ASEAN does not experience any kind of decoupling status. Furthermore, the ASEAN region also depicts SD status *i.e*. the most preferred decoupling status between EG and CE, which states that EG is higher than the environmental impact in the respective years of the study.

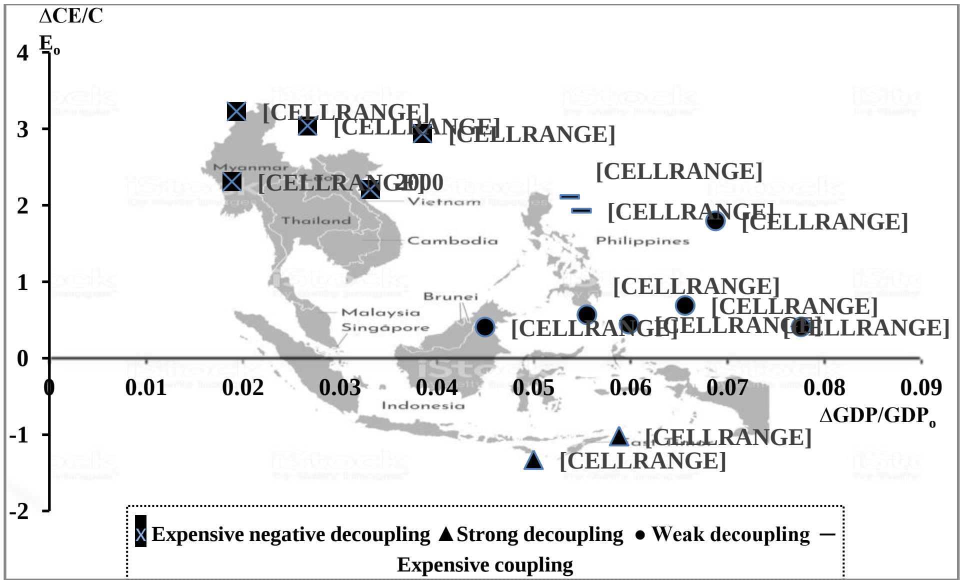

Figure 5: Decoupling Analysis of ASEAN Region

Source: Authors Own Calculations

4.2 Country-Specific Decoupling Analysis

Figure 6 exhibits the decoupling status of EG from environmental impact for ASEAN countries for a span of 2000-2014, using the Tapio decoupling indicator. The graph demonstrates that in most of the ASEAN countries four main decoupling statuses are observed i.e. END status, WD status, EC status, SD status. However, RD and SND was also observed in Malaysia, Singapore, and Thailand in a couple of years.

The most preferred decoupling status is SD, which is observed in all the countries in multiple years, such as in Indonesia (2010, 2013 and 2014), Malaysia (2002, 2006 and 2012), Philippines (2001, 2006 and 2009), Thailand (2008 and 2001), Vietnam only observed SD status in (2012). Singapore has the more stable decoupling status between EG and CE as it observed SD in most of the study period because of it aggressively moving towards clean/green energy compared to other countries in ASEAN region, that can be witnessed by a huge investment *i.e.* 2.4 million dollars by a Norway based REC company in solar energy, that is capable to produce 800 megawatts electricity and it's also as considered as world's largest project. Besides, the world's largest biodiesel renewable plant supported by Finland's Neste Oil company would also be installed in Singapore with an output capacity of 250 million gallons/year (Makover et al., 2009). The second most stable decoupling status is WD, Thailand has more WD status such as in year (2000, 2005, 2006, 2007, 2010, and 2013), supported by Luken and Piras (2011) who also stated that Thailand is relatively more decoupled than any other ASEAN country. According to the World Bank (2018), Thailand experienced tremendous economic development as it transforms it's status from a low-income country to upperincome countries. Besides, Thailand's CE/capita significantly increases from 2.7-3.9 $MtCO_2$ between 2000-2016 (Crippa, 2019). In case of other ASEAN countries, Indonesia in (2003, 2005 and 2006), Malaysia (2001, 2004 and 2014), the Philippines in (2003, 2004, 2005 and 2011), Vietnam in (2006, 2007 and 2013), while Singapore only observed WD status in (2006 and 2014).

Although the END is the un-preferred decoupling status, and it demonstrates that CE comparatively grew more than the EG. In comparison with other ASEAN countries Singapore, Thailand and the Philippines experienced less END status i.e. (2009, 2008 and 2013), (2001, 2004 and 2014), and (2000, 2008, 2010 and 2014). Vietnam experienced nine years of END status though the economy grew faster during 2000-2010, however, CE growth also tripled, while CI to GDP almost reached to 48% and this is all due to fossil fuel-intensive growth model, which turns Vietnam into energy importer from energy exporter country (ADB, 2013; Audinet et al., 2015; Khoung, 2017; Kim & Le, 2018). Malaysian economy preferred EG over the higher intensity of CE due to which Malaysia encountered END status in eight periods of study (Begum et al., 2015). Indonesia in seven years of study period exhibits END status because the country's EG is accelerated with the intensive use of coal, deforestation, and depletion of natural resources, the study of Iskandar (2019) also demonstrated that CE grew more than EG in Indonesia.

EC status demonstrated that there is no decoupling between EG and CE. Malaysia and Singapore have more stable results, demonstrating EC status only in the year (2011) and (2005). The decoupling status is worse in Thailand and Philippines which exhibits EC status in (2000, 2002, 2003, and 2012) and (2007, 2012 and 2013). Furthermore, Vietnam observed EC in (2005 and 2011) while Indonesia observed EC in (2002 and 2012). SND status is also observed in Singapore (2001) and in Thailand (2009) demonstrating that CE is more than EG in the specific years of the study. Besides, RND status is also observed in (2009) in Malaysia.

