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Decomposition and Decoupling Analysis of Carbon Emissions from Economic Growth: A Case Study of Pakistan

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Abstract

Climate change induced by the growth of carbon dioxide emissions has become a global concern. Therefore, it's necessary to pinpoint the factors that drive carbon emissions to provide suitable mitigation policies. This study uses Taipo Decoupling Index and Log Mean Divisa Index (LMDI) decomposition techniques to examine Pakistan's decoupling status between environmental impact and economic growth and to analyze driving forces of carbon emissions over a time span of 1990-2014. The outcome suggests that Pakistan has experienced four decoupling statuses, where the most prominent is the expensive negative decoupling status. Furthermore, energy intensity and carbon intensity usually encouraged decoupling, while economic growth and energy structure restricted it. The population has a neutral effect on decoupling. The decomposition results demonstrated that population, energy structure, and economic growth significantly contributed to carbon emissions. While, energy and carbon intensity help in curbing carbon emissions. This study provides useful insights to mitigation carbon emissions. Besides, it also helps in promoting sustainable economic growth.

Keywords: log mean divisia index, decomposition, CO_2, decoupling elasticity analysis, Pakistan.

1. Introduction

Global warming caused by greenhouse gas (GHG) emissions is one of the alarming issues around the world that poses a severe threat to all living organisms. The consumption of fossil fuel is the main driving force of GHG emissions (Majeed & Mumtaz, 2017 & Leal et al., 2019). GHG emissions accounted for 47,599 million tonnes of carbon dioxide emissions ($MtCO_2$) in 2012 and it approximately tripled during the past six decades reaching 36,138.3 million tons in 2014 from 9385.8 million tons in 1960 with an annual growth rate of 2.6% (USAID, 2016: Shuai et al. 2019). The report of the International Panel on Climate Change (IPCC, 2014) documented the last five decades

(1983-2012) as the warmest years caused by a higher concentration of GHG in the atmosphere.

Anthropogenic activities are held responsible for 95% global climate change resulting from increased GHG emissions due to dependence on fossil fuels. According to the global perspective, conventional energy sources are the main reason behind GHG emissions (Meinshausen et al., 2009; Sari & Soytas, 2009; Majeed & Mazhar, 2019b). Both developed and developing nations are facing the problem of deteriorating environmental quality, however, the conditions are more severe in developing countries (Majeed, 2018; Majeed & Mazhar, 2019a). According to the statistics of British Petroleum (BP, 2018) a decline of 1.1×109 tons of CO_2 emissions has been observed on behalf of developed nations while developing countries offset the efforts of developed nations by increasing CO_2 emissions by 6.1×109 tons.

The discussion on climate change emphasizes the need for delinking economic growth from environmental harms, as economic growth is considered the main factor behind the climatic change. According to the United Nations Environmental Protection (UNEP, 2011), the process of delinking economic growth from GHG emissions is termed as "Decoupling". The concept of decoupling was introduced by the Organization for Economic Co-operation and Development (OECD, 2002) in order to decouple the economic growth from environmental impact. Initially, decoupling was used "to decouple economic growth from resource consumption" (Juknys, 2002). Later it widened to "decouple environmental pollution from resource consumption". Until 2005 when Tapio (2005) proposed Tapio decoupling indicator and decomposed it into eight sub-groups. Initially, the decoupling technique was widely used in the energy fields but after the 1970s, when climate change and its impact on earth were recognized as a global threat than it widened its boundaries to the environmental fields. Due to its usefulness, many researchers employed it to analyze the decoupling of environmental impacts from economic growth (Lu et al., 2007; Vavrek & Chovancova, 2016; Wang et al., 2018 and Zhao et al., 2017). However, decoupling analysis does not cover the environmental externalities effect, so in order to have the complete analysis, the LMDI decomposition technique has been accompanied by the Tapio decoupling technique to determine the changes in CO_2 emissions more effectively (Zhao et al., 2017).

Decomposition techniques are used to examine variation in energy consumption and CO_2 emissions (Andreoni & Galmarini, 2012; Zhang & Lahr, 2014; and Zhang et al., 2011) and it also helps to capture the changes in regressand variable by a change in a specific regressor (Ang & Lee, 1996). There are two basic techniques that are commonly used for decomposition analysis namely Structure Decomposition Analysis (SDA) and Index Decomposition Analysis (IDA) (Hoekstra & Bergh, 2003). Due to possible errors in results and lack of complete decomposition in SDA, IDA is preferred over SDA because of Log Mean Divisia Index (LMDI) technique which provides complete decomposition with no error term in the outcome (Ang & Choi, 1997). LMDI decomposition technique has been extensively used in the literature (De Freitas & Kaneko, 2011; Liu et al., 2007; Fan et al., 2015; Wang et al., 2011 & Xu et al., 2012) to analyze the changes in environmental impact across countries, provinces, sectors, and industries.

1.1 Theoretical Aspects of Decoupling

Decoupling theory has long been the subject of debate among the scholars, while some are against and others are in favor of it. The efficacy of decoupling economic output from the environmental impact and consumption of energy has been questioned by many scholars (Ward et al., 2016). In order to assess the relationship between consumption of energy and affluence growth, Bithas and Kalimeris (2013) analyzed decoupling of energy consumption and affluence relationship and found a decoupling effect less positive than the contemporary indicator of energy consumption and affluence in the relevant literature. Ward et al. (2016) found that economic growth cannot be decoupled from energy consumption and resource consumption by comparing the historical data and model projections. However, a scenario of decoupling GDP growth from CO_2 emissions led by fossil fuel consumption can be projected.

The empirical evidence in this section acknowledged the potential of decoupling in modern economies. Several decoupling analyses were investigated, in order to examine the nexus between economic output and environmental bads, for example, Van Canehgam et al. (2010) analyzed the decoupling status of economic efficiency predictors in the Flemish industries. The outcome suggested that during 1995-2006, Flemish experienced absolute and relative decoupling between energy use and economic growth. De Freitas and Kaneko (2011) used the OECD decoupling index to analyze the decoupling of CO_2 emissions from economic growth in Brazil during 2004-2009 and claimed that absolute decoupling took place in 2009. Besides the scholarly literature on decoupling, Obama (2017) former president of the United States (US) before leaving Presidential office, emphasized on the importance of decoupling emissions of the energy sector from economic growth in the article "The Irreversible Momentum of Clean Energy". The former US president said that emissions from the energy sector decreased by 9.5% and the economy grew by more than 10% during his presidency (2008-2015) (Deutch, 2017).

Although the overview of the decoupling approach is summed up, it has remained relevant for achieving the Paris Agreement's (2016), which has been signed by 175 parties to fight climate change. However, the previous debate on decoupling highlighted its role in achieving the Paris Agreement, which is to reduce the current rise in temperature to 2^0C. Therefore, in order to achieve the aim of the Paris agreement, it is important to determine the driving forces of CO_2 emissions that would also help to achieve sustainable economic development. This has led our interest to decouple economic growth from CO_2 emissions and empirically examine environmental driving factors and their impact on decoupling. We define our research area to Pakistan because of its reliance on fossil fuels and are one of the developing countries

There are several perspectives from various researchers (Shuai et al. 2019; Wu et al. 2018 & Madaleno and Moutinho, 2018) on the decoupling of economic growth from CO_2 emissions on an aggregate and disaggregated level, such as, across the countries, provinces as well as the sectors that emphasizes the importance of decoupling theory. Shuai et al. (2019) analysed 133 countries differentiated on income level and analyze their decoupling statuses using Tapio decoupling elasticity. Wu et al. (2018) examined the developed and developing countries by using the comparative decoupling analysis, such as OECD, Tapio, and IGTX decoupling model, while the correlation coefficient of

Spearman's rank test has been used to analyze the relationship among the three decoupling models. Madaleno & Moutinho (2018) analyzed the European countries by employing the decoupling and the LMDI decomposition technique. Wang & Li (2016) analyzed China and India's energy consumption by using the IPAT (Influence of Population, Affluence, and Technology) model and LMDI technique to find out the driving forces of the energy consumption in China and India. While Qi et al. (2016) used the LMDI decomposition technique to identify the driving factors of CO_2 emissions in the production and consumption sectors of China.

