Resour Environ Econ, 2019, 1(1): 16-28
DOI: 10.25082/REE.2019.01.003

RESEARCH ARTICLE

# Decoupling of greenhouse gas emissions from economic growth in Cameroon

Jean Engo

**Abstract:** Knowledge of decoupling indicators and its determinants is useful for formulating targeted policy recommendations. To this end, the Log-Mean Divisia Index and Tapio models were applied in this paper to study the decoupling relationship among economic growth and GHG emissions in Cameroon over the period 1971-2014. The analyzes were conducted according to the three major periods that marked Cameroon after independence and the decoupling indicators were broken down into seven factors while considering the three main GHGs emitted in this country (*i.e.* $CO_2$, $CH_4$, and $N_2O$). The results showed that weak decoupling, strong decoupling, and strong negative decoupling occurred in Cameroon during the periods 1971-1984 and 1994-2014 which represent the periods before and after the economic crisis, respectively. In addition to these three decoupling statuses, recessive decoupling only appeared during the economic crisis period (1984-1994). From 1971 to 1984 and between 1994 and 2014, carbon intensity, economic activity, population, and emission factor not only contributed to the increase of Cameroon's GHG (particularly $CO_2$) emissions but also prevented decoupling. Unlike the period 1984-1994, energy intensity contributed to reducing environmental pollution while promoting decoupling during the periods 1971-1984 and 1994-2014. Although all played an important role in decoupling, we found that after the introduction of natural gas into the country's energy mix from 2007, the effect of renewable energies on the mitigation of Cameroon's $CO_2$ emissions remained higher than the substitution of fossil fuels. However, to develop a cleaner economy, Cameroon should maintain modest economic growth and continuously transform economic development pathways, while encouraging the use of renewable energy to further reduce energy intensity per unit of GDP per capita.

**Keywords:** Cameroon, economic growth, decoupling, $CO_2$ emission, energy intensity, greenhouse gas, environmental pollution

## 1 Introduction

Humanity is facing huge and complex challenges, including environmental degradation, resource scarcity,and climate change.In recent decades, climate change has affected natural and human systems in all regions of the world.[1] These changes, which have been observed since about 1950, are naturally related to human influences and can be summed up in phenomena such as the increase of the number of heavy rainfalls, the decrease of the extremely cold temperatures, the increase of the extremely hot temperatures, and the extreme rise in sea level.[2] Based on the results of several studies, climatologists have pointed out that these climatic effects are mainly caused by a largenumber of greenhouse gases (GHG) currently concentrated in the atmosphere. Global emissions of various GHGs have increased steadily since last century and reached 438 parts per million (ppm) in 2008.[3] This figure was 58% above the pre-industrial level and is close to the 450 ppm threshold, which represents the level associated with a 50% chance of exceeding the overall average temperature variation target of 2°C.[4] Mainly driven by strong demographic and economic growth based on high fossil fuel consumption in developing countries, global GHG concentration is expected to reach about 685 ppm by mid-century and more than 1,000 ppm by 2100.[1,3]

Among the top three GHGsregulated by the Kyoto Protocol, atmospheric concentrations of carbon dioxide ($CO_2$) which account for more than 70% of the global GHG emission are currently estimated at 403 ppm and are expected to reach about 530 and 780 ppm by 2050 and 2100, respectively.[3,5] Methane ($CH_4$), which is 25 times more powerful than $CO_2$ over a 100-year period,

**Received:** January 15, 2019; **Accepted:** February 5, 2019; **Published:** February 9, 2019

* **Correspondence to**: Jean Engo, Center for Energy and Environmental Policy, School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China; Email: jean_engo@yahoo.fr

**Citation:** Engo J. Decoupling of greenhouse gas emissions from economic growth in Cameroon. *Resour Environ Econ*, 2019, **1**(1): 16-28.

is the second largest contributor to global warming created by humans. Since the pre-industrial period, the concentration of this gas in the atmosphere has more than doubled, reaching about 1,800 parts per billion (ppb) in recent years and is expected to reach more than 2000 ppb by 2050.[3,6] Nitrous oxide ($N_2O$) has heat-trapping effects approximately 310 times more potent than $CO_2$. Over the past 800,000 years, atmospheric concentrations of this gas have rarely exceeded 280 ppb, but since the 1920s they have increased to 328 ppb in 2015 and are expected to reach 350 ppb by 2050.[3,7] One of the worst consequences of these GHG concentration levels is that they would increase the global average temperature from 2.0°C to 2.8°C in the middle of the century and from 3.7°C to 5.6°C at the end of the century.[1,3] Therefore, limiting climate change would require substantial and sustainable reductions in GHG emissions, which, coupled with adaptation, can limit the risks associated with climate change. To this end, more ambitious national climate policies should be put in place to separate GHG emissions from the path of economic growth of developed and developing countries, and in particular, those where industrial emergenciesare expected by 2035 to 2050, like Cameroon.[8]

Cameroon is a country of 475442 square kilometres located in the Congo Basin, specifically between the Gulf of Guinea and Lake Chad.[9] Ten years after its independence, Cameroon's economic development was dominated by oil revenues and its growth increased from 3.09 to 8.06% in 1970 and 1985, respectively.[10] This growth suddenly dropped to 6.77% in 1986 and remained negative between 1987 (-2.14%) and 1993 (-7.93%) due to the economic crisis in the country as a result of falling prices for oil and other commodities in international markets.[10,11] Thanks to huge reforms in economic policy, and despite the devaluation of the CFA franc in 1994,[12] the country's economic growth became positive again and gradually increased from 2.06% in 1994 to 4.03% and 5.92% in 2003 and 2014, respectively.[10] Cameroon's economic growth has slowed in the last three years not only because of the poor global economy but also because of the various security challenges that the country is currently facing along its border with neighboring Nigeria.Meanwhile, Cameroon's population has grown at an average annual growth rate of 2.8% and is currently estimated at over 25 million.[9,10] At the same time, the country's energy consumption increased by 70.87%, from 2.7 to 9.27 Mtoe in 1971 and 2016, respectively.[5,13] This strong energy and economic growth have significantly increased GHG emissions by 34.86%, from 65737.63 to 100922.13 kt$CO_2$e in 1970and 2012, respectively.Over the same period, the country's $CO_2$, $CH_4$ and $N_2O$ emissions also increased by 89.58%, 55.24%,and 55.55%, respectively.[10] As Cameroon's current vision is to reduce its GHG emissions by 32% by 2035,[14] the question of how to decouple GHG emissions from economic growth is currently the most important and urgent issue for this country.