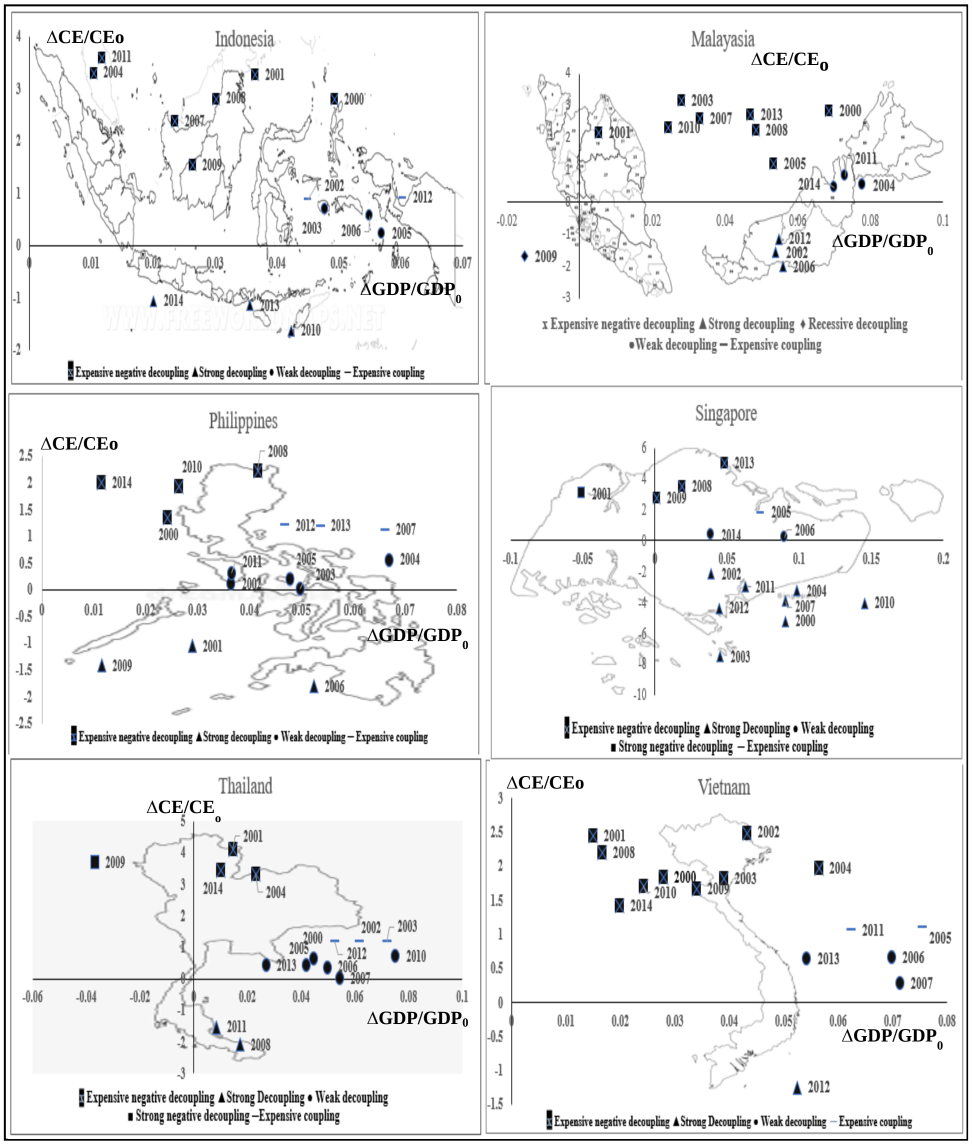

Figure 6: Decoupling Analysis of Asean Countries

Source: Authors Own Calculations

4.3 Decomposition Analysis

This section contains the decomposition of environmental impact into its pre-determined factors based on Kaya identity using the LMDI decomposition technique along with the non-chaining decomposition for the period of 2000-2014 with a five-year time interval.

4.3.1 ASEAN Decomposition Analysis

Figure 7 indicates that the major factor of degrading environmental quality in ASEAN region is CI, followed by EI however, EI helps to decrease environmental impact in phase 1. Population and affluence contribute to higher CE, the results are consistent with the study of (Ab-Rahim, 2016; Saudi et al., 2017; Wenju & Zheng, 2018). The ES share to the total CE is somehow constant in phase 1 and 2, while it rapidly increases in the last phase of the study (Ang, 2008; Kraft & Kraft, 1978).

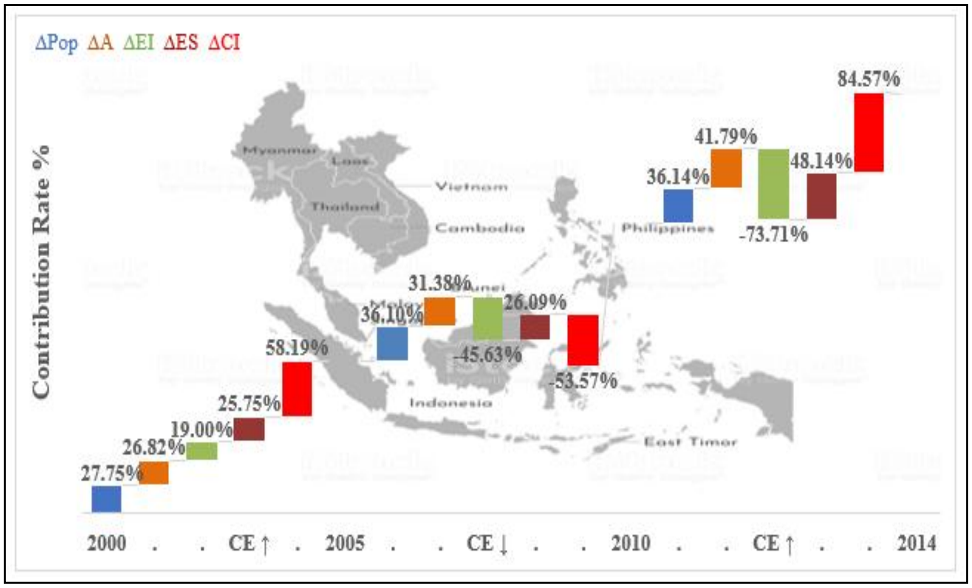

Figure 7: Decomposition Analysis of Environmental Impact on Its Factor
Source: Authors Own Calculation

4.3.2 Factor Specific Decomposition Analysis

Population is one of the most influencing factors behind the increase of CE in member countries of the ASEAN region. *Figure 8* demonstrates the decomposition results, which exerts that population specific CE in Indonesia is comparatively high in ASEAN region as the country is highly populated in ASEAN region and fourth at global level, which possesses an immense negative impact on the environmental quality of country (Saboori et al., 2012; Alam et al., 2016; Sukono et al., 2019; Sasana, 2017). Furthermore, according to the Central Intelligence Agency (2016) report, Singapore is totally urbanized, with an annual 2.02% population growth, which caused depletion of about 90% of natural forests which put immense pressure on environmental quality (Ali et al., 2017; Zambrano-Monserrate et al., 2018). Similarly, Vietnam is also the second most populated country with an annual average growth rate of 2.2% but however, population contributions to total CE are significantly low compared to other factors (Tuan, 1997; Nguyen et al., 2018). In addition, the population in all the selected ASEAN countries led to increase CE throughout the study period.

Economic growth is also one of the paramount factors behind an increase in CE at global as well as country level. Among six ASEAN countries, Indonesia experienced 6% growth during 1990-2016, while Vietnam's EG induced CE significantly increases from 14 million tonnes to 80 million tonnes in the last three decades, along with an EG rate of 6.5% from 2000-2015. Figure 8 demonstrates that affluence (EG) significantly affected CE in six ASEAN countries (Diputra, 2018; Lim et al., 2014; Al-Mulali et al., 2015; Shahbaz et al., 2019). Furthermore, EG significantly increases CE in phase 1 and 3, while due to financial crises of 2007-2008, CE was significantly affected and resulted in decrease during phase 2 in Malaysia, Singapore, and Thailand, while Philippines experienced little increase in CE, though Indonesia and Vietnam CE do not exhibit significant decrease due to high reliance on conventional energy sources. However, during recovery from financial crises in phase 3, CE in all the countries continues to increase rapidly due to a boom in economic activities (Peters et al., 2012).