The above empirical evidence emphasized the importance of decoupling phenomena in environmental economics. To the best of our knowledge, so far, this important area has been ignored in the case of Pakistan. Therefore, the current study is an effort to fill up this research gap by using novel techniques that are the Tapio decoupling index and the LMDI decomposition technique to examine the decoupling status and driving forces of CO_2 emissions in Pakistan. The current analysis will identify the responsible factor that leads to an increase in CO_2 emissions, along with it, it will also provide policy makers with a detailed insight about CO_2 emissions mitigation strategies by controlling such factors.

According to the need of the study, following research questions are raised to be addressed: To know the decoupling status between economic growth and environmental impact during 1990-2014 for Pakistan: to elaborate the responsible factor that causes an increase in CO_2 emissions, to explore the most influential factor affecting the decoupling progress of Pakistan. Based on the research questions following research objectives are made to be examined; (1) to empirically scrutinize the decoupling status of economic growth from CO_2 emissions. (2) to find out the contribution of each factor to the total CO_2 emissions. (3) to find out the response of each factor towards the decoupling status of the country.

1.2 Decoupling Theories

Decoupling marks its importance in environmental economics, however, there are two main decoupling theories i.e. Absolute and Relative decoupling theory. Figure 1 demonstrates the relationship of economic growth with CO_2 emissions specifically with respect to each theory.

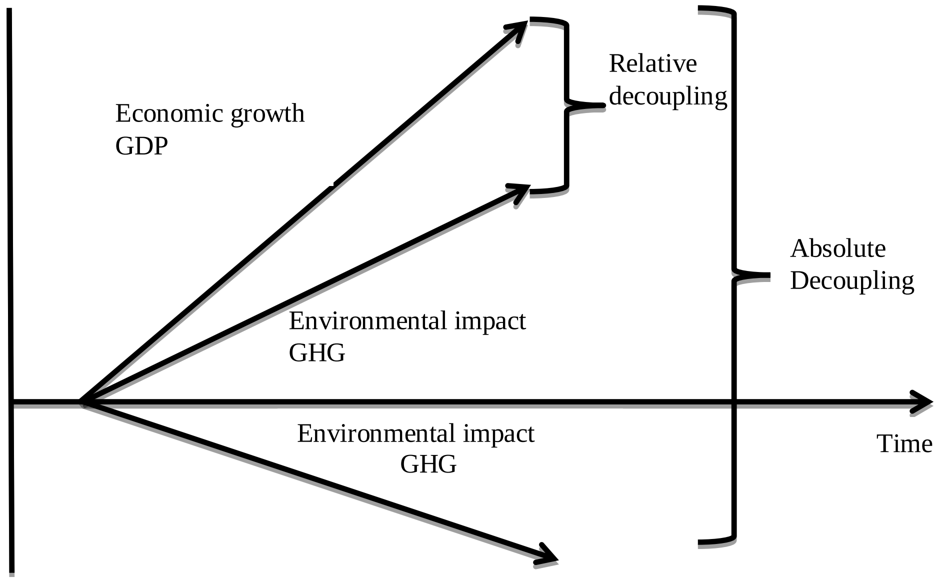

Figure 1: Relative and Absolute Decoupling

Absolute decoupling applies to the situation when an increase in economic growth results in the lowering of CO_2 emissions, while relative decoupling is the situation in which the economic growth is relatively higher than emissions' growth (UNEP, 2011).

Prior to the decoupling phenomena, multiple studies analyzed the presence of an Environmental Kuznets Curve (EKC), which considered an inverted U-shaped association between economic growth and environmental impact, but in recent literature, the reliability of EKC has been challenged (Stern, 2004). The findings showed that EKC is absent when considered the specification measures, diagnostic statistics and employment of correct methods (Perman and Stern, 2003). Borghesi and Vercelli (2003) concluded that local emissions-based analysis yields an acceptable result, while global level studies do not produce the expected results, which implies that in general EKC hypothesis is not acceptable. Therefore, there is a need for some concrete measures that overcome the flaws of EKC and provide suitable and accurate results, such as the Tapio decoupling index and the LMDI decomposition technique.

This paper is intended to present the study in a rigorous framework, facilitating the findings of appropriate data and reducing the likelihood of missing data. The rest of the research is structured as follows: in the "literature review" chapter, a critical evaluation of the prior literature on the decoupling and decomposition is provided. The section "methodology and data sources" describes theoretical as well as empirical methodology along with data sources of the factors, the section is followed-up by "results and discussion" section, which elaborates the outcome computed by means of various applied methods. The whole study was finally concluded, and some policy recommendation is given in "conclusion and policy recommendation" section.

2. Literature Review

Worldwide anxiety regarding climatic change has provoked serious attention towards delinking CO_2 emission from economic growth. For developing/emerging economies, the key definition of decoupling is "A state in which economic growth can be achieved, while both resource use and environmental impact can be reduced simultaneously".

So far, two main methods for decoupling phenomena have been used frequently in the literature, which are the decoupling index suggested by "the Organization for Economic Co-operation and Development (OECD, 2002)" and Tapio decoupling indicator (2005). OECD first implemented a relatively easy indicator, which was basically transformed from the pace of intensity change. The index was easy to measure but it did not give a clear indication to ascertain the behavior of real economic growth and CO_2 emissions. Tapio (2005) proposed an elasticity-based index to address this weakness, considering both the importance of elasticity and the path of emissions/economic changes; further, the indicator identified eight different statuses of decoupling relationship.

Prior to the decoupling phenomena, the EKC hypothesis was frequently applied to the environmental research area, which is considered as an inverted U-shaped relationship between economic development and environmental quality, besides, it also gives the sign of relative decoupling in long run, when economic growth exceeds more than emissions growth. EKC theory has been supported by the studies of Alam (2010), Munir & Khan (2014), Ali et al. (2016) and Majeed & Luni (2019), who stated that a positive correlation exists in the short-term between economic growth and CO_2 emissions, whilst CO_2 emissions decrease in the long-term due to environment-friendly technologies/policies.

In addition, EKC is somehow relevant to the decoupling technique, but it fails to provide accurate and annual decoupling status for the country. Therefore, currently decoupling techniques are intensively used in the environment and energy literature, for the purpose to disintegrate economic growth from CO_2 emissions/energy consumption. The literature at the country, province and sector level highlights the usefulness of the decoupling. The decoupling measurements are widely used in developing and developed nations like China and Western countries in order to achieve sustainable economic growth.

2.1 Country Specific Analysis

Economic growth is perceived to be the key factor that increases CO_2 emissions, however, decoupling helps to achieve sustainable economic growth by delinking CO_2 emissions from economic growth. Engo (2018) examines the decoupling relationship for Cameroon and found out that economic activity, demographic change, and energy intensity lead to weak decoupling. The LMDI decomposition demonstrates that the industrial sector has significantly contributed to environmental impact. The major factor that promotes economic and emissions growth is the consumption of primary energy (Siddiqui & Majeed, 2016), while Roman-Collado et al. (2018) analyzed Columbia's consumption of energy and CO_2 emissions link and reported that population and activity effect boosted the consumption of energy, while energy intensity and energy structure help to curb energy consumption. Energy consumption of China and India has been analyzed by Wang & Li (2016). The outcome suggested that China has experienced relative decoupling from 1980-1999 because of high-income growth and lesser energy use, while India did not experience any status of the decoupling. De Freitas & Kaneko (2011) and Wang et al. (2005) examined the decoupling status of Brazil and China using the OECD decoupling model and LMDI decomposition technique. Results depict that energy structure along with energy and carbon intensity lead to decrease emissions of CO_2 in both countries.

