Asian Economic and Financial Review
ISSN(e): 2222-6737
ISSN(p): 2305-2147
DOI: 10.18488/journal.aefr.2019.96.724.742
Vol. 9, No. 6, 724-742

URL: www.aessweb.com

ECONOMIC GROWTH AND ENVIRONMENTAL QUALITY: STYLIST FACTS AND ENVIRONMENTAL KUZNETS CURVE : CASE OF TUNISIA

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Article History
Received: 1 April 2019
Revised: 3 May 2019
Accepted: 5 June 2019
Published: 8 July 2019

Keywords:
Environmental Kuznets Curve
Growth
Tunisia
Energy consumption
CO_2 emissions
Energy.

JEL Classification:
Q5; Q6; O1; Q56; Q54; R11.

ABSTRACT

In this paper we studied the link between economic growth and the environment. We discussed the inverse U-shaped relationship between environmental pollutants and economic growth. First, we analyzed the long-term observation of the growth of CO_2 emissions which is characterized by three phases. Second, we estimated the EKC curve for Tunisia. The results of our estimates revealed a problem of autocorrelation of errors which we solved by using the Cochran-Orcutt method. The model was corrected for $\rho = 0.4$. In addition, we noticed that the Durbin-Watson model without the dummy variable is better than the model that incorporates the dummy variable. This finding confirmed the existence of an inverted U-shaped CEK. Our results show that the country has not yet reached the threshold of development from which economic growth is accompanied by a reduction of pollutant emissions. More precisely, the value of GDP* is $2062,647 which is much lower than the $8,000 found by Seldon and Song (1994) characterizing the reversal point of the inverted U curve. Tunisia is therefore in the phase where an increase in GDP is accompanied by a deterioration of the environment.

Contribution/ Originality: This paper analyzes the causal relationships between three variables by combining literature on the EKC curve with the literature on the links between energy use and economic growth. Finally, our analysis is followed by a descriptive study of the relationship between energy consumption and environmental degradation in Tunisia during the last decades.

1. INTRODUCTION

A major problem attracting the attention of economists and policymakers in recent years is the link between economic growth and respect for the environment. This relationship between economic growth and the environment has been analyzed according to three approaches: weak sustainability, strong sustainability and the "economic-ecological" approach.

The weak sustainability approach has its origins in the neoclassical approach and states that there is no decoupling between the level of economic activity and the degradation of the environment. In other words, stopping economic growth would not bring about an improvement in the quality of the environment.

Contrary to the previous theory, a second approach, strong sustainability, advocates that natural capital determines the well-being of man and becomes a limiting factor of growth. Increasing energy and raw material consumption contributes to economic growth, and the resulting greenhouse gas emissions contribute to the deterioration of the environment. The theory of strong sustainability thus considers macroeconomics as a subsystem of a finite and non-growing ecosystem. The consequences of the economic crisis have relativized the scope of this approach since it is no longer a question of substitutability or complementarity between natural capital and physical capital with the appearance of followers of the "economic-ecological" approach.

Among these supporters is the London school which frames the relationship between the ecological system and the economic system in terms of coevolution or "feedback". The proposed sustainability rule is halfway between the two previous approaches. This is concerned with the role of technical progress in achieving the goal of sustainable development. Thus, growth can only be equated with sustainable development if it contributes to human well-being without destroying the mechanisms that ensure the reproduction of its resources.

In 1972, at the request of the "Club of Rome"[1], a team of researchers produced a systematic vision of the relationship between growth and the environment from a model and concluded that there was interdependence between economic growth, climate change[2] and resource depletion.

The environment is then defined as the set of natural and cultural conditions in which living organisms develop and whose consideration is more of a necessity than a moral duty that must be part of a framework of “sustainable development ", based on a dual principle of inter and intra-generational equity. In addition to modeling, researchers have used econometric tools to explore the links between economic growth, energy consumption and environmental degradation.

Two reasons justify the introduction of energy consumption in analyzes of the impact of growth on the quality of the environment. The first is that growth is based on primary energy resources that are then used by end-users contributing to the formation of GDP (agriculture, manufacturing, transportation, tertiary and residential). The second reason is that it has been proven that global greenhouse gas emissions come mainly from the consumption of energy, thus contributing to environmental degradation.

We review this work in section two, distinguishing between three areas of research. Knowing that the use of energy for economic growth needs mainly generates CO_2 emissions from carbon in fuels, we devote section three to a long-term analysis of growth and CO_2 emissions for the case of Tunisia. We analyze its volatility over time and indicate the stylized facts that mark this environmental indicator over time. This analysis is followed by a descriptive study of the relationship between energy consumption and environmental degradation in Tunisia during 1985-2008, which will be the subject of section four. We will then in section five check the Kuznets U-shape, which describes the relationship between pollution and economic development, in the case of the Tunisian economy. Finally, we dedicate the last section to the factors that contribute to increasing pollutant emissions from energy use.

2. THEORETICAL OVERVIEW AND EMPIRICAL CHECKS

The relationships between energy consumption and economic growth, and between economic growth and environmental pollution, have been the subject of intense research in recent decades. Work in this area can be divided into three areas of research.

1 The Club of Rome is a group of scientists, economists, national and international officials, as well as industrialists from 53 countries, concerned with the complex issues facing all societies, both industrialized and developing.

2 The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "climate change that is directly or indirectly attributed to human activity that affects the composition of the global atmosphere directly or indirectly and that comes to the fore add to the natural variability of the climate observed during comparable periods ".

2.1. The link between Economic Growth and Energy Consumption

The first axis focuses on the link between economic growth and energy consumption going back to the pioneering work of Kraft and Kraft (1978). A uni-directional causal relationship from output to energy consumption for the United States during 1947-1974 was found. Several authors have drawn from this work to examine the causal relationship between these variables for other countries in different time periods using different econometric techniques as is shown in Table 1.1 below.