EI significantly increases CE in Indonesia due to its dependence on fossil fuels *i.e.* reached up to 50% of total energy consumption from 1999-2009, in which coal consumption has been tripled reaching up to 29% and oil up to 44% (Hwang & Yoo, 2014). Similarly, the Philippines energy sector is also dependent on primary energy *i.e.* oil 40% and coal 20% of total energy consumption, though figure 8 shows that EI contributes to CE with a decreasing rate during three phases of the study (Lim et al., 2014). Like the Philippines, Malaysia energy induced CE also shows a decreasing trend during the three phases of the study. Vietnam also experienced a decrease in energy-related CE in phase 1 and 2, while it experienced a sudden increase in CE in phase 3 (Fodha & Zaghdoud, 2010; Binh, 2011; Nguyen *et al*., 2009; Tuan, 1997; Ozturk & Acaravci, 2013; Linh & Lin, 2014; Shahbaz *et al*., 2019). Singapore also encountered a decrease in energy induced CE in phase 1 *i.e.* Singapore experienced a decline in energy consumption from 12 tonnes in the 1990's up to 7 tonnes in 2003 (Zambranno-Monserrate *et al*., 2018). Thailand experienced high energy-related CE during phases 1 and 3, however, due to financial crises it exerts a decrease in CE during phase 2. ES has the dominant role in country's/regional CE as it possess the share of fssil fuel energy in the total energy consumption, figure 8 shows ES contribution to total CE in the selected ASEAN countries. Indonesia's ES significantly reduces CE in phase1 and 2 while at phase 3 it leads to increase CE. Similarly, Singapore also experienced a decrease in energy sector-specific CE in phase 1, however in phases 2 and 3, ES contributes to CE with a decreasing rate, the same results are also experienced in the Philippines, in which ES contributes to CE with decreasing rate in overall three phases. Malaysia and Thailand exerts the lowest ES induced CE in phase 1 and 3 compared to all ASEAN countries, though in phase 2 they have experienced rapid increase in CE (Muangthai et al., 2014). Further, Vietnam experienced a decrease in ES induce CE in phase 2, while in phase 1 and 3 it also encountered high CE from ES. CI contribution to CE in all six ASEAN countries is ambiguous during the three phases of the study.

In the case of Vietnam and Singapore, CI significantly contributed to the CE in phase1 and 3 while both countries experienced negative CE in phase 2. The Philippines exerts more stable results in concern with CI because CI induced CE decreased from phase 1 and reaches up to -

57% in the last phase in Philippines. Indonesia and Malaysia experienced similar results as both countries demonstrated significant contributions to CE in phase 1 and 3, while in phase 2 their CE rapidly increased, however, Indonesia exerts negative CE in phase 3. In addition, Thailand's ES induced CE significantly increased from phase 1 until phase 3 of the study.

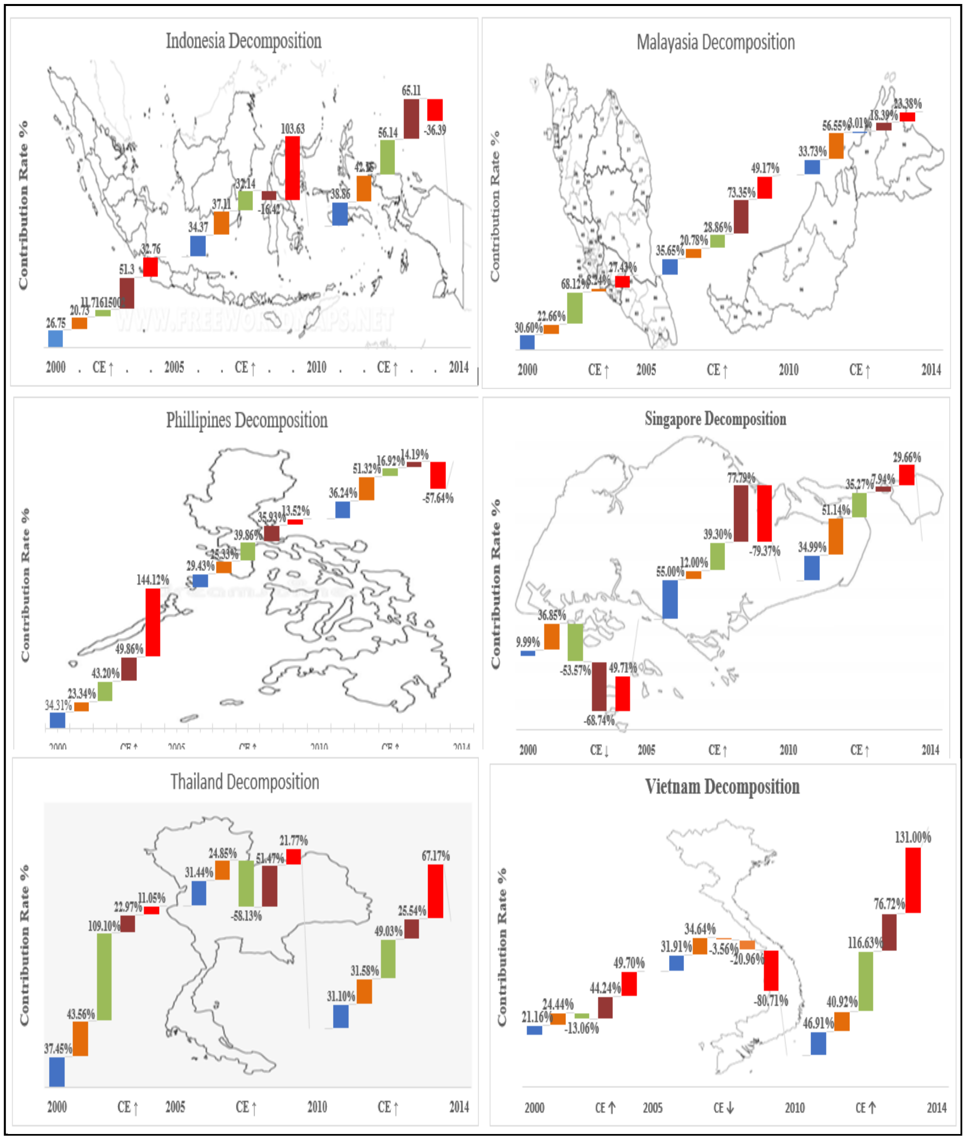

Figure 8: Decomposition Analysis of Environmental Impact into Its Factor

4.4 Extended Decomposition Technique

Quantitively analyzing the drivers of the decoupling, along with their contribution to the CE could helped to recognise the responsible factors of decoupling and strengthening the impact of such factors could lead to attain the ideal SD status between EG and CE. The LMDI and Tapio decoupling index are gathered to examine the driving forces and internal impact mechanism of the decoupling trend. Likewise, the analysis period is split into three phases to keenly observe the impact mechanism.

4.4.1 Regional Extended Decomposition Analysis

The extended decomposition analysis results are illustrated in figure 9, which depicts that regional decomposition effects are decomposed into five factors, namely population, affluence, EI, ES, and CI for the period of 2000-2014. The outcome of the extended decomposition technique stated that population, affluence, and ES are the major factors that restrict decoupling in the ASEAN region. However, EI and CI are the main drivers of decoupling the EG from environmental impact and lead the ASEAN region towards the SD status.

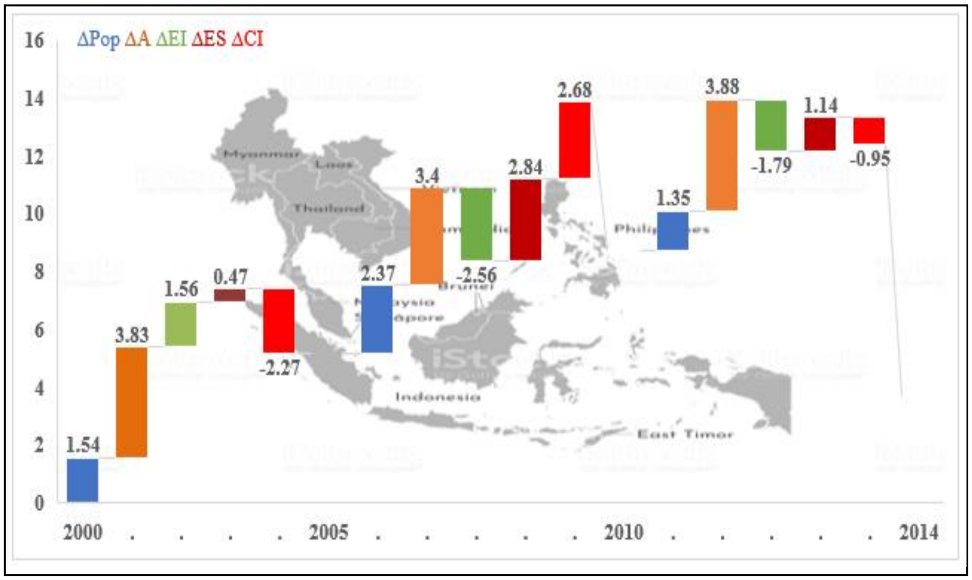

Figure 9: Extended Decomposition Analysis (authors own calculations)