The concept of decoupling was first introduced in environmental studies by (Zhang 2000),[15] to explore the decoupling link between economic growth and carbon emissions in China. The OECD recognized this concept in 2002 as an indicator, which identified two decoupling measurement statuses, namely absolute and relative decoupling.[16] As a result, a series of decoupling surveys were conducted and technological opportunities, as well as increased resource productivity and decoupling, were identified. (Wu, *et al*, 2018)[17] examined decoupling trends in economic growth and $CO_2$ emissions in typical developed and developing countries over the period 1965-2015, based on decoupling theories. They concluded that developed countries were strongly decoupled and that their stabilization had increased slightly, while developing countries showed a weak decoupling, fluctuating significantly and inconsistently. (Wang, *et al*, 2018)[18] combined the Tapio and LMDI models to compare the decoupling relationship between economic growth and $CO_2$ emissions from China and the US. They found that China experienced expansive coupling and low decoupling in most years between 2000 and 2014, while the United States experienced mainly weak and strong decoupling. (Dai, *et al*, 2016)[19] also combined the Tapio and LMDI models to study the emergence of decoupling among economic growth and energy-related $CO_2$ emissions in the BRICS countries between 1995 and 2014. They found that only five states of decoupling appeared among these countries, including weak decoupling, strong decoupling, expansive negative decoupling, expensive coupling, and recessive decoupling. They also concluded that the energy intensity effect played a positive role in reducing $CO_2$ emissions in the five BRICS countries. Since decoupling is so crucial for sustainable development, many researchers have tried to study decoupling in recent years, including (Engo, 2018; Mikayilov, *et al*, 2018; Zhang, *et al*, 2019; Li, *et al*, 2015; Zhang & Da, 2015).[20–24] The main objective of all this research is to produce effective guidelines and policies to promote economic growth without increasing environmental pressures.

However, we noted that previous studies used $CO_2$ as a proxy for decoupling economic growth and environmental pollution, and most of them had defined decoupling status only, without exact reasons.Furthermore, in Cameroon, the few studies available on the question of energy-related to environmental pollution such as those of (Tamba, 2017; Noubissi Domguia & Njangang, 2017; Hilaire & Hervé, 2012),[25–27] have only evaluated the causal relationships between environmental, economic, and energy factors. Based on these considerations, the objective of this study is to evaluate the decoupling relationship between economic growth and GHG emissions in Cameroon over the period 1971-2014, based on the Tapio model.The analyzes were carried out according to Cameroon's three major periods of economic development, particularly the period preceding the economic crisis (1971-1984), the period of economic crisis (1984-1994) and the period following the crisis (1994-2014). The study took into account the three main GHGs emitted in Cameroon (*i.e.* $CO_2$, $CH_4$, and $N_2O$) and the decoupling indicators were broken down into seven factors, including the demographic factor, economic activity, renewable energies, energy intensity, carbon intensity, the substitutionof fossil fuel, and the emission factor. With regard to its contribution, this study attempts not only to bridge the gap of previous studies but will also contribute to strengthening the literature in the context of Cameroon. In addition, this study shows the behavior of Cameroon's main drivers of GHG emissions and provides decoupling indicators that can contribute to the policy development needed to achieve the country's GHG emissions mitigation vision. Based on our best knowledge, this study is the first to measure the effect of renewable energies on decoupling.

The rest of this paper is structured as follows. The method used to achieve the objective of this study is presented in section 2. The study's results are presented and discussed in section 3, while we conclude the study in section 4.

## 2 Methodology and data sources

### 2.1 Data sources

This study's data cover a 44-year period from 1971 to 2014. Population and GDP data are estimated in millions and billions, respectively, while energy data are estimated in tonnes of oil equivalent (Toe). Data on $CO_2$ emissions are estimated in tonnes of $CO_2$ ($tCO_2$) while those for $CH_4$ and $N_2O$ are estimated in tonnes of $CO_2$ equivalent ($tCO_2e$). All this data was collected from the World Bank and the International Energy Agency.[10,13]

### 2.2 Method of decoupling and decomposing GHG emissions

Among all the existing decoupling methods, the one introduced by (Tapio, 2005)[28] from (Vehmas J, Malaska P, Luukkanen J, Kaivo-oja J, Hietanen O, Vinnari M, 2003)[29] works is the most currently used, since he is the founder of the eight logical indicators used in decoupling status definition. According to (Tapio, 2005),[28] the relationship between economic growth and $CO_2$ emissions can be decoupled using the following model.

$$\omega_{(C,GDP)} = \frac{\%\Delta C}{\%\Delta GDP} \tag{1}$$

where $\omega_{(C,GDP)}$, $\%\Delta$C, $\%\Delta$GDP represents the decoupling index of $CO_2$ emissions and gross domestic product, percent changes in carbon emissions and percent changes in the gross domestic product, respectively. As one of this study's objectives is to evaluate the decoupling indicators of the three main GHGs emitted in Cameroon, the Equation 1 as follows.

$$\omega_{(GHG_i,GDP)} = \frac{\%\Delta GHG_i}{\%\Delta GDP} = \frac{\frac{GHG_i^t - GHG_i^0}{GHG_i^0}}{\frac{GDP^t - GDP^0}{GDP^0}} \tag{2}$$

where $\omega_{(GHG_i,GDP)}$ and $\%\Delta GHG_i$ are the decoupling index of gas type i (*i.e.* $CO_2$, $CH_2$, and $N_2O$) and the growth rate of this gas between a base year (0) and a target year (t), respectively.After determining the decoupling indicators of these gases based on the Equation 2, we proceed to the identification of decoupling statuses according to the eight logical indicators defined by Tapio as presented in Table 1.

According to Cameroon's second national communication,[30] $CO_2$ is the most emitted GHG in this country, followed by $CH_4$ and then $N_2O$. Based on these indicators and given the lack of data as described in the previous subsection, specific reasons that led to the decoupling status defined by Equation 2 were determined according to the main driving forces of Cameroon's $CO_2$emissions. To this end, we applied the Logarithmic Mean Divisia Index (LMDI) method, which makes it possible to identify the contributions of a set of factorial variables to the target variable.[31] However, to assess $CO_2$ emissions at the national level, the Kaya model,[32] whose general form is expressed by Equation 3, is often used.

$$C = POP \times \frac{C}{E} \times \frac{E}{GDP} \times \frac{GDP}{POP} = POP \times CI \times EI \times GD \tag{3}$$

where C, GDP, E, and POP denote total carbon emissions, gross domestic product, energy consumption, and population, respectively.In addition, CI, EI, and GD refer to the carbon intensity per unit of energy used to produce a unit of GDP, energy intensity per unit of GDP per capita

**Table 1.** The eight logical decoupling status of Tapio

| Decoupling statuses | | ω(GHG$_i$GDP) | %ΔGDP | %ΔGHG$_i$ |
|---|---|---|---|---|
| Coupling | Expansive coupling (EC) | [0.8; 1.2] | + | + |
| | Recessive coupling (RC) | [0.8; 1.2] | - | - |
| Decoupling | Weak decoupling (WD) | [0; 0.8] | + | + |
| | Strong decoupling (SD) | [- ∞; 0.8] | + | - |
| | Recessive decoupling (RD) | [0.8; ∞ ] | - | - |
| Negative decoupling | Expansive negative decoupling (END) | [1.2; ∞] | + | + |
| | Weak negative decoupling (WND) | [0; 0.8] | - | - |
| | Strong negative decoupling (SND) | [- ∞; 0] | + | - |

Source: (Tapio 2005)

and economic activity, respectively. The contributions of the factors presented in Equation 3 on Cameroon's $CO_2$ emissions between the base year (0) and the target year (t) were determined by the following equations:

$$\Delta C_T = C^t - C^0 = \Delta C_{CI} + \Delta C_{EI} + \Delta C_{GD} + \Delta C_{POP} \tag{4}$$

$$\Delta C_{CI} = \sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{CI_i^t}{CI_i^0}\right) \tag{5}$$

$$\Delta C_{EI} = \sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{EI_i^t}{EI_i^0}\right) \tag{6}$$

$$\Delta C_{GD} = \sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{GD_i^t}{GD_i^0}\right) \tag{7}$$

$$\Delta C_{POP} = \sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{POP_i^t}{POP_i^0}\right) \tag{8}$$