2.2 Province Specific Analysis

Jiang et al. (2019) and Siping et al. (2019) analyzed the decoupling status of China's Guangdong and Yunnan province using Tapio decoupling analysis accompanied by EKC and found weak decoupling in both provinces using Tapio decoupling analysis, while based on EKC strong decoupling was found only in Guangdong's province over the long run. The three structures of Yunnan province; primary, secondary and tertiary sectors experienced weak negative decoupling status. Zhou et al. (2017) investigated China's industrial CO_2 emissions from the economic output by applying the Tapio and LMDI decomposition technique. Findings showed that North West, South West, and North Coastal regions encountered decoupling in various years. The energy consumption effect is more powerful than technology's effect on decoupling. Generally, the manufacturing and transport sector, apart from Beijing and Tianjin, raise environmental impact. Energy intensity reduces environmental impact, while economic growth increases environmental impact, but it is less effective in developed regions. Luo et al. (2017) evaluated China's agricultural sector across different regions and periods with the Tapio decoupling model. As a result, cattle (livestock) and rice season were considered as the two major contributors to environmental impact in the agriculture sector, while among different regions, East China experienced more periods of decoupling between 1997 and 2014 compared to other regions.

2.3 Sector Specific Analysis

Pakistan's power sector emissions have been analyzed by Lin & Raza (2019) through the LMDI decomposition technique. Population, activity effect, and GDP are founded as the major driving factors of CO_2 emission, whereas energy and carbon intensity helped to reduce it. The consumption and production industry of China has been investigated by Qi et al. (2016) with the LMDI method. The outcome suggested that CO_2 emissions have been reduced by energy intensity, and also promote decoupling. Similarly, Tang et al. (2014) evaluated the tourism industry of China using the bottom-up approach and the Tapio decoupling index during 1990-2012. The findings support the presence of the weak decoupling and expensive negative decoupling between the tourism industry and the environmental harms of China.

Leal et al. (2019) analyzed different sectors of Australia by employing the Tapio decoupling model and LMDI decomposition technique, while energy efficiency is examined by the efficiency index. The result supports the existence of strong decoupling that occurred in commercial and agricultural sectors, whereas industrial, construction, transportation, and residential sectors exhibit weak decoupling. Andreoni & Galmarini (2012) discovered relative decoupling in Italy's agriculture industry by implementing a complete decomposition method from Laspeyers index methods. The results showed that Italy was unable to achieve absolute decoupling during the study period because the main factors behind the increase in environmental impact were economic activity and energy intensity.

The critical literature review found that, by using decoupling methods, long prevailing positive association between economic growth and CO_2 emissions can be broken. However, the nexus between emissions and economic growth has been under analysis for a long time. The scenario got more attention after the industrial revolution of the 1970s. But after the devastating effects of the industrial revolution in the form of climate change are witnessed, the need for emission-less economic growth is emphasized and decoupling becomes important in the literature. The above literature is systematically compiled on the country, province and sectoral level to provide insights about the importance of decoupling at aggregate and disaggregated level. The studies are gathered based on similarities with our analysis in terms of techniques and variables.

The availability of vast literature on decoupling exhibits its importance in energy and environmental fields. Nevertheless, as far as Pakistan is concerned, this important area remains unexplored. Thus, the current study is an attempt to fill this research gap and contributes in the following ways to the existing literature. First, the study expands the existing literature by employing novel techniques in the environmental research area. Second, the paper would be considered as a gateway for further research in this area. Third, the study will give insights to policy makers about the provision of suitable CO_2 emissions mitigation policies. Fourth, the result elaborates the main driving factors of CO_2 emissions, which will help to reduce CO_2 emissions by controlling the effects of such factors.

3. Methodology and Data Sources

3.1 Theoretical Framework

CO_2 emissions and economic growth nexus is the most debated topic among researchers (Siddique & Majeed, 2016 & Majeed & Ayub, 2018). According to EKC, there exist an inverted U-shaped relationship between CO_2 emission and economic growth. However, there are also some criticisms on EKC like Stern (2004) stated that EKC fails when diagnostic statistics and the correct techniques are used. Borghesi and Vercelli (2003) stated that EKC domestically gives suitable results but on a global level, its result is not applicable. So, in response to these criticisms, an advanced method needed to evaluate the link between economic output and environmental beds more accurately. In 2005, Tapio proposed a decoupling index that gives a more accurate and annual decoupling status between CO_2 emissions and national output, further the LMDI decomposition technique is employed that gives a perfect decomposition of CO_2 emissions into prearranged factors i.e. based on Kaya identity (1990).

This section further explains in detail the theoretical foundation and empirical models of the Tapio decoupling index (2005) and the LMDI decomposition technique based on Kaya identity (1990).

3.1.1 Decoupling Indicator

Petri Tapio proposed the decoupling indicator to delink economic output from environmental harms (Tapio, 2005). Decoupling indicators comprises three categories *i.e.*

strong decoupling, weak decoupling, and recessive coupling and these are further divided into eight sub-categories, including expensive negative decoupling, expansive coupling, weak decoupling, strong decoupling, recessive decoupling, recessive coupling, weak negative decoupling, and strong negative decoupling. Decoupling can simply be referred as "breaking the link between "environmental hurts" and "economic output" (OECD, 2002). According to the Tapio (2005), the decoupling indicator can be described as,

$$\text{DI} = \frac{(CO_{2t}-CO_{2t-1})/(CO_{2t-1})}{(GDP_t-GDP_{t-1})/(GDP_{t-1})} = \frac{\Delta CO_2/CO_{2t-1}}{\Delta \text{GDP}/GDP_{t-1}} = \frac{\%\Delta CO_2}{\%\Delta GDP} \quad (1)$$

In the above expression, the CO_{2t-1} and GDP_{t-1} represent lags of CO_2 emissions and economic growth, respectively, while ΔC and ΔG represent the change in CO_2 emissions and economic growth. These values are calculated based on a continuous chaining method i.e. t–(t -1). The $\%\Delta CO_2$ and $\%\Delta GDP$ represent the growth rate in the subsequent two years of CO_2 emission and GDP. Figure (2) exhibits the decoupling status based on the decoupling indicator (DI).