4.4.2 Factor Specific Extended Decomposition Analysis

The combination of the Tapio decoupling indicator and the LMDI decomposition technique leads to the extended decomposition analysis, which shows factor specific response towards the decoupling progress in a specific country. The positive coefficient signals the weakening of decoupling process, while negative coefficient demonstrates the strengthening of decoupling progress between EG and CE. Figure 10 shows the outcome of extended decomposition analysis, which reveals that population, affluence and EI responded as the main drivers which drive all the selected ASEAN countries far from achieving strong decoupling between EG and CE, though, in case of Indonesia and Singapore, EI plays an important role in strengthening the decoupling process.

ES (ratio of coal, oil, and natural gas consumption in total energy consumption) is an important factor, as most of the selected ASEAN countries mainly reliant on primary energy consumption. The results stated that ES weakens the decoupling progress in Malaysia, Philippines, and Thailand throughout the study period, while in the case of Indonesia and Vietnam, ES weakens the decoupling of EG from CE in phase 1 and 3, while significantly strengthen the decoupling progress in phase 2. In turn, Singapore also exhibits that ES leads to couple EG with CE, unlikely in phase 1, where it helps to strengthen the decoupling relationship between EG and CE.

CI remains the most significant factor which strengthens the decoupling progress in most of the ASEAN countries, as depicted in figure 10, CI leads Malaysia and Thailand towards strong decoupling between EG and CE in all the three phases of the study. Singapore and Vietnam exert similar results up to some extent, as in case of both countries, CI helps to strengthen the decoupling progress in phase 1 and 3, while in phase 2 CI coupled EG with CE. In addition, the Philippines and Indonesia demonstrated the same results, however Indonesia in phase 3 and Philippines and phase 1 experienced strengthening of decoupling progress between EG and CE due to CI, while in the rest of the phases CI significantly weakens the decoupling process.

The decoupling and decomposition techniques are widely used in the current environmental literature at the sectoral, provincial, national, regional, and global levels. A regional comparative study has been carried out by Zhang et al. (2020) for ASEAN and China as both are trade partners for consecutive past ten years. Similar to our findings, they have also found that population, affluence, and CI are the responsible factors that raises CE, while EI played a significant role to curb it. Similarly, Madaleno and Moutinho (2018) examined a group of 15 European Union (EU) countries and stated that the overall EU experienced SD status between EG and CE, while the ASEAN region mainly observed WD status. While in country-specific analysis of the EU, their results are more stable than ASEAN, as most of the countries experienced WD status, however, most ASEAN member countries experienced END status, except for Singapore which mainly observed SD status during the analysis period. The financial crises significantly affected the whole world and lead to a decrease in emissions but however, ASEAN is more dependent on fossil fuels, that’s why financial crises have little impact on ASEAN’s CE. Furthermore, the EU also observed improvement in the EG-CE relationship after the Kyoto protocol.

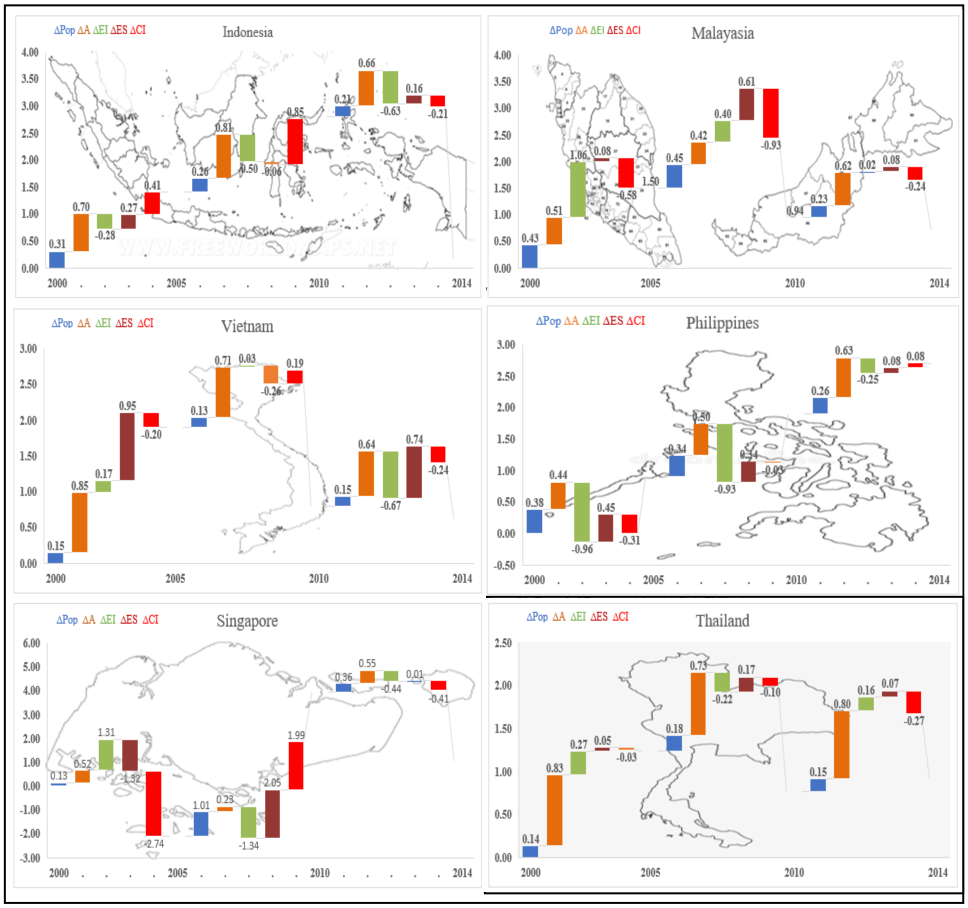

Figure 10: Extended Decomposition Analysis ASEAN Countries
Source: Authors Own Calculations

5. Conclusion and Policy Recommendations

Global energy-related CE increased from 23,692.49 Mt (2000) to 33,809 Mt (2014), with an annual growth rate of 2.58%. The global CE was rising rapidly until the financial crises of 2009, which demonstrate that EG and CE are two inter-related factors.

The Tapio decoupling analysis reveals that, in general ASEAN region experienced WD status, followed by the END status between EG and CE. The results suggested that there exists a space to further improve the regional decoupling status. The country-specific analysis reveals that Singapore has a SD status between EG and CE, demonstrating that EG and CE are inversely related to each other. Further, Thailand witnessed mostly WD status, Philippines exhibits END status, along with WD status. Malaysia, Indonesia, and Vietnam experienced END status throughout the analysis period.

The decomposition of CE into pre-determined factors demonstrated that generally in ASEAN region, population and affluence substantially contributed to the CE throughout analysis period. However, CI remains the main driving factor of CE, followed by EI but in one of the three phases EI helps to decrease CE. The share of ES remains constant during first two phases, while indicates a rapid rise during the last phase. The country-specific analysis reveals that population, affluence, and ES significantly increases CE in the respective ASEAN countries. However, EI and CI tend to reduce CE in the ASEAN countries, while in some of the country's EI helped to increase CE during the study period.