Meanwhile, oil, hydropower,and biofuel were the three main sources of Cameroon's energy supply until 2006. Natural gas has been introduced into the country's energy mix since 2007, and currently accounts for 4.82% of total energy supplies, while biofuel, oil, and hydroelectricity account for 69.06, 22.24 and 3.85%, respectively.[10] However, assessing the impact of this government action, which consisted to improve the country's energy efficiency, was also the subject of this study. We sought to understand the behavior of renewable energies and the substitution of fossil fuels effects on $CO_2$ emissions after introducing natural gas into the country's energy mix.To this end, Kaya's identity (*i.e.* carbon intensity) was expanded in this article,[33] which allowed us to rewrite Equation 3 as follows.

$$\begin{aligned} C &= \frac{C_i}{E_i} \times \frac{E_i}{TF} \times \frac{TF}{E} \times \frac{E}{GDP} \times \frac{GDP}{POP} \times POP \\ &= Z \times FI \times RE \times EI \times GD \times POP \end{aligned} \tag{9}$$

where $C_i$, $E_i$, and TF denote carbon emissions of fossil fuel type (i), fossil fuel consumption of type (i), and total fossil fuels consumption, respectively. f, FI, and RE refer to emission factor, fossil fuel substitution, and renewable energies, respectively.To determine the effects of these factors on Cameroon's $CO_2$ emissions, particularly over the period 2007-2014, taking into account the available data, the following equations obtained from Equation 9 were applied.

$$\begin{aligned} \Delta C_T &= C^t - C^0 = \Delta C_Z + \Delta C_{FI} + \Delta C_{RE} \\ &+ C_{EI} + \Delta C_{GD} + \Delta C_{POP} \end{aligned} \tag{10}$$

$$\Delta C_Z = \sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{Z_i^t}{Z_i^0}\right) \tag{11}$$

$$\Delta C_{FI} = \sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{FI_i^t}{FI_i^0}\right) \tag{12}$$

$$\Delta C_{RE} = \sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{RE_i^t}{RE_i^0}\right) \tag{13}$$

$$\Delta C_{EI} = \sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{EI_i^t}{EI_i^0}\right) \tag{14}$$

$$\Delta C_{GD} = \sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{GD_i^t}{GD_i^0}\right) \quad (15)$$

$$\Delta C_{POP} = \sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{POP_i^t}{POP_i^0}\right) \quad (16)$$

Meanwhile, to determine the exact reasons for the decoupling status, we applied Equation 4 to Equation 8 and Equation 10 to Equation 15 in Equation 2 to obtain the following equations:

$$\omega_{(C,GDP)} = \frac{GDP^0}{C^0 \times (GDP^t - GDP^0)} \times [\Delta C_{CI} + \Delta C_Z + \Delta C_{FI} + \Delta C_{RE} + \Delta C_{EI} + \Delta C_{GD} + \Delta C_P OP] \quad (17)$$

$$\omega_{CI} = \frac{GDP^0}{C^0 \times (GDP^t - GDP^0)} \times \left[\sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{CI_i^t}{CI_i^0}\right)\right] \quad (18)$$

$$\omega_{Z} = \frac{GDP^0}{C^0 \times (GDP^t - GDP^0)} \times \left[\sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{Z_i^t}{Z_i^0}\right)\right] \quad (19)$$

$$\omega_{FI} = \frac{GDP^0}{C^0 \times (GDP^t - GDP^0)} \times \left[\sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{FI_i^t}{FI_i^0}\right)\right] \quad (20)$$

$$\omega_{RE} = \frac{GDP^0}{C^0 \times (GDP^t - GDP^0)} \times \left[\sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{RE_i^t}{RE_i^0}\right)\right] \quad (21)$$

$$\omega_{EI} = \frac{GDP^0}{C^0 \times (GDP^t - GDP^0)} \times \left[\sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{EI_i^t}{EI_i^0}\right)\right] \quad (22)$$

$$\omega_{GD} = \frac{GDP^0}{C^0 \times (GDP^t - GDP^0)} \times \left[\sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{GD_i^t}{GD_i^0}\right)\right] \quad (23)$$

$$\omega_P OP = \frac{GDP^0}{C^0 \times (GDP^t - GDP^0)} \times \left[\sum_{i=1}^{n} \frac{C_i^t - C_i^0}{lnC_i^t - lnC_i^0} \times ln\left(\frac{POP_i^t}{POP_i^0}\right)\right] \quad (24)$$

where, $\Delta C_{CI}$, $\Delta C_Z$, $\Delta C_{FI}$, $\Delta C_{RE}$, $\Delta C_{EI}$, $\Delta C_{GD}$, $and\ \Delta C_{POP}$ are variables that measure the carbon intensity effect, the emission factor effect, the effect of fossil fuel substitution, the effect of renewable energies, energy intensity effect, the effect of economic activity, and the effect of the population, respectively, on Cameroon's total $CO_2$ emissions. Similarly, $\omega_{CI}$, $\omega_Z$, $\omega_{FI}$, $\omega_{RE}$, $\omega_{EI}$, $\omega_{GD}$, $and\ \omega_{POP}$ are variables that indicate the effects of each of the previous variables on the decoupling of GHG from Cameroon's economic growth. However, the results of our analyzes are presented and discussed in the following section.

## 3 Results and discussions

To study the decoupling relationship between GHG emissions and economic growth in Cameroon over the period 1971-2014, we distinguished three main periods and the results obtained for this purpose are as follows.

### 3.1 Cameroon's decoupling indicators from 1971 to 1984

Table 2 presents the decoupling indicators from the relationship among GHG emissions (including $CO_2$, $CH_4$, and $N_2O$) and economic growth in Cameroon during the period preceding the economic crisis and the devaluation of the CFA franc (1971-1984).

Table 2 shows that the relationship between GHG emissions and economic growth was dominated by a weak decoupling over the period 1971-1984. A strong negative decoupling occurred between 1979 and 1980 for the three gases, and between 1973 and 1974 for $CO_2$ emissions and from 1975 to 1976 for $CH_4$ and $N_2O$ emissions; whereas strong decoupling was observed only during the periods 1973-1974, 1977-1978, 1980-1981 and 1973-1975 for $N_2O$ and $CH_4$ emissions, respectively.These results, in agreement with those of other studies, indicate that Cameroon's economic development