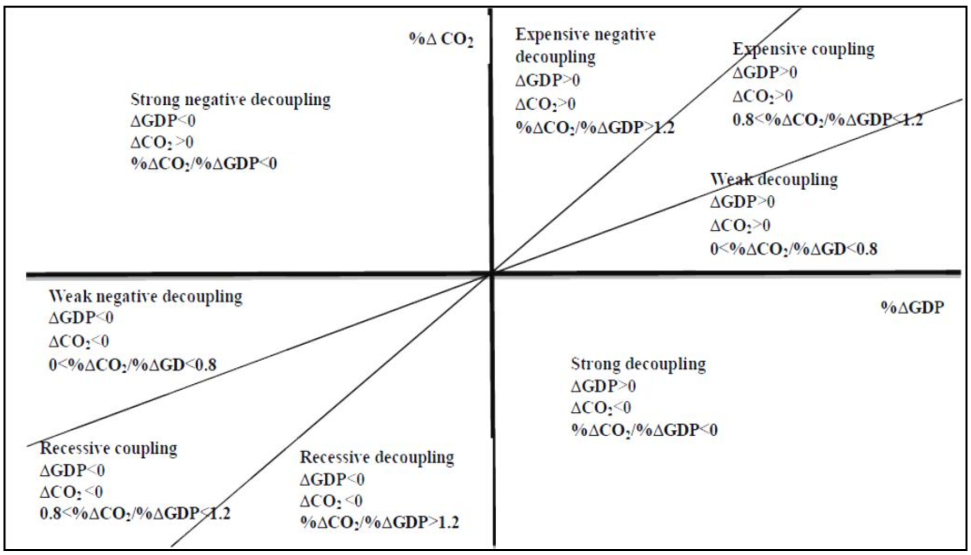

Figure 2: The Framework of Decoupling States (Tapio, 2005)

3.1.2 Framework for Index Decomposition Method (IDA)

The nexus between CO_2 emissions and economic growth is one of the most debated topics among researchers (Siddique & Majeed, 2015; Majeed & Ayub, 2018). Various methods are employed by researchers to investigate the correlation between these two factors. These methods include Tapio elasticity analysis, Variance decomposition, Auto-Regressive Distributed Lag (ARDL) model, Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model analysis, LMDI decomposition, simple regressions and many others (Climent & Pardo 2007). These methods are used according to the need of the study to solve the specific problem. The other methods except LMDI and Tapio decoupling indicator end up with the residual term and, they do not give perfect decomposition. So, looking at the objectives and needs of the study Tapio elasticity analysis and LMDI decomposition method are used in this study. Due to simplicity, ease of use and preference over the other methods LMDI technique is used in this study (Ang, 2004). Decomposition models are divided into two group's i.e. Index Decomposition Analysis (IDA) and Structural Decomposition Analysis (SDA). IDA is preferred over SDA due to perfect decomposition, further, it has two extensions namely Divisia Index methods and Laspeyres Index methods.

IDA is widely used in energy-relevant areas, like energy efficiency and energy security since the 1980s, but after 1990 when climate change threat arose then it widened its boundaries to GHG emissions and particularly to energy-induced emissions (Xu & Ang, 2013). Due to ease of use, simplicity, and ease of results interpretation, LMDI is preferred in IDA techniques as it can also manage incomplete datasets (Xu et al., 2016). Decomposition analysis includes chaining and non-chaining techniques. The non-chaining technique covers the first and last year of the study, but it did not engage the intervening years in the analysis. Although chaining analysis uses all the intermediate years from initial till last year of the study and primarily it is used for a single country and industrial analysis.

The major problem with the LMDI is that it transforms variables into log form and that the negative values in the data set turn into zero. Ang & Choi (1997) propose the solution that "a small positive value should be replaced with a small negative value". The IDA structure based on Laspeyers index and Divisia index is shown in Figure (3);

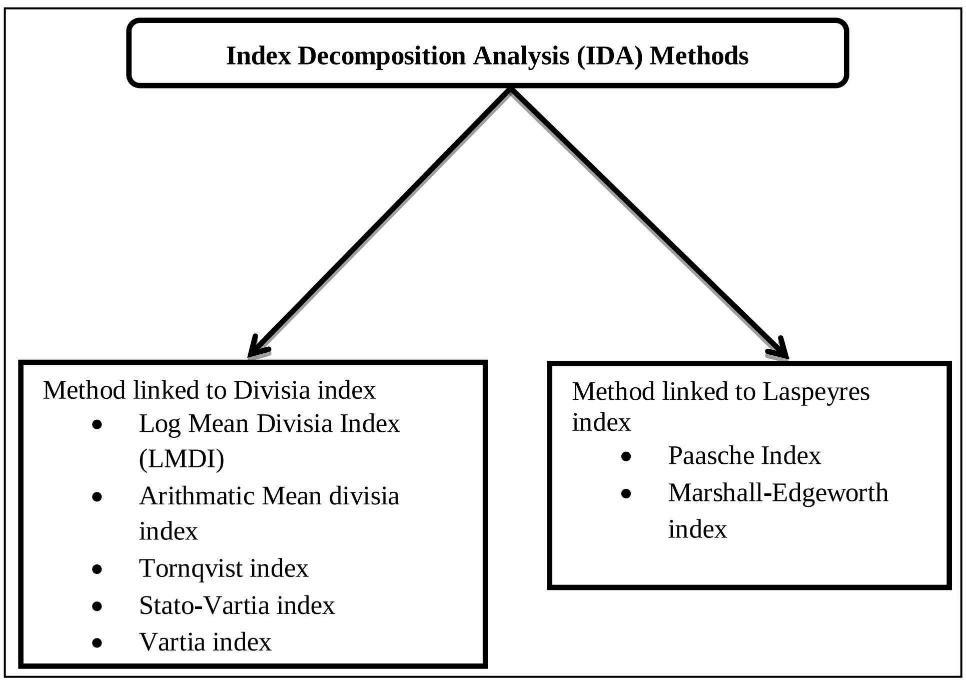

Figure 3: Framework of Index Decomposition Analysis (IDA)

3.2 Decomposition Model

There are numerous methods for decomposition that are used to assess the variations in CO_2 emissions countrywide or globally, among all of them LMDI decomposition technique is widely used i.e. based on the Kaya identity. Yoichi Kaya (1990) first proposed this model at the IPCC (1990) to represent CO_2 emissions in its prearranged five main factors that is demonstrated in eq (2),

$$\mathrm{C} = i = 13Ci = \sum_{i=1}^{3} \mathrm{P} \times \frac{G}{P} \times \frac{E}{G} \times \frac{Ei}{E} \times \frac{Ci}{Ei} = \sum_{i=1}^{3} P \times A \times EI \times ES \times CI \quad (2)$$

In the equation 2, P represents population; G is for GDP (constant 2010 US$), E represents total energy consumption in metric ton of oil equivalent (Mtoe), E*i* (Mtoe) demonstrates consumption of *i* fuel energy, and C*i* (Mtoe) depicts the energy-induced CO_2 emission of *i* fuel. Further, A represents GDP per person, energy intensity represented by EI, *i.e.* energy consumption per unit of GDP, ES represents energy structure i.e. share of i fuel in total energy consumption and CI represents carbon intensity, i.e. CO_2 emissions per unit of energy use. i=1, 2 and 3 represent natural gas, petrol, and coal, respectively.

LMDI technique along with the chaining decomposition is used in this study to assess the changes in CO_2 emission from initial to a final year. Equation 3 depicts the change in CO_2 emissions i.e. decomposed into five factors based on Kaya's (1990) identity;

$$\Delta \mathrm{C} = C_t - C_{t-1} = \Delta C_P + \Delta C_A + \Delta C_{EI} + \Delta C_{ES} + \Delta C_{CI} \quad (3)$$

The above equation demonstrates the variation in CO_2 emissions due to variation in the population, GDP per person, energy structure, energy intensity, and carbon intensity. These variables are calculated as follows,

$$\Delta P = \sum_{i=1}^{3} \frac{C_{it}-C_{it-1}}{lnC_{it}-lnC_{it-1}} \ln\left[\left(\frac{P_t}{P_{t-1}}\right)\right] \quad (4)$$

$$\Delta A = \sum_{i=1}^{3} \frac{C_{it}-C_{it-1}}{lnC_{it}-lnC_{it-1}} \ln\left[\left(\frac{A_t}{A_{t-1}}\right)\right] \quad (5)$$

$$\Delta EI = \sum_{i=1}^{3} \frac{C_{it}-C_{it-1}}{lnC_{it}-lnC_{it-1}} \ln\left[\left(\frac{EI_t}{EI_{t-1}}\right)\right] \quad (6)$$

$$\Delta ES = \sum_{i=1}^{3} \frac{C_{it}-C_{it-1}}{lnC_{it}-lnC_{it-1}} \ln\left[\left(\frac{ES_t}{ES_{t-1}}\right)\right] \quad (7)$$

$$\Delta CI = \sum_{i=1}^{3} \frac{C_{it}-C_{it-1}}{lnC_{it}-lnC_{it-1}} \ln\left[\left(\frac{CI_t}{CI_{t-1}}\right)\right] \quad (8)$$