The extended decomposition analysis of the ASEAN region shows that population, affluence, and ES weakens the decoupling between EG and CE in ASEAN region, while energy and CI helped to drive the ASEAN region towards SD of EG from CE. Furthermore, the country-specific analysis demonstrates that population, affluence, and ES in all the six ASEAN countries restricts the decoupling progress. However, EI has mixed effects on the decoupling relationship of Vietnam, Thailand, Singapore, Philippines, while it strengthens decoupling in Indonesia and restrict decoupling in Malaysia. Similarly, CI strengthen the decoupling in Thailand, Philippines, Malaysia, and Indonesia, while in case of Vietnam and Singapore it leads to restricts decoupling in some phases, and strengthens decoupling progress in other phases. In general, results suggests that the ASEAN region has more potential to enhance its decoupling status by focusing on ES, EG, and population effects, as well as little focus on EI and CI.

6. Contribution of the Study

The current study scrutinizes the relationship between EG and CE by employing novel methodologies such as "Tapio decoupling index and the LMDI decomposition technique". There is a vast literature on the ASEAN region and its member countries that elaborates on the relationship between EG and CE. However, most of the studies are based on econometrical analysis such as EKC hypothesis, and such studies ended up with residuals. Besides, EKC also fails to explain the annual decoupling status between EG and CE, besides the time period required for EG to decrease CE is also not specified. In turn, the current study provides the complete decomposition of CE into its pre-determined factor based on Kaya identity. Besides, analysis also identify the major driving factors of CE, which will help the specific region/country to attain sustainable EG by restricting the influence of such factors on the region/country environmental condition. Nevertheless, the current analysis also reveals the annual decoupling status of EG from CE, which will help the ASEAN region and its member countries policymakers to provide suitable carbon mitigation policies.

6.1 Theoretical Contributions

ASEAN region experienced rapid economic growth accompanied by increased rates of emissions, therefore suitable policies are required that enhance and promote sustainable economic growth. Keeping this in view, the current study is attempted to decouple EG from CE. The outcome of our analysis shows consistency with the studies of (Ab-Rahim, 2016; Saudi *et al*., 2017; Wenju & Zheng, 2018; Ang, 2008) at a regional level. While the literature of (Alam *et al*., 2016; Sukono *et al*., 2019; Sasana, 2017; Lim *et al.*, 2014;

Zambrano-Monserrate *et al*., 2018; Ali *et al*., 2017; Nguyen *et al*., 2018; Muangthai *et al*., 2014; Al-Mulali *et al*., 2015) shows consistency with our findings at country level.

The Himalayan Environmental degradation theory supports our results, as the theory states that anthropogenic activities are the basic reason behind environmental degradation. Furthermore, results are in contradiction with EKC and Environmental Citizenship theory, as the first theory states that in short-run EG increases CE, while in long run it tends to decrease CE, however, our results confirms that EG is the main driver of CE throughout study period. The Environmental Citizenship theory also states that human beings having knowledge about the threat of climatic change and degradation of environmental quality helps to improve it, however, our results demonstrated that population remains the main driving factor of CE that leads to the environmental degradation.

6.2 Policy Implications

The policy suggestion based on the empirical findings of the study is that the ASEAN region should focus on environmental policy at regional and national level. Furthermore, population, EG, and EI are the main drivers of CE at both regional and national levels that should be focused by the government to ensure the clean and green ASEAN vision. Renewable energy should be substituted with primary energy/carbon intensive energies to promote green growth.

6.3 Limitations and Future Directions

The present research has the following constraints: First, only CE is taken as an indicator for environmental pollution. Moreover, the current analysis is limited up to 2000-2014, because of the lack of the data. Furthermore, four ASEAN member countries are dropped from country-specific analysis due to the unavailability of energy-specific CE data.

The current analysis could be extended for other forms of GHG emissions, as well as other dimensions of environmental degradation. Furthermore, the impact of Initiative of ASEAN Integration could be analyzed in the future. Moreover, a comparative study on ASEAN member countries can be conducted.

Grant Support Details / Funding

This research work received no research grant.

REFERENCES

Ab-Rahim, R., & Xin-Di, T. (2016). The determinants of CO_2 emissions in ASEAN+ 3 countries. *Journal of Entrepreneurship and Business*, *4*(1), 26-37.

ADB. (2013). Viet Nam: Environment and climate change assessment. Retrieved from:

[ONLINE] Available at: https://www.adb.org/sites/default/files/institutional-document/33916/files/viet-nam-environment-climate-change.pdf (November 23rd, 2019).

Alam, M. M., Murad, M. W., Noman, A. H. M., & Ozturk, I. (2016). Relationships among carbon emissions, economic growth, energy consumption and population growth: Testing Environmental Kuznets Curve hypothesis for Brazil, China, India and Indonesia. *Ecological Indicators*, *70*, 466-479.

Ali, H. S., Abdul-Rahim, A. S., & Ribadu, M. B. (2017). Urbanization and carbon dioxide emissions in Singapore: Evidence from the ARDL approach. *Environmental Science and Pollution Research*, *24*(2), 1967-1974.

Al-Mulali, U., Saboori, B., & Ozturk, I. (2015). Investigating the environmental Kuznets curve hypothesis in Vietnam. *Energy Policy*, *76*, 123-131.

Ang, B. W. (2004). Decomposition analysis for policymaking in energy: Which is the preferred method? *Energy Policy*, *32*(9), 1131-1139.

Ang, B. W., & Choi, K. H. (1997). Decomposition of aggregate energy and gas emission intensities for industry: A refined Divisia index method. *The Energy Journal*, *18*(3), 59-73.

Ang, J. B. (2008). Economic development, pollutant emissions and energy consumption in Malaysia. *Journal of Policy Modeling*, *30*(2), 271-278.

ASEAN Secretariat. (2019). *ASEAN integration report 2019.* ASEAN, Jakarta.

Audinet, P., Singh, B., Kexel, D. T., Suphachalasai, S., Makumbe, P., & Mayer, K. (2015). *Exploring a Low-Carbon Development Path for Vietnam*. The World Bank.

Begum, R. A., Sohag, K., Abdullah, S. M. S., & Jaafar, M. (2015). CO_2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews*, *41*, 594-601.

Binh, P.T., (2011). Energy consumption and economic growth in Vietnam: Threshold cointegration and causality analysis. *Energy Policy*, *1*, 1-17.

Bithas, K., & Kalimeris, P. (2013). Re-estimating the decoupling effect: Is there an actual transition towards a less energy-intensive economy? *Energy*, *51*, 78-84.

Borghesi, S., & Vercelli, A. (2003). Sustainable globalisation. *Ecological Economics, 44*(1), 77-89.

British Petroleum. (2019). British petroleum statistical review of world energy. British Petoleum: London UK. [ONLINE] Available at: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-worldenergy.html (October 23rd, 2019).

Chen, J., Wang, P., Cui, L., Huang, S., & Song, M. (2018). Decomposition and decoupling analysis of CO_2 emissions in OECD. *Applied Energy*, *231*, 937-950.

Chen, S., & Chen, B. (2017). Coupling of carbon and energy flows in cities: A meta-analysis and nexus modelling. *Applied Energy*, *194*, 774-783.

Chen, Y., Zhao, J., Lai, Z., Wang, Z., & Xia, H. (2019). Exploring the effects of economic growth, and renewable and non-renewable energy consumption on China's CO_2 emissions: Evidence from a regional panel analysis. *Renewable Energy*, *140*, 341-353.