**Table 2.** Cameroons decoupling indicator during the period before the economic crisis (1971-1984)

| Years | ω ($CO_2$, GDP) | DS* | ω ($CH_4$, GDP) | DS* | ω ($N_2O$, GDP) | DS* | %△$CO_2$ | %△$CH_4$ | %△$N_2O$ | %△GDP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1971-1972 | 9.60E-07 | WD** | 0.253 | WD** | 0.285 | WD** | 0.04 | 0.006 | 0.007 | 0.02 |
| 1972-1973 | 3.19E-07 | WD** | 0.07 | WD** | 0.085 | WD** | 0.03 | 0.003 | 0.004 | 0.05 |
| 1973-1974 | 3.15E-07 | SND** | -0.036 | SD** | -0.046 | SD** | -0.003 | -0.003 | -0.005 | 0.1 |
| 1974-1975 | 7.05E-07 | WD** | -0.005 | SD** | 0.053 | WD** | 0.28 | 0 | 0.005 | 0.11 |
| 1975-1976 | 4.06E-07 | WND** | -0.46 | SND** | -0.444 | SND** | -0.08 | 0.02 | 0.02 | -0.05 |
| 1976-1977 | 1.15E-06 | WD** | 0.02 | WD** | 0.083 | WD** | 0.43 | 0.002 | 0.01 | 0.13 |
| 1977-1978 | 4.44E-07 | WD** | 0.114 | WD** | -0.046 | SD** | 0.07 | 0.02 | -0.01 | 0.22 |
| 1978-1979 | -5.76E-07 | WD** | 1.943 | WD** | 0.286 | WD** | 0.07 | 0.11 | 0.01 | 0.06 |
| 1979-1980 | -1.90E-05 | SND** | -5.063 | SND** | -0.496 | SND** | 0.08 | 0.09 | 0.009 | -0.01 |
| 1980-1981 | 1.34E-06 | WD** | 0.411 | WD** | -0.026 | SD** | 0.05 | 0.07 | -0.004 | 0.17 |
| 1981-1982 | 1.93E-06 | WD** | 0.875 | WD** | 0.316 | WD** | 0.07 | 0.06 | 0.02 | 0.07 |
| 1982-1983 | 4.66E-07 | WD** | 42.85 | WD** | 2.935 | WD** | 0.08 | 2.94 | 0.2 | 0.06 |
| 1983-1984 | -8.24E-07 | WD** | 0.293 | WD** | 0.093 | WD** | 0.04 | 0.02 | 0.006 | 0.07 |

*DS: decoupling status ; ** See the meaning in Table 1

followed a sustainable environmental security approach during the period 1971-1984.Before 1970, Cameroon's economy revolved around agriculture.Following the discovery of oil deposits throughout the country in the early 1980s, the Cameroonian government implemented policies to restructure its economy.As a result, the shares of agriculture and the tertiary sector in the national GDP decreased from 31 to 21.76%, and from 49.76 to 38.75% between 1971 and 1985, respectively; while that of the industrial sector increased from 19.23% to 37.47%, as shown in Figures 1. This helped to reduce the country's energy intensity per unit of GDP per capita from 0.45 Toe in 1971 to 0.27 Toe in 1984, as shown in Figures 1. Cameroon's economic sustainability and growth thus increased significantly, while dissociating weakly from environmental pollution.

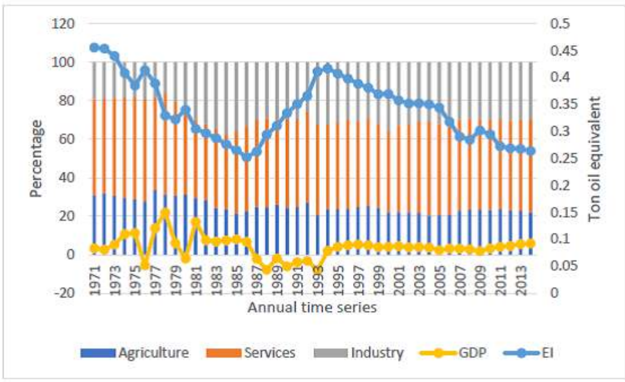


**Figure 1.** Trends in Cameroon's economic growth and Energy intensity per unit of GDP from 1971 to 2014

Figures 2 and Figures 6 show that energy intensity is the only factor that played an important role in decoupling economic growth from GHG (and more specifically $CO_2$) emissions over the study period.Although having contributed slightly to increased environmental pollution because of the 1976 economic downturn and the global financial crisis of the 1980s, as shown in Figures 6 during the 1975-1976 (1.77%) and 1979-1980 (2.76%) periods; the total effect of energy intensity had contributed to reducing Cameroon's $CO_2$ emissions by -27.01% over the period 1971-1984.This finding is consistent with other studies and reflects an improvement in the industrial processes and technologies implemented by Cameroon during this period, which means that the country should continue to promote technologies to reduce its intensity.

In contrast to energy intensity, Figures 6 shows that carbon intensity, followed by economic activity and demographic factors, helped to prevent the decoupling during the period 1971- 1984. Despite the fall observed in 1976 and 1980 as shown in Figures 1, Cameroon's economic growth increased from 3.47% in 1971 to 7.47% in 1984, while the country's population increased from 6697745 to 9742263 over the same period.This strong demographic and economic growth not only helped to increase environmental pollution due to these factors as shown in Figures 6 but also helped to slow decoupling. Figures 6 also shows that economic growth was the main driver of GHG (and more specifically $CO_2$) emissions over the 1971-1984 period, which indicates that policies aimed at optimizing Cameroon's economic development path should be implemented to promote decoupling.

## 3.2 Cameroon's decoupling indicators from 1984 to 1994

Caused mainly by the collapse of oil revenues and other commodities on the international markets[11], the

 

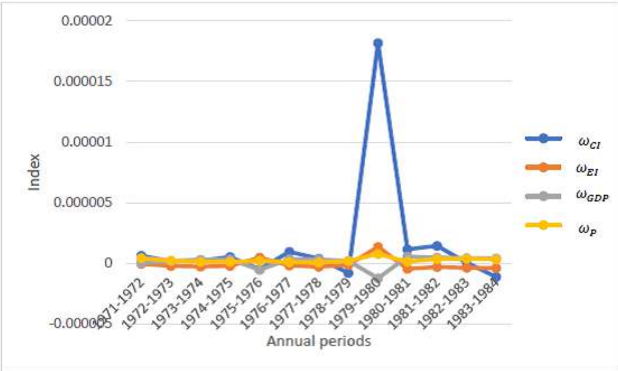


**Figure 2.** Decomposition of Cameroon's decoupling indicator during the period before the economic crisis (1971-1984)

economic crisis took hold in Cameroon in 1985, when the country grew by 8% (Figures 1), which was well above that of 1984 (7.47%). During this period of crisis, decoupling indicators derived from the relationship among economic growth and GHG emissions in Cameroon were as follows (See Table 3).

Table 3 shows that the relationship between GHG emissions and economic growth was dominated by a strong negative decoupling over the period 1984-1994, which means that Cameroon's GHG emissions have increased faster than economic growth while destabilizing the quality of the environment. This result, which differs from the majority of decoupling studies, reflects high energy and environmental cost in Cameroon's economic development process during this period and can be explained by the country's economic context at that time. Meanwhile, a weak decoupling occurred during 1984-1986, 1984-1985 and 1993-194, and 1985-1986 periods for $N_2O$, $CO_2$, and $CH_4$ emissions, respectively;whereas strong decoupling was achieved only for $CO_2$ and $CH_4$ emissions during the 1984-1985 and 1985-1986 periods, respectively. This result is in line with other studies and indicates that the country's economic growth has been greater than that of GHG emissions, reflecting Cameroon's efforts to judiciously align its resources to ensure good environmental health. Table 3 shows that recessive decoupling dominated the relationship between $CO_2$ emissions and economic growth, unlike $CH_4$ and $N_2O$ emissions, where this decoupling status only occurred in the 1986-1987 and 1988-89 and 1991-92 periods; indicating that Cameroon's GHG emissions declined in line with the economic slowdown during those periods. This can be explained by the declining share of the industrial sector in GDP and the increase in energy intensity, as shown in Figures 1.