Table-1.1. Results of Causal Tests between Energy Consumption and Economic Growth: An Empirical Synthesis.

Authors	Countries	Direction of causality
I- Studies in favor of a one-way relationship ranging from energy consumption to economic growth		
Erol and Yu (1987)	Japon	Cons.Ener→Revenue
Cheng (1997)	Brezil, Mexico, Venezuela	Cons.Ener→GDP au Brazil
Asafu-Adjaye (2000)	Asian developing country	Cons.Ener→Rev. in Inde and Indonesia
Soytas and Sari (2007)	G-7 and emerging economies	Cons.Ener→GDP in Turkey, French, Allemagne and Japan
Ghali and El-Sakka (2004)	Canada	Cons.Ener→GDP
Lee (2005)	18 developing country	Cons.Ener→GDP
Odhiambo (2009)	Tanzania	Cons.Ener→GDP
II- **Studies in favor of a unidirectional relationship ranging from economic growth to energy consumption**		
Kraft and Kraft (1978)	United state	PNB→Cons.Ener
Abosedra and Baghestani (1989)	United state	PNB→Cons.Ener
Cheng and Lai (1997)	Taiwan	PIB→Cons.Ener
Cheng (1997)	India	PIB→Cons.Ener
Soytas and Sari (2007)	G-7 and emerging economies	PIB→Cons.Ener in Italy and Kor□a
Odhiambo (2009)	South Africa, Kenya, Democratic Congo	PIB→Cons.Ener in Congo
III- **Studies in favor of a two-way relationship between energy consumption and economic growth**		
Glasure and Lee (1998)	South korea and Singapour	Cons.Ener↔GDP
Asafu-Adjaye (2000)	Asian developing country	Cons.Ener↔Revenue in Philippines and Thailande
Glasure and Lee (1998)	Korea	Cons.Ener↔ economic growth
Soytas and Sari (2007)	G-7 and emerging economies	Cons.Ener↔GDP in Argentine
Paul and Bhattacharya (2004)	India	Cons.Ener↔economic growth
IV- **Studies for a neutrality between energy consumption and economic growth**		
Yu and Hwang (1984)	Etats-Unis	Absence of causality
Cheng (1997)	Brasil, Mexico and Venezuela	Absence of causality in Mexico and Venezuela
Ozturk and Acaravci (2010)	Turkey	Absence of causality

The review of this work shows that there is a causal relationship between energy consumption and economic growth but that there is no consensus on the direction of this link. It is dependent on the methodology used, the country and the period under study. However, Stern (2002) highlights one observation from his review of the literature: that energy is essential for production. The mixed results may also result from countries having different patterns of energy consumption or sources of energy and these varied sources may have different impacts on an economy's output. Referring to the existing literature, we can interpret the different meanings of causality found between the two aggregates as follows:

- A uni-directional causal relationship of energy consumption to economic growth means that growth depends on energy consumption and a decrease in energy consumption can slow down this growth (Cheng, 1997; Ghali and El-Sakka, 2004; Odhiambo, 2009).

- A uni-directional relationship of output (measured by GDP or GNP by works) to energy consumption implies that the country is not totally dependent on energy for its growth, and that energy efficiency policies can be undertaken but with little or no effect on growth (Kraft and Kraft, 1978).
- If no causal relationship is found, then the "neutrality hypothesis" implies that energy control policies have little or no effect on economic growth (Asafu-Adjaye, 2000; Oh and Lee, 2004; Paul and Bhattacharya, 2004; Odhiambo, 2009).

Several authors have synthesized work that precedes their own (Lee, 2005; Erdal *et al.*, 2008; Lee and Chang, 2008; Ozturk, 2010; Ozturk and Acaravci, 2010). We continue this synthesis by adding other more recent works that we present in the above mentioned Table 1.1:

2.2. The link between Economic Growth and Environmental Pollutants

The second line of research focuses on the link between economic growth and the environment, discussing the inverted U-ratio between environmental pollutants and economic growth by examining the validity of the Environmental Kuznets Curve (EKC) assumption. This concept emerged as a result of empirical work without any prior theoretical underpinnings.

The Kuznets curve comes from Simon Kuznets' pioneering work on economic development in 1955, in which he found a bell-shaped relationship between per capita income and social inequality. The basic assumption of Kuznets was that income inequality between people naturally has negative impact on development (Kuznets, 1955). The idea of transposing this idea into the environmental field came from Grossman and Krueger in 1991 and since then the relationship between the level of wealth and pollutants emitted by a country has been called the "Kuznets environmental curve"[3] as can be seen in Figure 1.1 below.

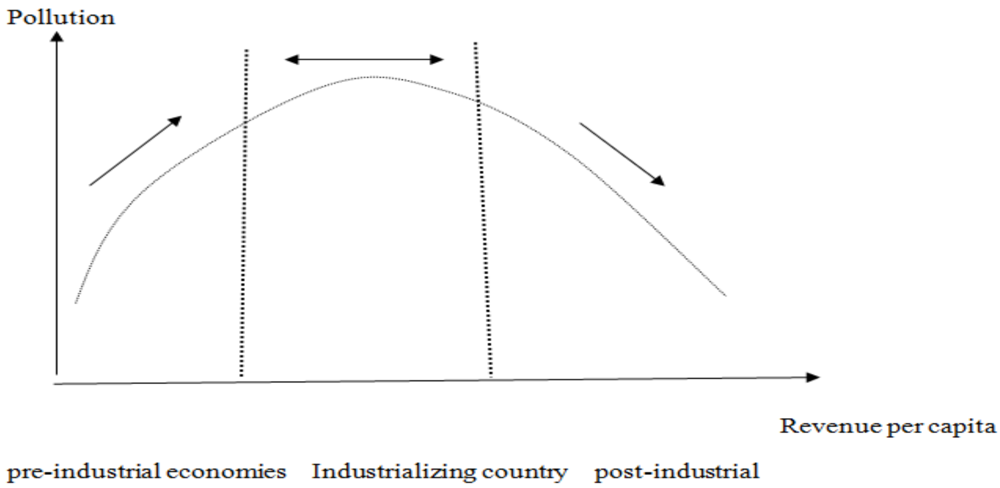

Figure-1.1. The Environmental Kuznets Curve.