Crippa, M., Oreggioni, G., Guizzardi, D., Muntean, M., Schaaf, E., Lo Vullo, E., ... & Vignati, E. (2019). Fossil CO2 and GHG emissions of all world countries. JRC Science for Policy Report. *Luxemburg: Publication Office of the European Union*. EDGAR website, https://edgar.jrc.ec.europa.eu

De Freitas, L. C., & Kaneko, S. (2011). Decomposing the decoupling of CO_2 emissions and economic growth in Brazil. *Ecological Economics*, *70*(8), 1459-1469.

Deutch, J. (2017). Decoupling economic growth and carbon emissions. *Joule*, *1*(1), 3-5.

Diputra, E. M. (2018). Is growth good or bad for the environment in Indonesia? *International Journal of Energy Economics and Policy*, *8*(1), 1-4.

Dong, F., Li, J., Wang, Y., Zhang, X., Zhang, S., & Zhang, S. (2019). Drivers of the decoupling indicator between the economic growth and energy-related CO_2 in China: A revisit from the perspectives of decomposition and spatiotemporal heterogeneity. *Science of the Total Environment*, *685*, 631-658.

Dong, K., Sun, R., Hochman, G., & Li, H. (2018). Energy intensity and energy conservation potential in China: A regional comparison perspective. *Energy*, *155*, 782-795.

Fan, T., Luo, R., Xia, H., & Li, X. (2015). Using LMDI method to analyze the influencing factors of carbon emissions in China's petrochemical industries. *Natural Hazards*, *75*(2), 319-332.

Fodha, M., & Zaghdoud, O. (2010). Economic growth and pollutant emissions in Tunisia: An empirical analysis of the environmental Kuznets curve. *Energy Policy*, *38*(2), 1150-1156.

Francisco, H. A. (2008). Adaptation to climate change: Needs and opportunities in Southeast Asia. *ASEAN Economic Bulletin*, *25*(1) 7-19.

Han, H., Zhong, Z., Guo, Y., Xi, F., & Liu, S. (2018). Coupling and decoupling effects of agricultural carbon emissions in China and their driving factors. *Environmental Science and Pollution Research*, *25*(25), 25280-25293.

He, Z., Xu, S., Shen, W., Long, R., & Chen, H. (2017). Impact of urbanization on energy related CO_2 emission at different development levels: Regional difference in China based on panel estimation. *Journal of Cleaner Production*, *140*, 1719-1730.

Hoad, D. (2015). Reflections on small island states and the international climate change negotiations (COP21, Paris, 2015). *Island Studies Journal*, *10*(2), 259-262.

Hwang, J. H., & Yoo, S. H. (2014). Energy consumption, CO_2 emissions, and economic growth: Evidence from Indonesia. *Quality & Quantity*, *48*(1), 63-73.

IEA. (2017). *Southeast Asia energy outlook*. IEA, Paris, France.

IPCC. (2014). Climate change 2014, synthesis report. IPCC, Geneva, Switzerland. [ONLINE] Available at: http://www.ipcc.ch/pdf/assessmentreport/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf

Iskandar, A. (2019). Economic growth and CO_2 emissions in Indonesia: Investigating the environmental Kuznets curve hypothesis existence. *Journal BPPK*, *20*(12), 42–52.

Jiang, J. J., Ye, B., Zhou, N., & Zhang, X. L. (2019). Decoupling analysis and environmental Kuznets curve modelling of provincial-level CO2 emissions and economic growth in China: A case study. *Journal of Cleaner Production*, *212*, 1242-1255.

Jiang, X. T., Dong, J. F., Wang, X. M., & Li, R. R. (2016). The multilevel index decomposition of energy-related carbon emission and its decoupling with economic growth in USA. *Sustainability*, *8*(9), 857-873.

Kaya, Y. (1990). Impact of carbon dioxide emission control on GNP growth: Interpretation of proposed scenarios. Paris, IPCC.

Khan, S., & Majeed, M. T. (2019). Decomposition and decoupling analysis of carbon emissions from economic growth: A case study of Pakistan. *Pakistan Journal of Commerce and Social Sciences (PJCSS)*, *13*(4), 868-891.

Khuong, N. D. (2017). Factors affecting CO_2 emission in Vietnam: A panel data analysis. *Organizations & Markets in Emerging Economies*, *8*(2), 244-257.

Khuong, P. M., McKenna, R., & Fichtner, W. (2019). Analyzing drivers of renewable energy development in Southeast Asia countries with correlation and decomposition methods. *Journal of Cleaner Production*, *213*, 710-722.

Kim, N. T., & Le, M. B. (2018). CO_2 emissions and economic growth in Vietnam: An ARDL bound testing approach. *Asian Journal of Economic Modelling*, *6*(1), 47-55.

Kraft, J., & Kraft, A. (1978). On the relationship between energy and GNP. *The Journal of Energy and Development*, *3*, 401-403.

Leal, P. A., Marques, A. C., & Fuinhas, J. A. (2019). Decoupling economic growth from GHG emissions: Decomposition analysis by sectoral factors for Australia. *Economic Analysis and Policy*, *62*, 12-26.

Letchumanan, R. (2010). Is there an ASEAN policy on climate change? *Climate Change: Is Southeast Asia Up to the Challenge*, LSE Ideas, SR004. London School of Economics.

Lim, K. M., Lim, S. Y., & Yoo, S. H. (2014). Oil consumption, CO_2 emission, and economic growth: Evidence from the Philippines. *Sustainability*, *6*(2), 967-979.

Lin, B., & Raza, M. Y. (2019). Analysis of energy-related CO_2 emissions in Pakistan. *Journal of Cleaner Production*, *219*, 981-993.

Lin, S. J., Beidari, M., & Lewis, C. (2015). Energy consumption trends and decoupling effects between carbon dioxide and gross domestic product in South Africa. *Aerosol Air Quality Research*, *15*, 2676-2687.

Linh, D. H., & Lin, S. M. (2014). CO_2 emissions, energy consumption, economic growth and FDI in Vietnam. *Managing Global Transitions: International Research Journal*, *12*(3), 219-232.

Liu, L. C., Fan, Y., Wu, G., & Wei, Y. M. (2007). Using LMDI method to analyze the change of China's industrial CO_2 emissions from final fuel use: An empirical analysis. *Energy Policy*, *35*(11), 5892-5900.

Loo, B. P., & Banister, D. (2016). Decoupling transport from economic growth: Extending the debate to include environmental and social externalities. *Journal of Transport Geography*, *57*, 134-144.

Lu, I. J., Lin, S. J., & Lewis, C. (2007). Decomposition and decoupling effects of carbon dioxide emission from highway transportation in Taiwan, Germany, Japan and South Korea. *Energy Policy, 35*(6), 3226-3235.

Luken, R. A., & Piras, S. (2011). A critical overview of industrial energy decoupling programs in six developing countries in Asia. *Energy Policy*, *39*(6), 3869-3872.

Luo, Y., Long, X., Wu, C., & Zhang, J. (2017). Decoupling CO_2 emissions from economic growth in agricultural sector across 30 Chinese provinces from 1997 to 2014. *Journal of Cleaner Production*, *159*, 220-228.

Ma, M., & Cai, W. (2018). What drives the carbon mitigation in Chinese commercial building sector? Evidence from decomposing an extended Kaya identity. *Science of the Total Environment*, *634*, 884-899.

Ma, M., Cai, W., & Cai, W. (2018). Carbon abatement in China's commercial building sector: A bottom-up measurement model based on Kaya-LMDI methods. *Energy*, *165*, 350-368.