However, Figures 3 and Figures 7 show that population growth and energy intensity were the main factors that contributed negatively to the development of decoupling in Cameroon during the period 1984-1994. Unlike the period 1984-1986, where energy intensity had contributed to reducing $CO_2$ emissions because of Cameroon's good economic growth during this period, as shown in Figures 1 and Figures 7, the effect of this factor on environmental pollution were positive and increasing between 1986 and 1994, which also helped to prevent decoupling (See Figures 3 and Table 3). We found that energy intensity contributed to increasing Cameroon's total $CO_2$ emissions by 38.56% over the period 1984-1994, which is different from the results of other decomposition analysis studiesand can be explained by the high energy consumption (and fossil fuels in particular) that Cameroon has achieved during this complex economic period. Figures 1 shows that Cameroon's energy intensity per unit of GDP rose from 0.25 Toe in 1986 to 0.41 Toe in 1994, reflecting the government's efforts to lift the country out of the economic crisis.Given that the country's population had increased at an average annual growth rate of 3%, from 9,000,345 to 10,456,81 between 1984 and 1994, the State was obliged to increase energy consumption, particularly in the transportation and industry sectors, to respond effectively to the diverse needs of its population. As a result, the demographic factor has contributed to increasing Cameroon's total $CO_2$ emissions by 39.92%, while helping to prevent the proper development of decoupling.

During 1984-1985, 1987-1989 and 1991-1992 periods, carbon intensity contributed to increasing carbon emissions by 7.84, 219 and 100.31% respectively, while economic activity only contributed to the 18% increase in these emissions between 1984 and 1986, as shown in Figures 7. This is in line with the results of other studies and can be explained by the strong economic growth experienced by Cameroon during these periods. At the same time, the cumulative effects of carbon intensity and economic activity have significantly contributed to reducing Cameroon's total $CO_2$ emissions by -135.54 and -42.93%, respectively. This means that, with the exception of the above-mentioned periods, these two factors played an important role in promoting decoupling over the period 1984-1994, which is different from previous decoupling studies and can be explained by the context of the country's economic crisis at that time.

## 3.3 Cameroon's decoupling indicators from 1994 to 2014

Figures 1 shows that, after being negative between 1987 and 1993, Cameroon's economic growth turned positive again in 1994, reflecting the country's exit from the crisis it had been experiencing for about eight years.

**Table 3.** Cameroons decoupling indicator during the economic crisis period (1984-1994)

| Years | ω($CO_2$,GDP) | DS* | ω($CH_4$,GDP) | DS* | ω($N_2O$,GDP) | DS* | %△$CO_2$ | %△$CH_4$ | %△$N_2O$ | %△GDP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1984-1985 | 5.53E-07 | WD** | -1.09 | SD** | 0.05 | WD** | 0.11 | -0.08 | 0.004 | 0.08 |
| 1985-1986 | -6.20E-06 | SD** | 6.41 | WD** | 1.39 | WD** | -0.03 | 0.43 | 0.09 | 0.06 |
| 1986-1987 | 6.68E-07 | RD** | 6.29 | RD** | 0.74 | RD** | -0.007 | -0.13 | -0.01 | -0.02 |
| 1987-1988 | -4.26E-07 | SND** | 8.03 | SND** | 1.34 | RD** | 0.09 | 0.62 | -0.1 | -0.07 |
| 1988-1989 | -2.46E-05 | SND** | 54.15 | SND** | -6.03 | SND** | 0.09 | 0.98 | 0.1 | -0.01 |
| 1989-1990 | 7.16E-06 | RD** | -1.11 | SND** | -0.61 | SND** | -0.02 | 0.06 | 0.03 | -0.06 |
| 1990-1991 | 1.25E-06 | RD** | 0.05 | RD** | -0.61 | SND** | -0.07 | -0.001 | 0.02 | -0.03 |
| 1991-1992 | -7.03E-06 | RD** | -0.11 | SND** | -0.74 | SND** | -0.06 | 0.003 | 0.02 | -0.03 |
| 1992-1993 | -1.17E-07 | SND** | -0.8 | SND** | -0.58 | SND** | 0.06 | 0.06 | 0.04 | -0.07 |
| 1993-1994 | -3.02E-07 | WD** | -16.48 | WD** | 9.32 | WD** | 0.05 | -0.34 | 0.19 | 0.02 |

*DS: decoupling status ** See the meaning in Table 1

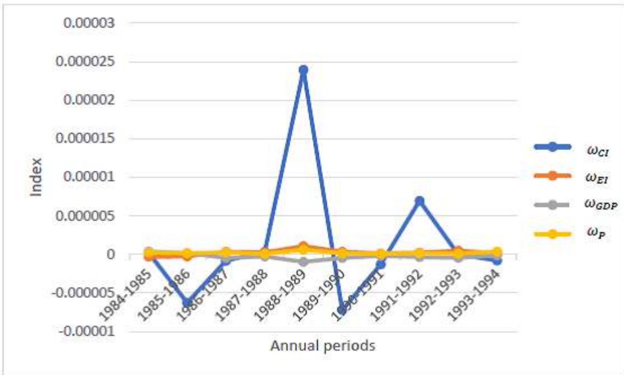


**Figure 3.** Decomposition of Cameroons decoupling indicator during the economic crisis period (1984-1994)

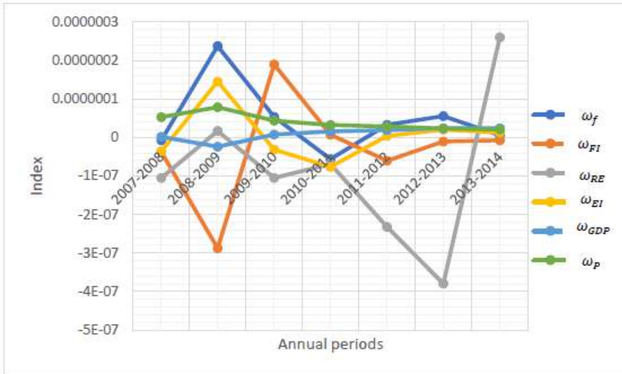


**Figure 5.** Decomposition of Cameroon's decoupling indicator during the period following the introduction of natural gas into the country's energy mix (2007-2014)

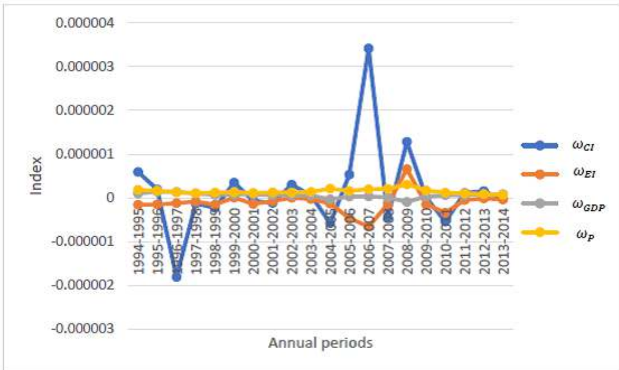


**Figure 4.** Decomposition of Cameroon's decoupling indicator during the period following the economic crisis and the devaluation of the CFA franc (1994-2014)