Source: Kuznets's environmental curve.

This curve has three phases. The first phase is characterized by very low income levels and the country's desire to grow causing further deterioration of its environment. The second phase describes economies in the process of industrialization, with middle-income, and marked by an urbanizing population, growing industries and intensifying natural resource needs, resulting in increasing amounts of pollutants affecting the environment. This can be explained by the fact that the search for growth outweighs the environmental concerns. It is at this phase that a maximum level of pollutant emission is observed. Finally, the third phase characterizes some high-income countries; it shows that environmental degradation will be decoupled from economic growth and will begin to

3 Panayotou (1993) is the first to give the inverted U-shaped relationship the Environmental Kuznets Curve because of its resemblance to Kuznets inverted U-relationship between income inequality and economic development.

decline after reaching a critical income threshold. Indeed, the economy can direct some of its investments towards the fight against the environmental pollution of productive processes. And then there is an inverse relationship between economic growth and environmental degradation as shown in the graph above in Figure 1.1.

Since the beginning of the '90s, a renewed interest has characterized this inverted U curve. However, empirical studies on the EKC audit drew different conclusions. We distinguished between work that confirms the environmental Kuznets curve hypothesis and those that do not. For example, Selden and Song (1994); Grossman and Krueger (1995); Stern and Common (2001) and Galeotti *et al.* (2006) verified the EKC hypothesis. However, De Bruyn *et al.* (1998) found an increasing and monotonous curve whereas Harbaugh (2000) found an N-shaped curve. In addition, Richmond and Kaufmann (2006) concluded that there is no significant relationship between economic growth and environmental pollutants.

We concluded that the composition of the panel but also the indicators used could justify the diversity of results. In fact, the most frequent criticisms of EKC studies are the inconsistency and incompatibility of the shapes and turning points found in different studies (Ekins, 1997; Harbaugh, 2000; Stern and Common, 2001). Others even think that the work of the 1990s over-represents OECD countries and underestimates the threshold of wealth from which economic growth would be accompanied by better environmental quality. This is why, given the specificity of each country, it would be more relevant to conduct studies on individual countries.

Tunisia has been subject to the verification of the Kuznets curve in several studies in Mhenni (2005) for a period from 1980 to 1997; Fodha and Zaghdoud (2010) for the period 1961-2004, and Shahbaz *et al.* (2013) during 1971-2010. The contribution of our study is to examine the link between economic growth, energy consumption and pollutant emissions.

To this end, and after having presented this axis of research in the general framework, we will also attempt to check the U-shape of Kuznets for the case of the Tunisian economy, a small developing economy that never stops increasing its interest in environmental issues, making them one of its political and economic priorities.

2.3. The links between Economic Growth, Energy Consumption and Pollutant Emissions

The third area of research studies the relationship between pollutant emissions, energy consumption and economic growth by simultaneously considering them in an integrated analysis. These studies attempted to analyze the causal relationships between the three variables by combining the Environmental Kuznets Curve literature with the literature on the links between energy use and economic growth (Richmond and Kaufmann, 2006; Soytas and Sari, 2007; Apergis and Payne, 2009; Soytas and Sari, 2009; Wang *et al.*, 2010). We noted that the studies revealed different results dependent on the countries and the period chosen in the analysis, as well as the econometric techniques used.

Soytas and Sari (2007) found that in the United States during 1960-2004 energy consumption was the main source of pollutant emissions and that GDP did not explain CO_2 emissions. Zhang and Cheng (2009) reached the same conclusion by analyzing China over the period 1960-2007. Granger's causality tests and the impulse response study showed that energy consumption was the main source of pollutant emissions and that GDP did not cause CO_2 emissions. In contrast, Shafik (1994) and an analysis of panel data covering 149 countries between 1961 and 1993 found that pollutant emissions increased with income levels. This result was confirmed by De Bruyn *et al.* (1998) since they showed that economic growth had a direct positive effect on pollutant emissions in their sample countries of Great Britain, the United States and Germany. They proved that polluting emissions go down if we reached a certain income threshold. Therefore, the pollutant-energy-income relationship needs to be studied carefully and in detail for any economy. Authors have sought to analyze the nature of this relationship for the case of Tunisia including Farhani and Ben Rejeb (2012).

Then, we studied the evolution over time of CO_2 emissions per capita (in metric tons per capita), energy consumption per capita (in ktoe per capita) and GDP per capita (in constant US $2005) in Tunisia during the period

1970-2010. The data are from a World Bank Publication (2013a). We first highlighted the stylized facts related to CO_2 emissions in Tunisia. Next, we explored the nature of the relationships between these three economic and environmental variables.