Madaleno, M., & Moutinho, V. (2018). Effects decomposition: Separation of carbon emissions decoupling and decoupling effort in aggregated EU-15. *Environment, Development and Sustainability*, *20*(1), 181-198.

Majeed, M. T., & Mazhar, M. (2020). Reexamination of environmental Kuznets curve for ecological footprint: The role of biocapacity, human capital, and trade. *Pakistan Journal of Commerce and Social Sciences*, *14*(1), 202-254.

Majeed, M. T. (2018). Information and communication technology (ICT) and environmental sustainability in developed and developing countries. *Pakistan Journal of Commerce and Social Sciences, 12*(3), 758-783.

Majeed, M. T., & Ayub, T. (2018). Information and communication technology (ICT) and economic growth nexus: A comparative global analysis. *Pakistan Journal of Commerce and Social Sciences, 12*(2), 443-476.

Majeed, M. T., & Luni, T. (2019). Renewable energy, water, and environmental degradation: A global panel data approach. *Pakistan Journal of Commerce and Social Sciences*, *13*(3), 749-778.

Majeed, M. T., & Mazhar, M. (2019a). Environmental degradation and output volatility: A global perspective. *Pakistan Journal of Commerce and Social Sciences, 13*(1), 180-208.

Majeed, M. T., & Mazhar, M. (2019b). Financial development and ecological footprint: A global panel data analysis. *Pakistan Journal of Commerce and Social Sciences, 13*(2), 487-514.

Majeed, M. T., & Mumtaz, S. (2017). Happiness and environmental degradation: A global analysis. *Pakistan Journal of Commerce and Social Sciences*, *11*(3), 753-772.

Majeed, M. T., Samreen, I., Tauqir, A., & Mazhar, M. (2020). The asymmetric relationship between financial development and CO 2 emissions: the case of Pakistan. *SN Applied Sciences*, 2, 1-11.

Makower, J., Pernick, R., & Wilder, C. (2009). Clean energy trends. *Clean Edge Report*. [ONLINE] Available at: http://www.cleanedge.com/reports/pdf/Trends2010.pdf

Marquardt, J. (2016). *How power shapes energy transitions in Southeast Asia: A complex governance challenge.* New York, USA.

Mofijur, M., Mahlia, T. M. I., Silitonga, A. S., Ong, H. C., Silakhori, M., Hasan, M. H., Putra, N., & Rahman, S. M. (2019). Phase change materials (PCM) for solar energy usages and storage: An overview. *Energies*, *12*(16), 3167-3187.

Muangthai, I., Lewis, C., & Lin, S. J. (2014). Decoupling effects and decomposition analysis of CO_2 emissions from Thailand's thermal power sector. *Aerosol Air Quality Research*, *14*, 1929-1938.

Naminse, E., & Zhuang, J. (2018). Economic growth, energy intensity, and carbon dioxide emissions in China. *Polish Journal of Environmental Studies*, *27*(5), 2193–2201.

Nguyen, H. T., Aviso, K. B., Le, D. Q., & Tokai, A. (2018). Main drivers of carbon dioxide emissions in Vietnam trajectory 2000-2011: An input-output structural decomposition analysis. *Journal of Sustainable Development*, *11*(4), 129-147.

Nguyen, N. T., Ha-Duong, M., & Sandra, G. (2009). The clean development mechanism in Vietnam: Potential and limitations. In *Paper accepted to present at the fourth GMSARN International Conference*.

Obama, B. (2017). The irreversible momentum of clean energy. *Science*, *355*(6321), 126-129.

OECD Secretariat. (2002). *Sustainable development: Indicators to measure decoupling of environmental pressure from economic growth*, Paris, OECD.

Ozturk, I., & Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics*, *36*, 262-267.

Pan, S. Y., Gao, M., Kim, H., Shah, K. J., Pei, S. L., & Chiang, P. C. (2018). Advances and challenges in sustainable tourism toward a green economy. *Science of the Total Environment*, *635*, 452-469.

Pao, H. T., & Chen, C. C. (2019). Decoupling strategies: CO_2 emissions, energy resources, and economic growth in the Group of Twenty. *Journal of Cleaner Production*, *206*, 907-919.

Peters, G. P., Marland, G., Le Quéré, C., Boden, T., Canadell, J. G., & Raupach, M. R. (2012). Rapid growth in CO_2 emissions after the 2008–2009 global financial crisis. *Nature Climate Change*, *2*(1), 2-4.

Qi, T., Weng, Y., Zhang, X., & He, J. (2016). An analysis of the driving factors of energy-related CO_2 emission reduction in China from 2005 to 2013. *Energy Economics*, *60*, 15-22.

Ren, S., Yin, H., & Chen, X. (2014). Using LMDI to analyze the decoupling of carbon dioxide emissions by China's manufacturing industry. *Environmental Development*, *9*, 61-75.

Saboori, B., Sulaiman, J. B., & Mohd, S. (2012). An empirical analysis of the environmental Kuznets curve for CO_2 emissions in Indonesia: The role of energy consumption and foreign trade. *International Journal of Economics and Finance*, *4*(2), 243-251.

Sandu, S., Yang, M., Mahlia, T. M. I., Wongsapai, W., Ong, H. C., Putra, N., & Rahman, S. M. (2019). Energy-related CO_2 emissions growth in ASEAN countries: Trends, drivers and policy implications. *Energies*, *12*(24), 4650-4665.

Sasana, H. (2017). The increase of energy consumption and carbon dioxide (CO_2) emission in Indonesia. In *The 2nd International Conference on Energy, Environmental and Information System (ICENIS) 2017*.

Saudi, N. S., Munir, Q., Mahmud, M., & Saudi, A. S. (2017). CO2-GDP NEXUS: Case for ASEAN 5. *International Journal of Advanced and Applied Sciences*, *4*(12), 199-205.

Shahbaz, M., Haouas, I., & Van Hoang, T. H. (2019). Economic growth and environmental degradation in Vietnam: Is the environmental Kuznets curve a complete picture? *Emerging Markets Review*, *38*, 197-218.

Shen, L., Wu, Y., Shuai, C., Lu, W., Chau, K. W., & Chen, X. (2018). Analysis on the evolution of low carbon city from process characteristic perspective. *Journal of Cleaner Production*, *187*, 348-360.

Shi, Q., Chen, J., & Shen, L. (2017). Driving factors of the changes in the carbon emissions in the Chinese construction industry. *Journal of Cleaner Production*, *166*, 615-627.

Shuai, C., Chen, X., Wu, Y., Zhang, Y., & Tan, Y. (2019). A three-step strategy for decoupling economic growth from carbon emission: Empirical evidence from 133 countries. *Science of the Total Environment*, *646*, 524-543.

Siddique, H. M. A., & Majeed, M. T. (2015). Energy consumption, economic growth, trade and financial development nexus in South Asia. *Pakistan Journal of Commerce and Social Sciences*, *9*(2), 658-682.

Siddique, H. M. A., Majeed, M. T., & Ahmad, H. K. (2016). The impact of urbanization and energy consumption on CO_2 emissions in South Asia. *South Asian Studies*, *31*(2), 745-757.

Silitonga, A. S., Masjuki, H. H., Ong, H. C., Sebayang, A. H., Dharma, S., Kusumo, F., Siswantoro, J., Millano, J., Daud, K., Mahli, T.M.I., & Chen, W. H., Sugiyanto, B. (2018). Evaluation of the engine performance and exhaust emissions of biodiesel-bioethanol-diesel blends using kernel-based extreme learning machine. *Energy*, *159*, 1075-1087.