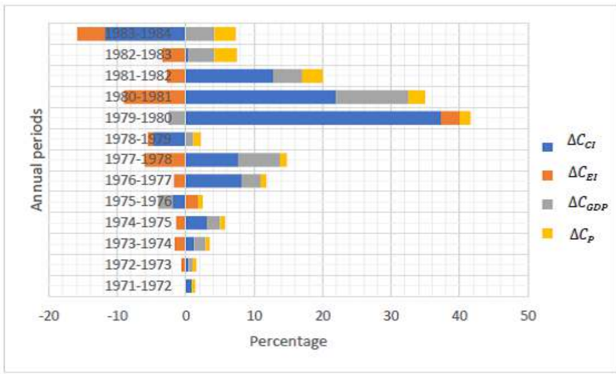


**Figure 6.** Cumulative decomposition of Cameroon's CO2 emissions during the period before the economic crisis (1971-1984)

 

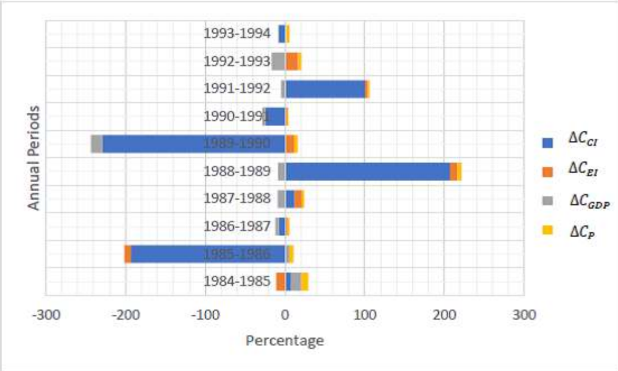


**Figure 7.** Cumulative decomposition of Cameroon's CO2 emissions during the economic crisis period (1984-1994)

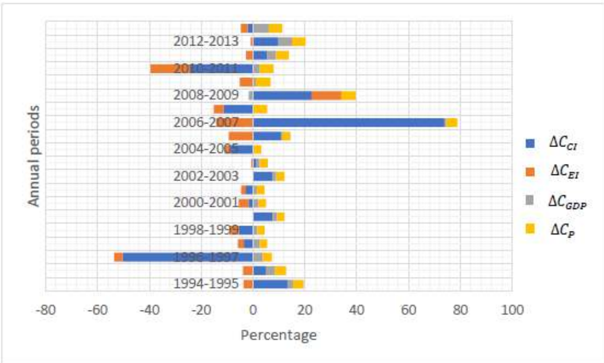


**Figure 8.** Cumulative decomposition of Cameroon's CO2 emissions during the period following the economic crisis and the devaluation of the CFA franc (1994-2014)

Unfortunately, the French Republic devalued the country's currency (the CFA franc) just after it came out of the crisis in 1994.[12] Table 4, therefore, represents decoupling indicators resulting from the relationship among economic growth and GHG emissions in Cameroon following these two unfortunate events.

Table 4 shows that during the period 1994-2008, the relationship between GHG emissions and economic growth was dominated by a weak decoupling, meaning that GHG emissions increased more slowly than economic growth.Unlike $CO_2$ and $N_2O$ emissions, where strong decoupling was observed only 3 and 2 times, respectively, this decoupling status dominated the relationship among $CH_4$ emissions and economic growth in Cameroon between 1994 and 2008; which means that economic growth increased faster than GHG emissions during these periods.These results are consistent with other studies and show the good economy and environmental sustainability in Cameroon after the crisis.

In order to maintain positive economic growth and less harmful to the environment after the crisis, the Cameroonian government had readjusted its economic and energy

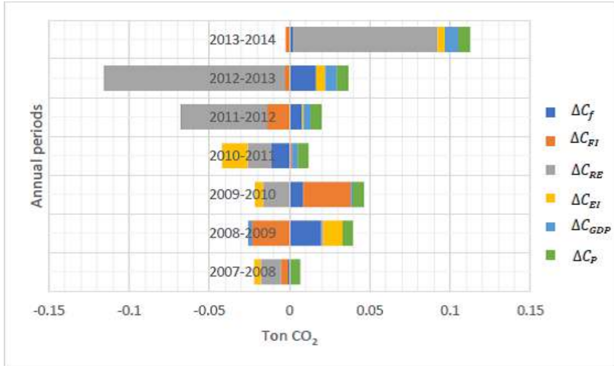


**Figure 9.** Cumulative decomposition of Cameroon's CO2 emissions during the period following the introduction of natural gas into the country's energy mix (2007-2014)

policies. As a result, the country's energy intensity per unit of GDP per capita declined from 0.41 Toe in 1994 to 0.26 Toe in 2014, whereas its economic growth increased from 2.06 to 5.92% over the same period, as shown in Figures 1. During this period, the share of agricultural and industrial sectors in the national GDP remained almost stable, while that of the service sector increased due to the emergence of new information and communication technologies.The government has privatized several state-owned enterprises, while others, particularly energy-intensive ones, have seen technological and managerial improvements.Furthermore, several works to improve the country's energy supply have been completed.However, all these actions had not only contributed to reducing energy intensity but also to reduceits effect on Cameroon's total $CO_2$ emissions by -66.92%.Energy intensity was, therefore, the most important factor in promoting decoupling over the period 1994-2014 (See Figures 4), which is in line with other studies.This suggests that Cameroon should continue to improve technology and energy policy to achieve dynamic decoupling.

Meanwhile, Cameroon's population increased by 41%, from 13109660 in 1994 to 22239904 in 2014, whereas the country's GDP per capita increased from 994.64 to 1293.63 constant 2010 USD during the same period. The immediate consequence of this strong demographic and economic growth is that these two factors contributed to increasing Cameroon's total $CO_2$ emissions by 80.29% and 39.69%, respectively. Figures 8 shows that the effects of these factors increased positively throughout the study period, which also made it possible to progressively prevent decoupling, as shown in Figures 4. In addition to these two factors, carbon intensity contributed to increasing Cameroon's total $CO_2$ emissions by 46.93%, indicating that carbon intensity

**Table 4.** Decomposition of Cameroon's decoupling indicator during the period following the economic crisis and the devaluation of the CFA franc (1994-2014)