3. CO2 EMISSIONS IN TUNISIA: SOME STYLIZED FACTS

The distribution of GHG emissions shows that carbon dioxide (CO_2) emissions represent the predominant share of emissions currently in Tunisia at about 98%. The rest is divided between methane (CH_4) and nitrous oxide (N_2O) emissions. The CO_2 emissions are mainly generated through energy use from the carbon contained in the fuels. This explains the preponderance of this gas in all emissions from the energy sector and its use as an indicator of GHG emissions in the majority of empirical studies, to analyze the relationship between energy consumption and GHG emissions. The observation of the Tunisian case showed a marked volatility of emissions during the period 1970-2010. This volatility is presented in Figure 1.3 below. Figure 1.2 below shows the growth rate of CO_2 emissions per capita, energy consumption per capita and GDP per capita over the period 1970-2010.

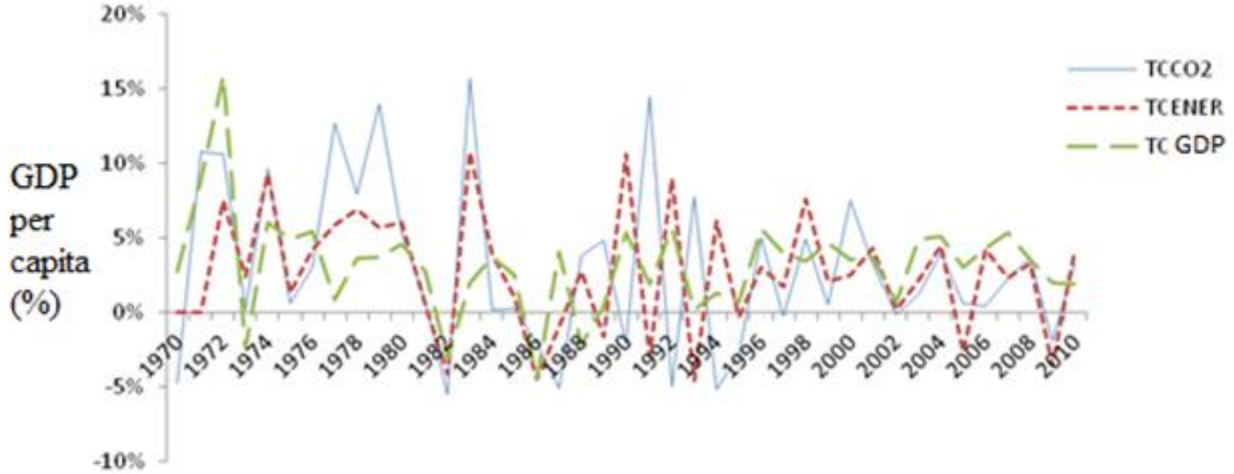

Figure-1.2. growth rate of CO_2 emissions per capita, per capita energy consumption and GDP per capita in Tunisia (1970-2010).
Source: World Bank data and author's calculations.

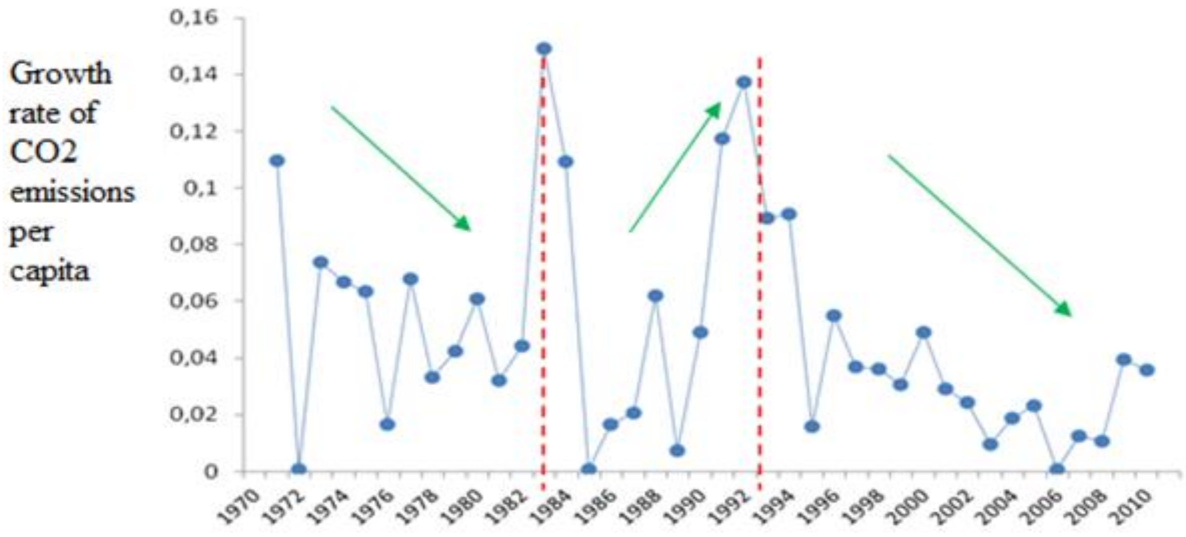

Figure-1.3. Volatility over time of the growth rate of CO_2 emissions per capita in Tunisia (1970-2010).
Source: World Bank data and author's calculations.

The long-term observation of the growth of CO_2 emissions is characterized by a loosening of volatility. Three sub-periods alternating between a downward trend following a bullish phase mark this volatility.