The evidence of perfect decomposition of the LMDI is given below by incorporating equations 4, 5, 6, 7 and 8 into equation 3.

$$\Delta C = \sum_{i=1}^{3} \frac{C_{it}-C_{it-1}}{lnC_{it}-lnC_{it-1}} \ln\left(\frac{P_t}{P_{t-1}}\right) + \sum_{i=1}^{3} \frac{C_{it}-C_{it-1}}{lnC_{it}-lnC_{it-1}} \ln\left(\frac{A_t}{A_{t-1}}\right) + \sum_{i=1}^{3} \frac{C_{it}-C_{it-1}}{lnC_{it}-lnC_{it-1}} \ln\left(\frac{EI_t}{EI_{t-1}}\right) + \sum_{i=1}^{3} \frac{C_{it}-C_{it-1}}{lnC_{it}-lnC_{it-1}} \ln\left(\frac{ES_t}{ES_{t-1}}\right) + \sum_{i=1}^{3} \frac{C_{it}-C_{it-1}}{lnC_{it}-lnC_{it-1}} \ln\left(\frac{CI_t}{CI_{t-1}}\right)$$

$$= \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{lnC_{it} - lnC_{it-1}} \left[\ln\left(\frac{P_t}{P_{t-1}}\right) + \ln\left(\frac{A_t}{A_{t-1}}\right) + \ln\left(\frac{EI_t}{EI_{t-1}}\right) + \ln\left(\frac{ES_t}{ES_{t-1}}\right) + \ln\left(\frac{CI_t}{CI_{t-1}}\right) \right]$$

$$= \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{lnC_{it} - lnC_{it-1}} \left[\ln\left(\frac{P_t A_t EI_t CI_t ES_t}{P_{t-1} A_{t-1} EI_{t-1} CI_{t-1} ES_{t-1}}\right) \right]$$

$$= \sum_{i=1}^{3} \frac{C_{it} - C_{it-1}}{lnC_{it} - lnC_{it-1}} \left[\ln\left(\frac{Ei_t}{Ei_{t-1}}\right) \right]$$

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

$$\Delta C = \Delta \mathrm{E}$$

The above equation shows that the LMDI technique gives the perfect decomposition without any residual term in the results. Therefore, it is preferred over the other decomposition techniques.

Now by incorporating equation (3) into (1), decoupling indicator is further decomposed into the following factors;

$$= \frac{\Delta \mathrm{C_P} + \Delta \mathrm{C_A} + \Delta \mathrm{C_{EI}} + \Delta \mathrm{C_{ES}} + \Delta \mathrm{C_{CI}} / CO_{2t-1}}{\Delta \mathrm{G} / GDP_{t-1}}$$

$$= \frac{\Delta C_P / CO_{2t-1}}{\Delta G / GDP_{t-1}} + \frac{\Delta C_A / CO_{2t-1}}{\Delta G / GDP_{t-1}} + \frac{\Delta C_{EI} / CO_{2t-1}}{\Delta G / GDP_{t-1}} + \frac{\Delta C_{ES} / CO_{2t-1}}{\Delta G / GDP_{t-1}} + \frac{\Delta C_{CI} / CO_{2t-1}}{\Delta G / GDP_{t-1}}$$

$$= D_P + D_A + D_{EI} + D_{ES} + D_{CI} \qquad (9)$$

The factors $D_P, D_A, D_{EI}, D_{ES}, and\ D_{CI}$ in equation (9) exhibit the response of population, economic growth, energy intensity, energy structure and carbon intensity to the decoupling progress in Pakistan.

3.3 Data and Variable

The data has been extracted from the World Bank (WB, 2019) and British Petroleum (BP, 2018) for a time span of 1990-2014, using 1990 as base year according to continuous chaining method. The decoupling indicator *i.e.* the regressand variable is the index of GDP (constant 2010 U.S dollars) and carbon emissions (kt). We have used time-series data of GDP, CO_2 emissions, population, GDP per person, energy structure and energy and carbon intensity for our analysis. Energy intensity is the ratio of energy consumption and GDP. Similarly, carbon intensity demonstrates, how much CO_2 emits by combustion of a single unit of energy.

Due to data limitations, variables are taken in different measurements such as population in (total), CO_2 in (kt) GDP (constant 2010 US$), GDP per capita (constant 2010 US$), energy intensity (kg of oil equivalent), energy structure (Mtoe) and carbon intensity (Mtoe), but when we applied the LMDI technique; all the variables are converted to percentage form because the divisia index methods evaluate the results of each unit by statistics, using the weighted logarithmic mean variations of the relevant factors (Lin & Raza, 2019).

4. Results and Discussion

This section shows the results of the Tapio decoupling index and the LMDI technique. Figure 4 demonstrates the trend for CO_2 emissions over the time period 1990-2014. It shows a continuous rise in CO_2 emissions during the analysis period. The energy consumption-induced CO_2 emissions in Pakistan grew significantly from 68242 (kt) in 1991 to 166298 (kt) in 2014. This reflects an annual increase of 0.84% (Alam, 2010). The CO_2 emissions grew rapidly from 1990-2007 and then CO_2 emissions got stagnant from 2007-2009 because of International Monetary Fund (IMF) bailout program due to which many duties were imposed on the poor manufacturing sector, resulting in the shutdown of many small and medium-sized firms that lead to the decline in CO_2 emissions (Nasir, 2012).

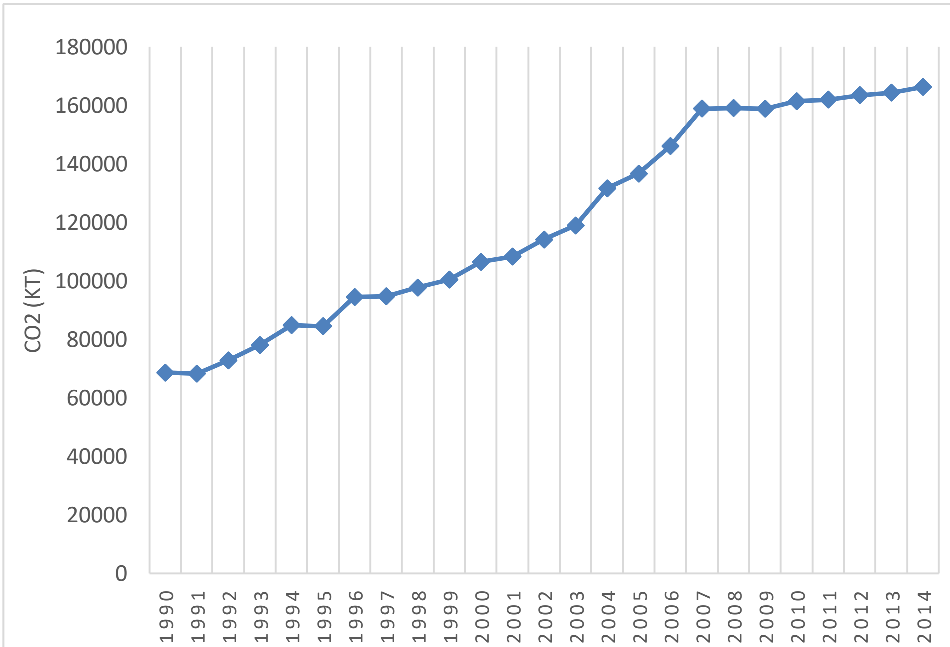

Figure 4: CO_2 Emissions Trend in Pakistan

4.1 Decomposition Analysis of CO_2 Emissions in Pakistan

In the context of the LMDI decomposition method from 1990-2014, figure 5 shows the decomposition factors such as population, GDP per capita, energy structure, energy, and carbon intensity contribution to CO_2 emissions in Pakistan.