| Years | ω($CO_2$,GDP) | DS* | ω($CH_4$,GDP) | DS* | ω($N_2O$,GDP) | DS* | %△$CO_2$ | %△$CH_4$ | %△$N_2O$ | %△GDP |
|---|---|---|---|---|---|---|---|---|---|---|
| 1994-1995 | 7.10E-07 | WD** | 0.625 | WD** | 0.27 | WD** | -0.03 | 0.02 | 0.01 | 0.04 |
| 1995-1996 | 3.40E-07 | WD** | 1.369 | WD** | 0.441 | WD** | -0.006 | 0.06 | 0.02 | 0.04 |
| 1996-1997 | -1.60E-06 | WD** | -0.451 | SD** | 0.31 | WD** | 0.05 | -0.02 | 0.01 | 0.05 |
| 1997-1998 | -9.80E-09 | WD** | 0.415 | WD** | 0.423 | WD** | 0.04 | 0.02 | 0.02 | 0.04 |
| 1998-1999 | -1.90E-07 | SD** | -0.429 | SD** | 0.26 | WD** | -0.1 | -0.01 | 0.01 | 0.04 |
| 1999-2000 | 5.60E-07 | WD** | -0.195 | SD** | 0.617 | WD** | 0.16 | -0.008 | 0.02 | 0.04 |
| 2000-2001 | -1.30E-08 | SD** | -0.059 | SD** | 0.199 | WD** | -0.02 | -0.002 | 0.009 | 0.04 |
| 2001-2002 | -5.20E-09 | WD** | -1.202 | SD** | 0.118 | WD** | 0.06 | -0.04 | 0.004 | 0.04 |
| 2002-2003 | 4.80E-07 | WD** | -0.046 | SD** | 0.407 | WD** | 0.03 | -0.001 | 0.01 | 0.04 |
| 2003-2004 | 2.11E-07 | WD** | -1.115 | SD** | 0.279 | WD** | 0.01 | -0.04 | 0.01 | 0.03 |
| 2004-2005 | -5.30E-07 | SD** | -0.328 | SD** | 0.466 | WD** | -0.02 | -0.007 | 0.01 | 0.02 |
| 2005-2006 | 2.50E-07 | WD** | 2.174 | WD** | -1.847 | SD** | 0.05 | 0.07 | -0.05 | 0.03 |
| 2006-2007 | 2.90E-06 | WD** | 1.909 | WD** | 2.136 | WD** | 0.32 | 0.06 | 0.06 | 0.03 |
| 2007-2008 | -3.80E-07 | WD** | 1.518 | WD** | -0.364 | SD** | 0.03 | 0.04 | -0.01 | 0.02 |
| 2008-2009 | 2.15E-06 | WD** | - | - | - | - | 0.12 | - | - | 0.01 |
| 2009-2010 | 5.04E-08 | WD** | - | - | - | - | 0.05 | - | - | 0.03 |
| 2010-2011 | -7.07E-07 | WD** | - | - | - | - | 0.003 | - | - | 0.04 |
| 2011-2012 | 2.20E-07 | WD** | - | - | - | - | 0.05 | - | - | 0.04 |
| 2012-2013 | 3.05E-07 | WD** | - | - | - | - | 0.09 | - | - | 0.05 |
| 2013-2014 | 8.90E-08 | WD** | - | - | - | - | 0.03 | - | - | 0..05 |

*DS: decoupling status ** See the meaning in Table 1

also played a negative role in decoupling, which is consistent with other studies. Figures 8 shows that carbon intensity contributed significantly to the increase in $CO_2$ emissions by 73.86 and 22.57% during the 2006-2007 and 2008-2009 periods, respectively; which also led to an increase in the decoupling index for these periods, as shown in Figures 4. This can be attributed to Cameroon's high energy consumption and strong economic growth over these periods.

However, among other measures taken by Cameroon to improve its energy efficiency over the period 1994-2014, we noted the introduction of natural gas into the country's energy mix in 2007. For this purpose, Table 4 shows that between 2007 and 2014, Cameroon's economic development was slightly dissociated from environmental pollution, indicating a low dependence of economic growth on GHG emissions related to energy. Figures 1 shows that over this period, the Cameroonian economy has remained virtually stable at the structural level, which has reduced energy intensity while promoting the achievement of low decoupling.

Figures 9 shows that from 2007 to 2014 renewable energy, fossil fuel substitution and energy intensity contributed to reducing Cameroon's $CO_2$ emissions by -0.11, -0.01, and -0.001 t$CO_2$, respectively. These results are consistent with those of other studies and reflect a great technological improvement in different sectors of Cameroon's economic activity during this period.Unlike the transport sector, where oil continues to satisfy all energy needs, we found that the introduction of natural gas into Cameroon's energy mix helped to improve technologies and energy consumption in this country's industrial sector. In addition, despite the fact that the advent of natural gas has contributed to reducing the share of renewable energy in Cameroon's energy mix, significant maintenance work has been done by the government to improve the efficiency of hydropower generation. Therefore, the effects of renewable energy and the substitution of fossil fuels had not only contributed to improving energy intensity and reducing environmental pollution, but also to promoting decoupling in Cameroon, as shown in Figures 5.

Meanwhile, Cameroon's economic and demographic indicators show that the country's GDP per capita increased from 1185.74 constant 2010 USD in 2007 to 1293.63 in 2014 constant 2010 USD, while its population grew by 17.28%, from 18395389 to 22239904 over the same period. Furthermore, Figures 1 shows that the share of the industrial sector in Cameroon's GDP increased from 29.81 to 30%, while that of the tertiary

 

(47%) and agricultural (22%) sectors remained almost stable. These indicators, which reflect high energy consumption, particularly in the industrial and transport sectors due to a sharp increase in urbanization in Cameroon, make it possible to understand from Figures 9 that population, economic activity and emission factor contributed to increasing the country's total $CO_2$ emissions by 0.047, 0.022 and 0.041 $tCO_2$, respectively. These results are consistent with previous studies and suggest from Figures 5 that these three factors contributed to preventing decoupling in Cameroon. However, Figures 5 shows that during the 2008-2009 period, the population, emission factor, energy intensity,and renewable energies contributed to increasing the decoupling index, whereas economic activity and substitution of fossil fuels played an important role in this decoupling. This situation can mainly be explained by the slowdown in economic activity experienced by Cameroon at this time, following the unfortunate events experienced by Cameroon in February 2008.[34]

## 4 Conclusion and policy implications

### 4.1 Conclusion

This study assesses the decoupling relationship between economic growth and GHG (including $CO_2$, $CH_4$, and $N_2O$) emissions in Cameroon from 1971 to 2014. The analyzes were conducted according to the three major periods that marked Cameroon after independence, namely the period before the economic crisis (1971-1984), the period during the economic crisis (1984-1994) and the period after the economic crisis and the devaluation of the CFA Franc (1994-2014). We used the LMDI and Tapio models to decompose and explore the effects of seven factors in decoupling and the main finding can be summarized as follows.

From 1971 to 1984 and between 1994 and 2014, three decoupling positions, namely strong decoupling, weak decoupling,and strong negative decoupling, emerged in the relationship among economic growth and GHG emissions in Cameroon, indicating that GHG emissions have increased slowerthan economic growth. At the same time, we found that in addition to these three decoupling statuses, recessive decoupling occurred in this relationship between 1984 and 1994, which means that GHG emissions have decreased faster than the economic recession.

However, we found that environmental pollution was higher in Cameroon from 1971 to 1984 than the period 1984-2014 because of the country's strong economic growth at that time. During the 1971-1984 and 1994-2014 periods, carbon intensity, economic activity, population, and emission factor not only contributed to the increase of Cameroon's GHG emissions but also prevented decoupling. During these two periods, energy intensity contributed to reducing environmental pollution by -27.01 and -66.92%, respectively, while promoting decoupling. In contrast to these periods, energy intensity (38.56%) was almost the main driver of CO2 emissions and played a negative role in Cameroon's decoupling process over the period 1984-1994. Meanwhile, the effects of renewable energies and the substitution of fossil fuels have contributed to reducing environmental pollution and promoting decoupling in Cameroon.

### 4.2 Policy implications

Based on the above results, several policy recommendations to achieve emission reduction targets and to develop a low-carbon economy can be formulated.

This paper shows that scale effects (population and economic activity) had a negative impact on decoupling in Cameroon over the period 1971-2014. To this end, stringent measures should be applied in energy-intensive sectors, such as industry and transport, in order to reduce their impact on the environment. Cameroon should maintain modest economic growth and continuously transform economic development pathways. Various policies should be implemented to encourage high value-added development technologies in secondary and tertiary sectors. Furthermore, the government should promote public transit while increasing publicity and education means to raise awareness of the need for a low-carbon lifestyle.