- Phase 1 (1970-1982): The easy access to fuels following the national production of petroleum products, coupled with a phase of intensive industrialization during the 1970s justifies the strong demand for energy and consequently the emissions of CO2 that result. Nevertheless, this rate has fallen as a result of the notable effects of the two oil crises on the consumption of energy. In the absence of an energy control policy in the country during this period, the explanation of the decrease in the volatility of CO2 emissions could be due to the decline in the pace of growth aggravated by the debt crisis of the decade the '80s..
- Phase 2 (1983-1993): Energy consumption is recorded at a high rate (11%) in 1983 and 1992 showing a strong demand due to the accelerated growth rate of energy-intensive industrial sectors such as BMCGI4 and the mines. This is illustrated in Figure 1.2 which shows that this increase in energy consumption is coupled by an increase in carbon emissions of 15%. Indeed, the economy had seen a revival of growth, the result of structural reforms that Tunisia has adopted since the mid-1980s. This resulted in positive and increasing CO2 emissions during this period.
- Phase 3 (1994-2010): But since then, the country's debt crisis in the 1980s has weighed heavily on the pace of growth, energy consumption and carbon emissions. We can see this by the decreasing rate of volatility in the growth rate of CO2 emissions with a recovery in 2006 in Figure 1.3 and the declining rates of these three indicators[5] in Figure 1.2. Another observation draws our attention: since 2002, the rate of economic growth has exceeded in value, those of energy consumption and CO2 emissions. This may explain why the two primary and final energy intensities began to decrease reaching respectively 0.31 and 0.24 toe / 1000 billion of GDP in 2008 compared to 0.42 and 0.32 toe / 1000 billion of GDP respectively in 1985. This decline seems to be related to the consequences of the energy control policy pursued by the country since 1986 (creation of the ANME6) and to the structural change in the production structure of the Tunisian economy which has resulted in the decline in the relative share of energy-intensive industries in favor of lower-energy industries and services.

4. RELATIONSHIP BETWEEN ENERGY CONSUMPTION AND POLLUTION IN TUNISIA: DESCRIPTIVE ANALYSIS

In Tunisia, crude oil resources declined remarkably from 1996 and Tunisia was forced to import more than half of its petroleum product requirements. An energy deficit has emerged, and since 2001, Tunisia has moved from being a surplus country to being a net importer of energy as can be seen in Figure 1.4. This deficit makes the country's economy vulnerable to increased energy expenditure and to the pressure on public finances, given the subsidization of energy products.

4 Building Materials, Ceramics and Glass Industries

5 From the mid-nineties, energy resources are barely able to cover the national demand for energy. This is attributed to the slowdown in domestic production of petroleum products in the face of ever-increasing energy consumption. These resources have also declined in 1996, and it is the development of the off-shore gas field of Miskar in the Gulf of Gabes in the same year that increased reserves.

6 Energy Control Agency called ANME today: National Agency for Energy Management

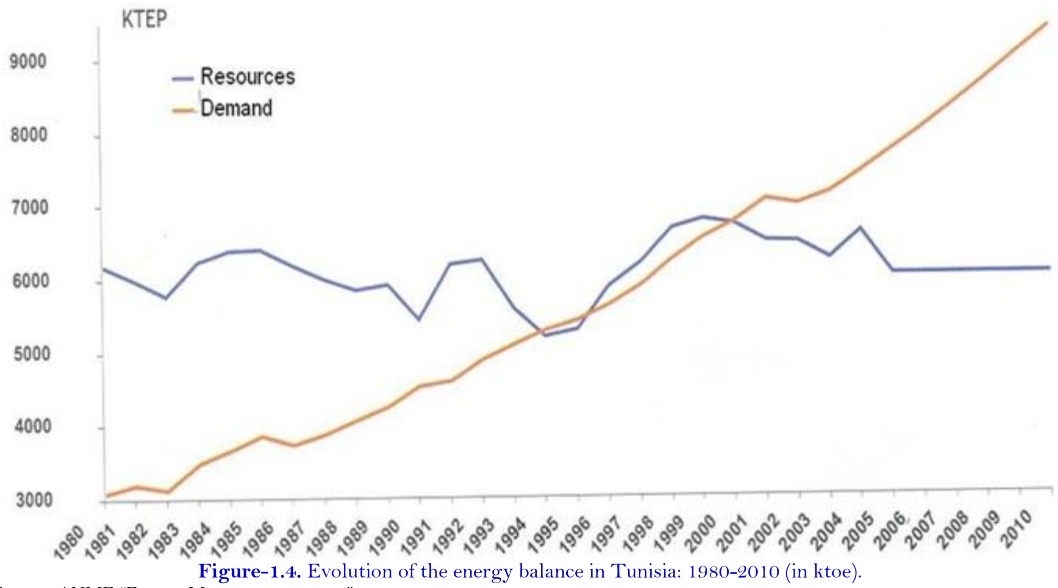

Figure-1.4. Evolution of the energy balance in Tunisia: 1980-2010 (in ktoe).

Source: ANME "Energy Management agency".

The relative share of petroleum products in the demand for primary energy has gradually declined in favor of natural gas, which has seen its share exceed 50% since 2009 (ANME). Primary energy consumption increased from 3889 ktoe in 1985 to 7900 ktoe in 2008 as shown in Figure 1.4, reaching around 10400 ktoe in 2013. Most of the natural gas, around 80%, is intended for the production of electricity.

The energy deficit has steadily widened to 2532 ktoe in 2013 Figure 1.5. It is likely to worsen to reach 3 million toes in 2014 (ANME).