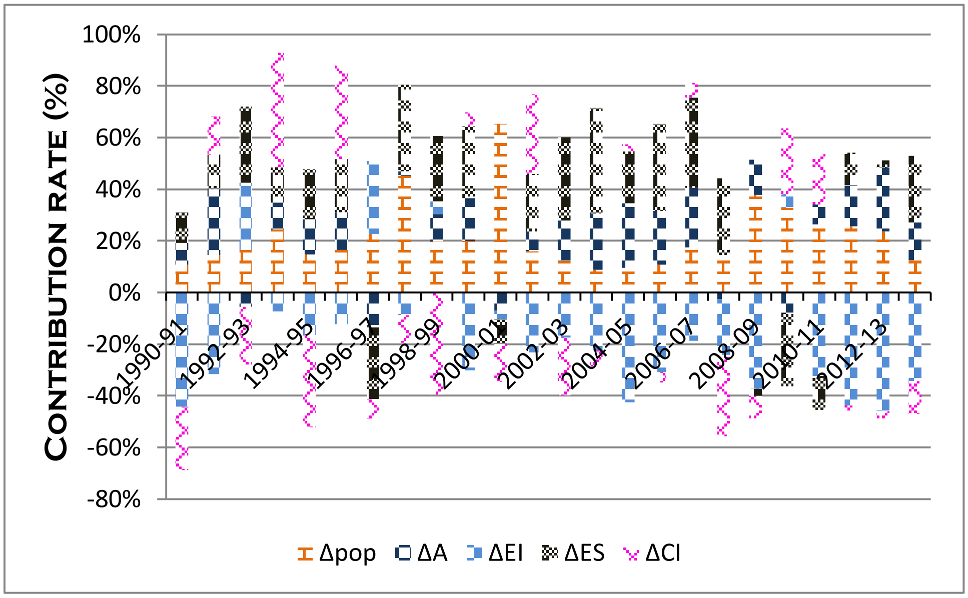

Figure 5: Contribution of Factors to CO_2 Emissions of Pakistan

Figure 5 demonstrates the decomposition of total CO_2 emissions into prearranged factors based on Kaya identity in Pakistan. The outcome of the LMDI decomposition technique exhibits that energy structure is the major driving factor of CO_2 emissions and the primary factor which reduces CO_2 emissions is energy intensity. Carbon intensity also contributed to CO_2 emissions in various years. According to Pakistan Economic Survey (2010-11) and Mahmood and Shahab (2014), carbon intensity for Pakistan was very high because of the combustion of fossil fuels in the manufacturing sector that was coupled with the population growth, leading to the rise in demand of energy. In return, energy is also produced from fossil fuels that also generate more CO_2 emissions. Further, it also stated that coal consumption in the industrial sector after 1990 become very high than ever in history. Another main contributor is the economic growth that significantly contributed to CO_2 emissions throughout the study period, Majeed and Luni (2019) also stated that CO_2 emissions rise with an increase in economic growth. Figure 5 results are conformed with the studies of (Lin & Raza (2019); Wang *et al*. (2018); Andreoni & Galmarini (2012) and De Freitas & Kaneko (2011).

4.2 Decoupling Performance in Pakistan

This section comprises the results of Tapio decoupling elasticity and the application of the LMDI decomposition technique to Tapio's decoupling index to determine each predictor's response to the decoupling process in Pakistan.

4.2.1 Decoupling Status of Pakistan

The findings obtained from the Tapio elasticity analysis support expensive negative decoupling during the analysis period, while weak decoupling, expensive coupling, and strong decoupling are also observed in the various years. The primary reason for the expensive negative decoupling is the combustion of highly carbon-intensive fossil fuels. Weak decoupling occurred when the growth of the economy is relatively higher than emissions growth. The expensive coupling depicts that CO_2 emissions and economic growth are not delinked, and both grew in positive terms.

Table 1: Decoupling Statuses in Pakistan

Time period	**$\Delta C/C_o$**	**$\Delta G/G_o$**	**Decoupling Indicator**	**Decoupling Status**
1990-1991	-0.004	0.050	-0.092	Strong decoupling
1991-1992	0.066	0.077	0.864	Weak decoupling
1992-1993	0.071	0.017	4.078	Expensive negative decoupling
1993-1994	0.087	0.037	2.343	Expensive negative decoupling
1994-1995	-0.004	0.049	-0.084	Strong decoupling
1995-1996	0.117	0.048	2.433	Expensive negative decoupling
1996-1997	0.002	0.010	0.275	Weak decoupling
1997-1998	0.031	0.025	1.222	Expensive negative decoupling
1998-1999	0.027	0.036	0.761	Expensive negative decoupling
1999-2000	0.060	0.042	1.418	Expensive negative decoupling
2000-2001	0.017	0.019	0.868	Expensive coupling
2001-2002	0.053	0.032	1.661	Expensive negative decoupling
2002-2003	0.042	0.048	0.870	Expensive coupling
2003-2004	0.106	0.073	1.450	Expensive negative decoupling
2004-2005	0.038	0.076	0.498	Weak decoupling
2005-2006	0.069	0.061	1.118	Expensive coupling
2006-2007	0.087	0.048	1.815	Expensive negative

				decoupling
2007-2008	0.001	0.017	0.065	Weak decoupling
2008-2009	-0.001	0.028	-0.052	Strong decoupling
2009-2010	0.016	0.016	1.002	Expensive coupling
2010-2011	0.003	0.027	0.126	Expensive coupling
2011-2012	0.009	0.035	0.271	Weak decoupling
2012-2013	0.005	0.043	0.115	Expensive coupling
2013-2014	0.012	0.046	0.256	Expensive negative decoupling

Table 1 demonstrates that Pakistan has experienced expensive negative decoupling, expensive coupling, strong decoupling, and weak decoupling during the analysis period. The intensive use of coal in the manufacturing sector leads Pakistan to a high pace of industrialization, which results in the growth of the economy, besides it also raises CO_2 emissions (Mahmood & Shahab, 2014). Strong decoupling of (1991; 1995 & 2009) occurred because of the early 1990s electricity supply shortage for industrial and commercial sector causes strong decoupling of 1991, because of labour-intensive production, electricity shortage affects CO_2 emissions more than the economic growth (Malik, 2012). The International Monetary Fund (IMF) bailout package of 1994-95 levied high taxes on the poor manufacturing sector that resulted in an immediate decrease in CO_2 emissions compared to economic growth. Strong decoupling of 2009 occurred due to a rise in Pakistan's GDP annually 8-9 percent from 2005-2008 more than the CO_2 emissions growth (Aziz and Ahmed, 2015).

Expensive coupling reveals that in some years there was no indication of decoupling between economic growth and CO_2 emissions. However, in several years growth of the economy is comparatively high than that of CO_2 emissions depicting weak decoupling. Overall expensive negative decoupling dominates among the other decoupling statuses in Pakistan.