This study showed that the effects of energy intensity, renewable energies, and substitution of fossil fuels played an important role in decoupling over the period 1971-2014. Therefore, Cameroon's energy structure still needs to be optimized to further reduce energy intensity per unit of GDP per capita in the country. This requires the use of more low-carbon energies, such as natural gas and renewable energies (*i.e.* hydropower, Biomass, wind and solar), which are energy resources available in significant quantities in this country. Cameroon should encourage the development of clean energy technologies such as carbon capture and sequestration (CCS), fuel cell vehicles and biofuels while implementing fiscal policies and subsidies to promote the quality of its environment. In addition, the State should develop repressive measures aimed at eliminating harmful industries that are not respectful of the country's environmental protection clauses.

Although this study was conducted in the context of Cameroon, its results can serve as a basis for the development of GHG mitigation policies in countries with development conditions similar to those of Cameroon.

## 5 Acknowledgments

The authors will like to dedicate this work to his family and more particularly to Jeanne Nelly Medou Asso'o, Glorya Engo, and Riskys Engo. Furthermore, we would like to thank the supervisor of this study, Professor Dr. Yi-Ming Wei, in China; and all those who participated in the scientific evaluation of this paper, especially editors and reviewers.

## 6 Conflict of interest

The authors declare that they have no conflict of interest.

## References

[1] Ypersele JV. Climate Change Projections for 2050 / 2100 and their Potential Impacts in the Middle East Why the IPCC? Established by WMO and UNEP in 1988. IPCC, January, 2015.

[2] IPCC. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2014.

[3] Marchal V, *et al*. OECD environmental outlook to 2050: Climate change chapter. Oecd, November, **2011**: 90.

[4] UNFCCC. Paris Agreement. Conference of the Parties on its twenty-first session, 21932, December, **2015**: 32.

[5] IEA. $CO_2$ emissions from fuel combustion. Oecd/Iea, **2017**: 1-155.

[6] Van Dingenen R, *et al*. Global trends of methane emissions and their impacts on ozone concentrations, JRC SCIENCE FOR POLICY REPORT, 2018.

[7] Davidson EA, Kanter D. Inventories and scenarios of nitrous oxide emissions. Environmental Research Letters, 2014, **9**(10): 1-12. https://doi.org/10.1088/1748-9326/9/10/105012

[8] MINEPAT. CAmeroun vision 2035. Ministere de l'économie, de la planification et de l'amenagement du territoire, June 2009: 76.

[9] CIA. The World Factbook - Central Intelligence Agency. Central Intelligence Agency (US), 2018.

[10] WDI. World Development Indicators, DataBank. The World Bank, 2018.

[11] OECD-AfDB. African Economic Outlook. OECD-AfDB, 2001: 71-82.

[12] Cogneau D, Herrera J. Ia devaluation du fcfa au cameroun: Bilan et perspectives. 1995: 23.

[13] IEA-CMR. Cameroon International Energy Agency Balances, 2018.

[14] INDC-CMR. Republique Du Cameroun Contribution Prevue Determinee Au Plan National ( Cpdn ) Intended Nationally Determined Contribution ( Indc ). Population, M W Us, Mds Cpdn, La Industrialis, Nouveau Pays, 2015: 1-17.

[15] Zhang Z. Decoupling Chinas Carbon Emissions Increase from Economic Growth: An Economic Analysis and Policy Implications. World Development, 200. 28(4): 739752.

[16] OECD. Indicators to measure decoupling of environmental pressure from economic growth. Sustainable development, 2010.

[17] Wu Y, Zhu Q, Zhu B. Decoupling analysis of world economic growth and $CO_2$ emissions: A study comparing developed and developing countries. Journal of Cleaner Production, 2018, **190**: 94-103. https://doi.org/10.1016/j.jclepro.2018.04.139

[18] Wang Q, Zhao M, Li R,*et al*. Decomposition and decoupling analysis of carbon emissions from economic growth: A comparative study of China and the United States. Journal of Cleaner Production, 2018, 197: 178-184. https://doi.org/10.1016/j.jclepro.2018.05.285

[19] Dai S, Zhang M, Huang W. Decomposing the decoupling of CO2 emission from economic growth in BRICS countries. Natural Hazards, 2016, **84**(2): 1055-1073. https://doi.org/10.1007/s11069-016-2472-0

[20] Engo J. Decomposing the decoupling of $CO_2$ emissions from economic growth in Cameroon. Environmental Science and Pollution Research, 2018. https://doi.org/10.1007/s11356-018-3511-z

[21] Mikayilov JI, Hasanov FJ, Galeotti M. Decoupling of $CO_2$ emissions and GDP: A time-varying cointegration approach. Ecological Indicators, 2018, **95**:615-628. https://doi.org/10.1016/j.ecolind.2018.07.051

[22] Zhang X, Zhao y, Wang C*et al*. Decoupling effect and sectoral attribution analysis of industrial energy-related carbon emissions in Xinjiang, China. Ecological Indicators, 2019, **97**: 1-9. https://doi.org/10.1016/j.ecolind.2018.09.056

[23] Li W, Sun S, Li H. Decomposing the decoupling relationship between energy-related CO 2 emissions. Natural Hazards, , 2015, **79**(2): 977-997. https://doi.org/10.1007/s11069-015-1887-3

[24] Zhang YJ, Da YB. The decomposition of energy-related carbon emission and its decoupling with economic growth in China. Renewable and Sustainable Energy Reviews, , 2015, **4**: 1255-1266. https://doi.org/10.1016/j.rser.2014.09.021

[25] Tamba JG. Energy consumption, economic growth, and $CO_2$ emissions: Evidence from Cameroon. Energy Sources, Part B: Economics, Planning and Policy, 2017, **12**(9): 779785. https://doi.org/10.1080/15567249.2016.1278486

[26] Noubissi Domguia E, Njangang H. Croissance économique et dégradation de l'environnement au Cameroun: Croissance conomique et dégradation de l'environnement. African Development Review, 2017, **29**: 615-629. https://doi.org/10.1111/1467-8268.12300

[27] Hilaire N, Hervé KF. TITRE: Effets de la croissance économique sur les missions de $CO_2$ dans les Pays du Bassin du Congo, **2012**: 1-17.

[28] Tapio P. 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, 2005, **12**(2): 137-151. https://doi.org/10.1016/j.tranpol.2005.01.001

[29] Vehmas J, Malaska P, Luukkanen J, *et al*. Europe in the global battle of sustainability: Rebound strikes back? Advanced sustainability analysis, publications of the Turku School of Economics and Business Administration, Series discussion and working papers, Turku, **2003**: 7.

[30] CNI. Climate change governance in Cameroon Official doc. UNFCCC-CAMEROON, **1994**: 160.

[31] Ang BW. LMDI decomposition approach: A guide for implementation. Energy Policy, 2015, (Sup: C)86: 233-238.

[32] Kaya Y. Impact of carbon dioxide emission on GNP growth: interpretation of proposed scenarios. Paris: Presentation to the Energy and Industry Subgroup, Response Strategies Working Group, IPCC. X'Pert Stress PW3208, Software for Residual stress analysis, PANalytical, The Netherlands, 1990.

[33] Peters GP, Andrew RM, Canadell JG, *et al*. Key indicators to track current progress and future ambition of the Paris Agreement. Nature Climate Change, 2017, **7**(2): 118-122. https://doi.org/10.1038/nclimate3202

[34] ACAT. Emeutes de Fevrier 2008: Suivi des recommandations, 2008: 18.