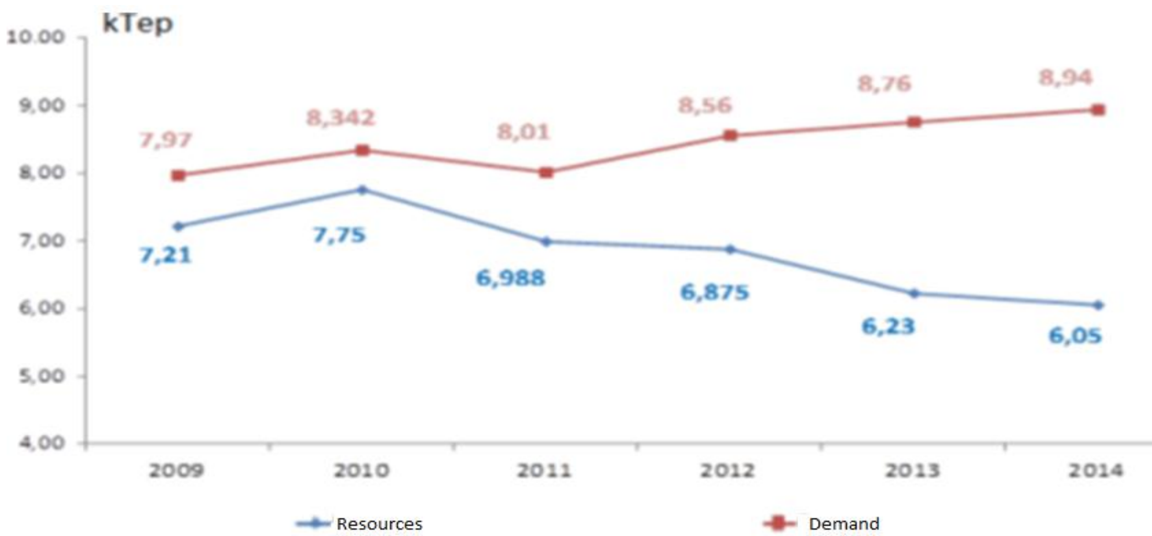

Figure-1.5. Evolution of the energy balance in Tunisia: 2009-2014.

Source: ANME "Energy Management agency".

The following Figure 1.6 traces the evolution of fuel consumption (petroleum products, natural gas and coking coal), electricity consumption and final energy consumption by end-users in Tunisia during the period 1985-2008.

Recent ANME data reveal that final energy consumption reached 7100 ktoe in 2013 against 7200 ktoe in 2010, a 1% decrease over the entire period 2010-2013.

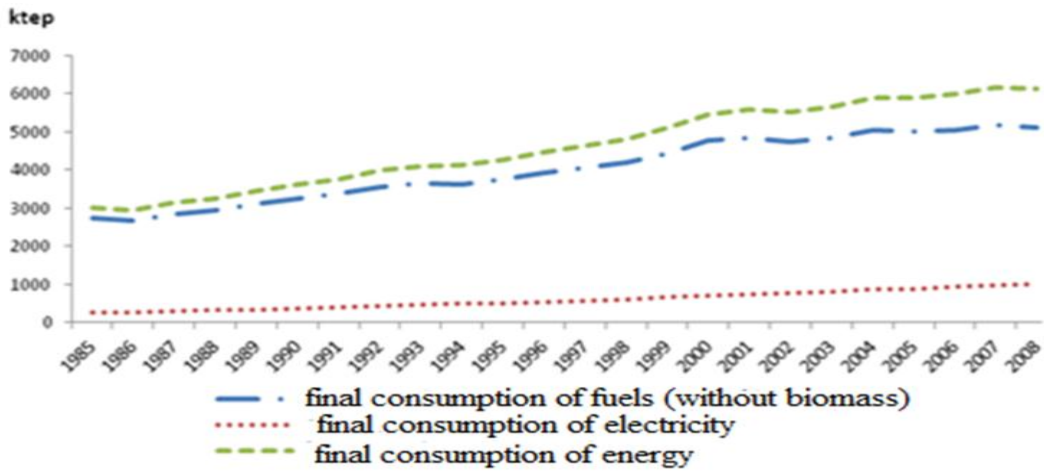

Figure-1.6. Final energy consumption in Tunisia: 1985-2008.

Source: Calculations and representation of the author from the ANME database.

Concerning the evolution of the product-specific structure of final energy consumption from 1985 to 2013, we note that petroleum products remained the most consumed fuel in Tunisia, but that natural gas and electricity also saw their shares doubling with both reaching 20% of the total final energy consumed in 2013 compared to only 10% and 9% in 1985 as shown in Table 1.2.

Table-1.2. Final Energy Consumption by Product (% of total).

	1985	2008	2013
Petroleum products	78%	63%	60%
Natural gas	10%	21%	20%
Coking coal	3%	0%	0%
Electricity	9%	16%	20%

Source: ANME.

GHG emissions from energy come from two sources: energy combustion and fugitive emissions. These emissions have steadily increased since 1990, in relation to economic development and related energy consumption. Thus, total discharge increased from 20.5 million tons in 1990 to 30.3 million tons in 2013 (ANME, 2014) representing an average annual growth of 3.3% over the 1990-2013 period but 2.6% between 2000 and 2013. Emissions of carbon dioxide, the dominant component of these emissions, increased from 18.8 million tons to about 29 million over the same period, representing an average growth rate of 2.4%. When compared to the population, the per capita ratio has changed between 1.6 and 2.5 tons during the period 1990-2010. The main sources of these emissions are energy industries, transportation and manufacturing industries as shown in Table 1.3 below.

Table-1.3. Emissions from combustion by sector.

KTECO2	1985	1990	1995	2000	2008	Variation 1985-2008*
Energy Industries	3 229	4 100	4 752	6 565	8 943	4,52%
Manufacturing industries	3 285	3 801	3 649	4 563	4 795	1,65%
Transport	3 127	3 548	4 425	5 713	6 248	3,18%
Tertiary	584	642	807	980	1 125	3,05%
Residential	1 176	1 390	1 713	1 916	2 030	2,4%
Agriculture	530	678	929	1 089	1 048	3,0%
Total	**11 930**	**14 159**	**16 276**	**20 826**	**24 189**	**3,12%**

Source: ANME Database.