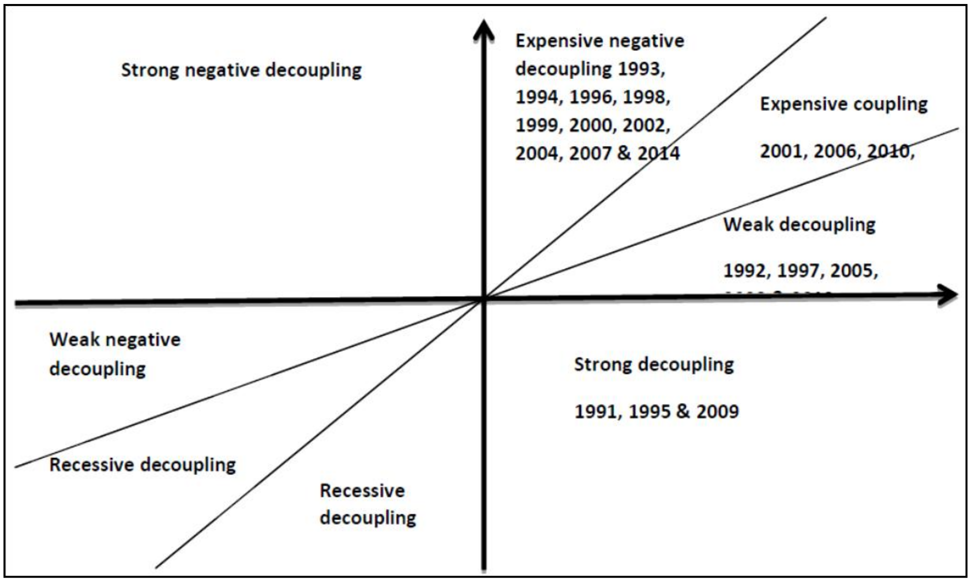

Figure 6: The Distribution of Pakistan into Sub-Categories if Decoupling

Figure 6 demonstrates a clear image of Pakistan's decoupling status during 1990-2014. Overall, Pakistan experienced four decoupling statuses during the study period, but the most prominent of all is expensive negative decoupling, which indicates that growth in CO_2 emissions is greater than economic growth. The main reason behind expensive negative decoupling is the shift of the cement industry from gas to coal energy that is more carbon-intensive, onwards to 2001 coal consumption of cement industry increases by 61% (Mahmood and Shahab, 2014). In a couple of years, the expensive coupling is also observed, indicating that CO_2 emissions and economic growth both have a positive trend with no decoupling relationship. Nonetheless, findings also include strong decoupling in (1991; 1995 & 2009) as a result of the 1990 electricity shortage, the IMF bailout package of 1994-95 and the rapid economic growth of 2005-2008 resulted in higher economic growth than that of CO_2 emissions. Weak decoupling has also been observed in several years, demonstrating a relatively higher economic growth than the growth in CO_2 emissions. Expensive negative decoupling is Pakistan’s prominent status of decoupling, which emphasizes the necessity of some concrete policy measures to stimulate economic growth and cut CO_2 emissions.

4.2.2 Decomposition of the Decoupling Process in Pakistan

Figure 7 depicts the results obtained during 1990-2014 by employing decomposition to the decoupling index in Pakistan. Energy and carbon intensity plays an important role in encouraging and strengthening the decoupling between "economic output" and "environmental harms", but the effect of energy intensity on decoupling process is stronger than carbon intensity, the results are consistent with the study of (Wang et al., (2018) & Zhang et al., (2019), while contradictory with the results of (De Freitas & Kaneko (2011) & Liang et al., (2017). Energy structure considered being the main factor limiting the decoupling progress except in 1996-1997 and 2009-2010 and our results are consistent with Zhang et al., (2019). This means that the energy structure drives the Pakistan economy far from achieving sustainable development/strong decoupling status.

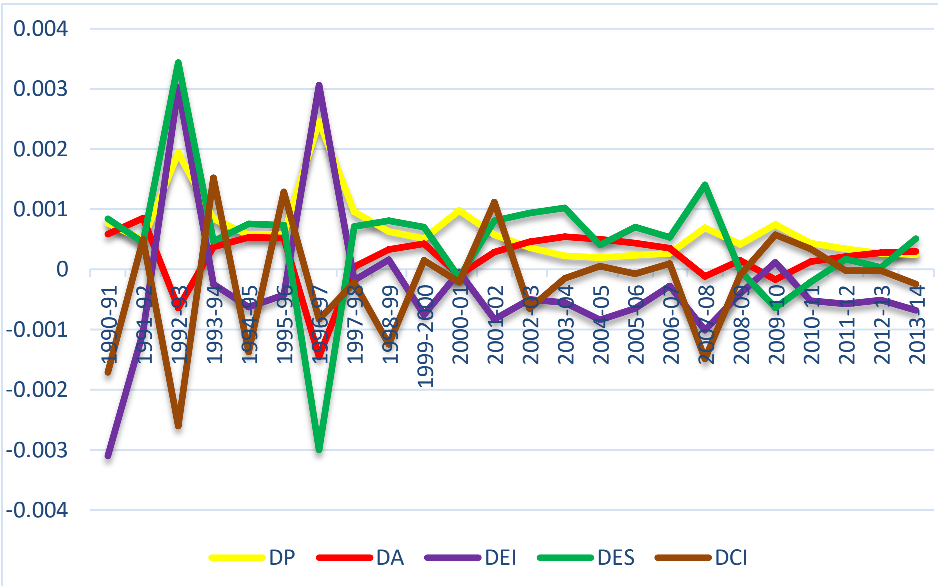

Figure 7: Decomposition of the Decoupling in Pakistan

Despite the dependence of economic growth on fossil fuel consumption, it also promotes decoupling, in (1993 & 1997) but, in general, economic growth restricts the decoupling of economic growth from environmental harms, the analysis is backed by a study of Wang et al., (2018). The population influence is mixed during the study period, as in some years it restricts decoupling, while in other years it promotes the decoupling process.

5. Conclusion

The current study investigates the decoupling and decomposition of environmental impact from economic growth for Pakistan during 1990-2014. In order to identify the paramount factors that drive CO_2 emission and the decoupling status between environmental impact and economic output, the analysis has been covered by the LMDI decomposition technique based on Kaya identity and the Tapio decoupling indicator recommended by Tapio (2005). In the last, LMDI has been employed to the Tapio's decoupling index to capture each factor's response towards the decoupling progress in Pakistan.

The findings of the decomposition approach reported that the main contributors to CO_2 emissions are population, per capita GDP and energy structure. Nonetheless, the energy structure leads to the reduction of CO_2 emissions in a few years, but overall it significantly increases CO_2 emissions during the study period. Energy and carbon intensity are the major factors that, contribute to the reduction of CO_2 emissions. The Tapio decoupling indicator results showed that Pakistan had four decoupling statuses, namely expensive negative decoupling, weak decoupling, strong decoupling, and expensive coupling, during the analysis period. Strong decoupling occurred in 1991, 1995 and 2009, indicating a reduction in CO_2 emissions as economic growth increased. Nevertheless, Pakistan has experienced expensive negative decoupling, highlighting the fact that, in most years, the growth of CO_2 emissions is beyond the economic growth, which alerts the government that it needs to diverge from fossil fuel energy to renewable energy.

In addition, the Tapio decoupling indicator highlights that the two paramount factors that lead the economy towards the strong decoupling are energy and carbon intensity, while population, energy structure, and economic growth, are the key factors restricting Pakistan's economy from strong decoupling.

5.1 Contribution of the Study

Techniques of decoupling and decomposition are employed to investigate the driving forces of CO_2 emissions and to delink economic growth from environmental impact, to attain long-lasting economic growth. The important area remains ignored as there is no literature available for Pakistan, while most of the literature belongs to industrialized countries; such as China and developed nations like Western countries. This study held its significance for Pakistan because it elaborates the nexus between environmental quality and economic growth by adopting novel techniques, such as the Tapio decoupling indicator and the LMDI technique. The study also covers the drawbacks of previous techniques such as EKC, because the current study gives a complete decomposition of environmental impact with no residual term, and the analysis also gives the annual decoupling status of "environmental harms from economic output" during 1990-2014. In addition, the analysis also helps in determining the paramount drivers of CO_2 emissions that could help to attain long-term economic growth by restricting the influence of such factors.