Siping, J., Wendai, L., L, Meng., Xiangjun, Y., Hongjuan, Y., Yongming, C., Haiyun, C., Hayat,Tt., Alsaedi, A., & Ahmad, B. (2019). Decoupling environmental pressures from economic growth based on emissions monetization: Case in Yunnan, China. *Journal of Cleaner Production*, *208*, 1563-1576.

Sok, T. (2019). Initiative for ASEAN integration (IAI): Contributions of the ASEAN dialogue partners. *Asian Vision Institute*, *2019* (10), 1-12.

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World Development*, *32*(8), 1419-1439.

Sukono, S., Albra, W., Zulham, T., Majid, I., Saputra, J., Subartini, B., & Thalia, F. (2019). The effect of gross domestic product and population growth on CO_2 emissions in Indonesia: An application of the ant colony optimisation algorithm and cobb-douglas model. *International Journal of Energy Economics and Policy*, *9*(4), 313-319.

Tang, Z., Shang, J., Shi, C., Liu, Z., & Bi, K. (2014). Decoupling indicators of CO_2 emissions from the tourism industry in China: 1990–2012. *Ecological Indicators*, *46*, 390-397.

Tapio, P. (2005). Towards a theory of decoupling: Degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001. *Transport Policy*, *12*(2), 137-151.

Tay, S., Lee, C., & Yi, L. (2017). ASEAN approaches to environmental protection and sustainable Development: Cooperating across borders, sectors, and pillars of regional community. *S. Tay & JP Tijaja Global Megatrends: Implication for the ASEAN Economic Community*, 98-122.

The World Bank. (2018). Country Overview - Thailand. [ONLINE] Available at: https://www.worldbank.org/en/country/thailand/overview (March 14th, 2019)

Tuan, N. A. (1997). Energy and environmental issues in Vietnam. *Natural Resources Forum*, *21*(3), 201-207.

UNEP. (2011). *Decoupling natural resource use and environmental impacts from economic growth*. UNEP, Nairobi.

USAID. (2016). *Greenhouse gas emissions in Pakistan*. Pakistan, USAID.

Van Caneghem, J., Block, C., Van Hooste, H., & Vandecasteele, C. (2010). Ecoefficiency trends of the Flemish industry: Decoupling of environmental impact from economic growth. *Journal of Cleaner Production*, *18*(14), 1349-1357.

Vehmas, J., Luukkanen, J., Kaivo-oja, J., Panula-Ontto, J., & Allievi, F. (2012). *Key trends of climate change in the ASEAN countries*. Tampere: Finland Futures Research Centre, University of Turku.Finland.

Wang, C., Chen, J., & Zou, J. (2005). Decomposition of energy-related CO_2 emission in China: 1957–2000. *Energy*, *30*(1), 73-83.

Wang, J., & Yang, Y. (2020). A regional-scale decomposition of energy-related carbon emission and its decoupling from economic growth in China. *Environmental Science and Pollution Research*, *27*, 20889–20903.

Wang, Q., & Li, R. (2016). Drivers for energy consumption: A comparative analysis of China and India. *Renewable and Sustainable Energy Reviews*, *62*, 954-962.

Wang, Q., & Su, M. (2020). Drivers of decoupling economic growth from carbon emission–An empirical analysis of 192 countries using decoupling model and decomposition method. *Environmental Impact Assessment Review*, *81*, 106356.

Wang, W. W., Zhang, M., & Zhou, M. (2011). Using LMDI method to analyze transport sector CO_2 emissions in China. *Energy, 36*(10), 5909-5915.

Wang, Z., & Yang, L. (2015). Delinking indicators on regional industry development and carbon emissions: Beijing–Tianjin–Hebei economic band case. *Ecological Indicators*, *48*, 41-48.

Ward, J. D., Sutton, P. C., Werner, A. D., Costanza, R., Mohr, S. H., & Simmons, C. T. (2016). Is decoupling GDP growth from environmental impact possible? *PLOS ONE*, *11*(10), 1-14.

Wen, L., & Li, Z. (2019). Driving forces of national and regional CO_2 emissions in China combined IPAT-E and PLS-SEM model. *Science of the Total Environment*, *690*, 237-247.

Wenju, T., & Zheng, X. (2018). Study of factors affecting carbon emissions—based on an empirical analysis of ASEAN. *Journal of Resources and Ecology*, *9*(5), 500-507.

World Bank. (2020). World development indicators. World Bank: Washington DC.

Wu, D., Yuan, C., & Liu, H. (2018a). The decoupling states of CO_2 emissions in the Chinese transport sector from 1994 to 2012: A perspective on fuel types. *Energy and Environment*, *29*(4), 591-612.

Wu, Y., Chau, K. W., Lu, W., Shen, L., Shuai, C., & Chen, J. (2018b). Decoupling relationship between economic output and carbon emission in the Chinese construction industry. *Environmental Impact Assessment Review*, *71*, 60-69.

Wu, Y., Zhu, Q., & Zhu, B. (2018c). Decoupling analysis of world economic growth and CO_2 emissions: A study comparing developed and developing countries. *Journal of Cleaner Production*, *190*, 94-103.

Xu, S. C., He, Z. X., Long, R. Y., Chen, H., Han, H. M., & Zhang, W. W. (2016). Comparative analysis of the regional contributions to carbon emissions in China. *Journal of Cleaner Production*, *127*, 406-417.

Yang, L., Yang, Y., Zhang, X., & Tang, K. (2018). Whether China's industrial sectors make efforts to reduce CO_2 emissions from production? A decomposed decoupling analysis. *Energy*, *160*, 796-809.

Yu, Y., Chen, D., Zhu, B., & Hu, S. (2013). Eco-efficiency trends in China, 1978–2010: Decoupling environmental pressure from economic growth. *Ecological Indicators*, *24*, 177-184.

Zambrano-Monserrate, M. A., Carvajal-Lara, C., & Urgiles-Sanchez, R. (2018). Is there an inverted U-shaped curve? Empirical analysis of the Environmental Kuznets Curve in Singapore. *Asia-Pacific Journal of Accounting & Economics*, *25*(1-2), 145-162.

Zhang, C., & Lin, Y. (2012). Panel estimation for urbanization, energy consumption and CO_2 emissions: A regional analysis in China. *Energy Policy*, *49*, 488-498.

Zhang, H., & Lahr, M. L. (2014). China's energy consumption change from 1987 to 2007: A multi-regional structural decomposition analysis. *Energy Policy*, *67*, 682-693.

Zhang, J., Fan, Z., Chen, Y., Gao, J., & Liu, W. (2020). Decomposition and decoupling analysis of carbon dioxide emissions from economic growth in the context of China and the ASEAN countries. *Science of the Total Environment*, *714*, 136649-136686.

Zhang, M., & Bai, C. (2018). Exploring the influencing factors and decoupling state of residential energy consumption in Shandong. *Journal of Cleaner Production*, *194*, 253-262.

Zhang, X., Zhao, Y., Wang, C., Wang, F., & Qiu, F. (2019). Decoupling effect and sectoral attribution analysis of industrial energy-related carbon emissions in Xinjiang, China. *Ecological Indicators, 97*, 1-9.

Zhao, X., Zhang, X., Li, N., Shao, S., & Geng, Y. (2017). Decoupling economic growth from carbon dioxide emissions in China: A sectoral factor decomposition analysis. *Journal of Cleaner Production*, *142*, 3500-3516.

Zhou, X., Zhang, M., Zhou, M., & Zhou, M. (2017). A comparative study on decoupling relationship and influence factors between China's regional economic development and industrial energy–related carbon emissions. *Journal of Cleaner Production*, *142*, 783-800.