Nevertheless, the statistics reveal that there is a decoupling between economic growth and GHG emissions due to energy in Tunisia between 2000 and 2013. Indeed, the average annual growth rate of GDP over this period is 3.8% and only 2.6% for GHG emissions over the same period (ANME, 2014).

The international comparison shows that Tunisia had a per capita CO2 emission value in 2011 that was lower than the global average but above the average for Africa and Asia Table 1.4.

Table-1.4. CO2 emissions per capita in 2011: International comparison.

TCO2/ inhabitant	OECD	Non-OECD Europe and Euroasia	Middle East	World	China	Non-OECD of America	Tunisia	Asia	Africa
	9,95	8,08	7,7	4,5	5,92	2,36	**1,98**	1,51	0,93

Source: AIE/WEO 2013.

5. IS THE ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS VALID FOR THE TUNISIAN CASE?

The EKC implies that at the beginning of the economic development process, the agents are not interested in the environment. When the income level meets the primary needs of the population and economy, we reach a threshold (also called the turning point) at which the agents start to worry about the environment and the trend reverses. Beyond this threshold, economic growth is accompanied by an improvement in environmental conditions and, above all, a reduction in pollution. This is called an inverted U-shaped (bell) relationship between pollution and economic development.

Grossman and Krueger (1995) concluded that the reversal of the relationship between economic growth and environmental degradation was not only empirically confirmed, but that it was mainly concerned with middle-income countries. They estimated by the generalized least squares method the following reduced form model:

$D_{it} = y_{it}\beta_1 + y_{it}^2\beta_2 + y_{it}^3\beta_3 + \tilde{y}_{it}\beta_4 + \tilde{y}_{it}^2\beta_5 + \tilde{y}_{it}^3\beta_6 + X_{it}\beta_7 + \varepsilon_{it}$

With D_{it}, the indicator of environmental degradation, here the concentrations recorded by the stations; y_{it}, the real per capita income of country i at date t; $\tilde{y}it$, the average per capita real income of the previous three years; X_{it}, a vector of control variables and εit, the error term.

In the literature:

- $\beta_1 > 0$ means that there is a scale effect of the economic activity,
- $\beta_2 < 0$ represents the effects of composition and technique and gives the inverted U shape.
- β_3 can detect more complex curve types. Thus, if $\beta_3 > 0$, we can speak of "re-coupling" between pollution and income beyond a certain threshold giving the relationship the appearance of an "N".

The income level per capita corresponding to the turning point of the curve (the "peak") is obtained by deriving the equation with respect to y.

$y^* = -\beta_1 / 2\beta_2$

Several authors have recently been interested in checking the environmental Kuznets curve for Tunisia.

The periods studied, the environmental indicators, the variables introduced to correct the bias of the omitted variables and the econometric techniques used differ from one study to another. For Tunisia, some confirm the existence of the EKC (Shahbaz *et al.*, 2013) while others do not (Mhenni, 2005; Farhani and Ben Rejeb, 2012). Fodha and Zaghdoud (2010) confirmed the inverted U shape of the EKC for the SO2 indicator but reversed it for carbon emissions.

Tunisia is a developing country whose average annual GDP per capita has risen sharply since the 1970s, rising above $3,000 (constant 2005) during the decade 2000-2010. It would theoretically be in the phase where growth should be accompanied by a degradation of the environment. It is true that the axes of growth in the country evolved from one decade to another passing from capitalism under control from the beginning of the 1970s until the mid-1980s, to the reform process based on a policy of economic liberalization that started with the structural adjustment plan put into effect since 1986. However, Tunisia started in the 1980s to put in place a long-term energy management policy based mainly on four instruments: institutional, regulatory, financial and fiscal.

Mhenni (2005) sought to analyze the nature of the country's U-shaped relationship during 1980-1997. He used several indicators of environmental pollution for this purpose and, drawing on the work of Selden and Song (1994) and Grossman and Krueger (1995) he estimated the following equation for Tunisia:

$IVAR_j = constant + \beta_1 GNP + \beta_2 (GNP)_2 + \beta_3 Dummy_{87} + \mu$

Where IVARj represents one of the indices of the quality of the environment selected. GNP is the gross national product per capita calculated in 1995 dollars. $Dummy_{87}$ represents a variable that takes the value 1 from 1988, which corresponds to the date of the implementation of the Structural Adjustment Program, the SAP, and zero before that date.

The author concluded that the model is satisfactory for both variables industrial emissions of CO2 and consumption of fertilizers. The shape of the curve is quadratic. This means that a severe degradation of the environment follows the increase of the GNP in the country. According to the author, Tunisia is still in Phase 1 of environmental decline of the EKC.

We aimed to contribute to the work on Tunisia by exploring the nature of this relationship for this middle-income country to see if the environmental Kuznets curve was verified and at what threshold. To this end, we empirically looked for the nature of the links between economic evolution, measured by the level of GDP per capita, and the quality of the environment estimated here by CO2 emissions during the period 1970-2010. We introduced a dummy variable that reflects the effect of adopting an energy control policy in the country. And we estimated by the ordinary least squares (OLS) method the following Equation 1:

$$CO2_t = Constant + \beta_1 (GDP_t) + \beta_2 (GDP_t)_2 + \varepsilon_t \qquad (1)$$

Where CO2 is CO2 emissions per capita, GDP is gross domestic product per capita. Then we estimated by the same OLS technique, a second equation where we introduced a variable dummy which represents a variable which takes the value 1 from 1986 which corresponds to the date of creation of the agency of control of the energy and the setting in place of a policy of energy control in the country.

$$CO2_t = Constant + \beta_1 (GDP_t) + \beta_2 (GDP_t)_2 + \beta_3 D_{86} + \varepsilon_t \qquad (2)$$

The level of GDP per capita that corresponds to the turning point of the curve is obtained by deriving the equation with respect to GDP such as:

$GDP^* = -\beta_1 / 2\beta_2$ (3)

Table-1.5. Model estimation - Dependent variable: CO2 per capita.