5.2 Theoretical/Policy Implications

For decades, there have been concerns about the link between economic growth and environmental impact, with several research studies to investigate the connection between these two. The current study aims to delink environmental harms from economic output. The results, however, are consistent with the literature of (Lin & Raza (2019); Wang et al. (2018); Andreoni & Galmarini (2012) & De Freitas & Kaneko (2011). Furthermore, the findings are also backed by theories of Ecological Modernization and Himalayan Environment Degradation, according to which advanced technologies help improve the environmental quality, while the second theory states that the main source of environmental degradation is the anthropogenic activities.

Based on empirical evidence, certain policy implications are given as follows; firstly, the government should promote environment-friendly technologies in the manufacturing sector to discourage environmental harms. Secondly, because renewable energy is more sustainable and less carbon-intensive, the government should take some strong stance on diverging economy's energy structure from fossil fuels to renewable energy.

5.2 Limitation and Future Research

The study integrated important factors that contribute significantly to economic growth as well as CO_2 emissions, taking factors of Kaya identity i.e. population, GDP per capita, energy structure, energy, and carbon intensity. Novel techniques such as Tapio decoupling indicator and LMDI methods are employed in this study. However, there are also some limitations of the current study. First, due to the unavailability of data, we limit the analysis up to 2014. Second, CO_2 emission is taken as a substitute of environmental degradation, other forms of GHG emissions such as methane, nitrous oxide and ozone can also be used as a proxy for environmental degradation. Third, in order to have a clearer picture, the impact of fossil fuel energy along with renewable energy consumption should be examined on environmental impact. However, for future work, the analysis could be expanded to the regional/provincial level in Pakistan. Furthermore, the analysis could also be widened to other dimensions of decoupling, such as decoupling economic growth from natural resource use.

REFERENCES

Ali, H. S., Law, S. H., & Zannah, T. I. (2016). Dynamic impact of urbanization, economic growth, energy consumption, and trade openness on CO_2 emissions in Nigeria. *Environmental Science and Pollution Research*, *23*, 12435-12443.

Alam, S. (2010). Globalization, poverty, and environmental degradation: Sustainable development in Pakistan. *Journal of Sustainable Development*, *3*(3), 103-114.

Andreoni, V., & Galmarini, S. (2012). Decoupling economic growth from carbon dioxide emissions: A decomposition analysis of Italian energy consumption. *Energy*, *44*(1), 682-691.

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

Ang, B. W., & Lee, P. W. (1996). Decomposition of industrial energy consumption: the energy coefficient approach. *Energy Economics*, *18*(1-2), 129-143.

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.

Aziz, R., & Ahmad, M. B. (2015). *Pakistan's power crisis. Special report*. Washington DC, United States Institute of Peace.

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. (2018). British petroleum statistical review of world energy. British Petoleum: London UK. [ONLINE] Available: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html (October 23rd, 2019).

Climent, F., & Pardo, A. (2007). Decoupling factors on the energy–output linkage: The Spanish case. *Energy Policy*, *35*(1), 522-528.

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.

Engo, J. (2018). Decomposing the decoupling of CO_2 emissions from economic growth in Cameroon. *Environmental Science and Pollution Research*, *25*(35), 35451-35463.

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.

Government of Pakistan (2011). Economic survey 2010-11. Ministry of Finance. Islamabad.

Hoekstra, R., & Van den Bergh, J. C. (2003). Comparing structural decomposition analysis and index. *Energy Economics*, *25*(1), 39-64.

IPCC. (2014). *Climate change 2014, synthesis report*. IPCC, Geneva, Switzerland. [ONLINE] Available: http://www.ipcc.ch/pdf/assessmentreport/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf (September 27th, 2019).

Juknys. (2002). Indicators to measure decoupling of environmental pressure from economic growth. *Sustainable Development*, *4,* 4-9.

Jiang, J. J., Ye, B., Zhou, N., & Zhang, X. L. (2019). Decoupling analysis and environmental Kuznets curve modelling of provincial-level CO_2 emissions and economic growth in China: A case study. *Journal of Cleaner Production*, *212*, 1242-1255.

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

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.

Liang, L., Hu, X., Tivendale, L., & Liu, C. (2017). The log mean divisia index based carbon productivity in the Australian construction industry. *Construction Economics and Building*, *17*(3), 68-84.

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

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.

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.

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.

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.

Mahmood, M. T., & Shahab, S. (2014). Energy, emissions and the economy: Empirical analysis from Pakistan. *The Pakistan Development Review*, *53*(4-II), 383-401.

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

Malik, A. (2012). Power crises in Pakistan: A crises in governance?. Pakistan Institute of Development Economics. (PIDE Monograph Series)

Meinshausen, M., Meinshausen, N., Hare, W., Raper, S. C., Frieler, K., Knutti, R., Frame, J. D., & Allen, M. R. (2009). Greenhouse-gas emission targets for limiting global warming to 2^oC. *Nature*, *458*, 1158-1162.

Munir, S., & Khan, A. (2014). Impact of fossil fuel energy consumption on CO_2 emissions: Evidence from Pakistan (1980-2010). *Pakistan Development Review*, *53*(4), 327-346.

Nasir, J. (2012). IMF Programs in Pakistan (1988-2008)–An Analysis. *Criterion Quarterly*, *6*(4), 1-20.

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

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

Perman, R., & Stern, D. I. (2003). Evidence from panel unit root and cointegration tests that the environmental Kuznets curve does not exist. *Australian Journal of Agricultural and Resource Economics*, *47*(3), 325-347.

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.

Román-Collado, R., Cansino, J. M., & Botia, C. (2018). How far is Colombia from decoupling? Two-level decomposition analysis of energy consumption changes. *Energy*, *148*, 687-700.

Sari, R., & Soytas, U. (2009). Are global warming and economic growth compatible? Evidence from five OPEC countries? *Applied Energy*, *86*(10), 1887-1893.

Shuai, C., Chen, X., Wu, Y., Zhang, Y., & Tan, Y. (2019). A three-step strategy for decoupling economic growth from carbon emission: Empirical evidences 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.

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

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

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.

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). Eco-efficiency trends of the Flemish industry: Decoupling of environmental impact from economic growth. *Journal of Cleaner Production*, *18*(14), 1349-1357.

Vavrek, R., & Chovancova, J. (2016). Decoupling of greenhouse gas emissions from economic growth in V4 countries. *Procedia Economics and Finance*, *39*, 526-533.

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

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., Zhao, M., Li, R., & Su, M. (2018). Decomposition and decoupling analysis of carbon emissions from economic growth: A comparative study of China and the United States. *Journal of Cleaner Production*, *197*, 178-184.

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.

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.

World Bank. (2019). World development indicators. World Bank: Washington DC.

Wu, Y., Zhu, Q., & Zhu, B. (2018). 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, J. H., Fleiter, T., Eichhammer, W., & Fan, Y. (2012). Energy consumption and CO2 emissions in China's cement industry: A perspective from LMDI decomposition analysis. *Energy Policy*, *50*, 821-832.

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.

Xu, X. Y., & Ang, B. W. (2013). Index decomposition analysis applied to CO_2 emission studies. *Ecological Economics*, *93*, 313-329.

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, M., Li, H., Zhou, M., & Mu, H. (2011). Decomposition analysis of energy consumption in Chinese transportation sector. *Applied Energy*, *88*(6), 2279-2285.

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.