	1	2	3	4
Constant	-1.133 (-7.255)	-1.001945 (-5.157)	-0.691 (-4.367)	-0.591 (-3.135)
GDP	0.001 (14.073)	0.001768 (10.331)	0.001745 (8.652)	0.001 (6.532)
GDP^2	-2.55E-07 (-9.517)	-2.36E-07 (-7.461)	-4.23E-07 (-6.020)	-3.83E-07 (-4.711)
D86		0.054150 (1.129)		0.058 (0.972)
R^2	0.96	0.96	0.92	0.92
Adjusted R-squared	0.96	0.96	0.92	0.92
D-W	0.99	0.98	2.04	1.98
Sum squared resid	0.309	0.299	0.227	0.221
Period	1970-2010	1970-2010	1970-2010	1970-2010
Estimation method	OLS	OLS	OLS	OLS

The results of these estimates revealed a problem of autocorrelation of errors (Durbin-Watson statistic <1). This is illustrated in the models (1) and (2) of Table 1.5 above. We solved this problem with the Cochran-Orcutt method. The model has been corrected for $\rho = 0.4$ and the results of the new estimates are shown in columns (3) and (4) of the same Table 1.5 above.

We noticed that the Durbin-Watson model (3) without the dummy variable was better than the model (4) that incorporated the dummy variable. Similarly, the parameters of the model (3) were in accordance with the theory with $\beta 1 > 0$ and $\beta 2 < 0$. This confirmed the existence of an inverted U-shaped EKC.

The value of GDP* = $- \beta 1 / 2\beta 2$ = $2062,647 is much lower than the $8,000 found by Selden and Song (1994) characterizing the turning point of the inverted U curve. Tunisia is therefore positioning itself in a phase where an increase in GDP is accompanied by a further deterioration of the environment Figure 1.7.

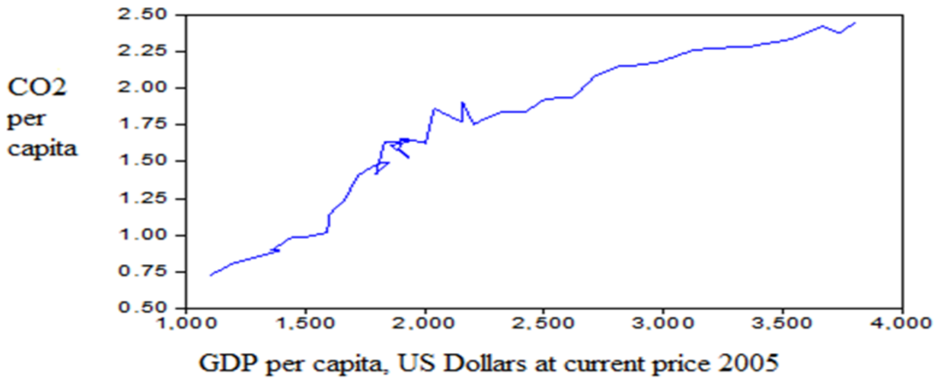

Figure-1.7. The EKC in Tunisia.

Source: ANME "Energy Management Agency".

6. VARIABLES CONTRIBUTING TO THE EXPLANATION OF CO2 EMISSIONS

This section identifies the factors that contribute to increasing pollutant emissions from energy consumption. The analysis of the causes of CO_2 emissions is often based on the likely effects of economic, energy and demographic variables.

6.1. The change in Activity and Economic Structure

Economic activity is valued by GDP while economic structure is measured by the contribution of each sector to economic activity (value added of the sector / GDP). Figure 1.8 below shows the overalland sectoralvariation of GDP.

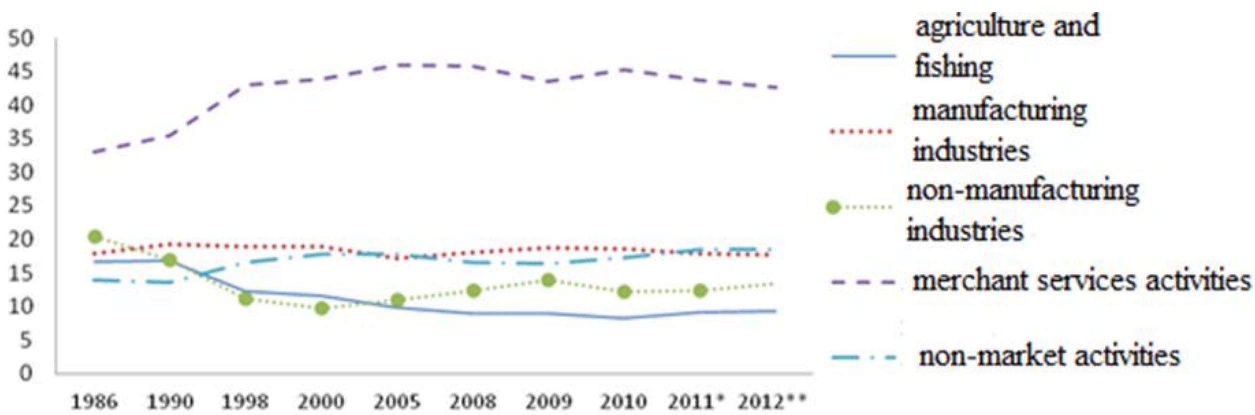

Figure-1.8. Structure of value added by sector of activity.

Source: Ministry of Development and International Cooperation (MDCI).

Tunisia has recorded GDP growth between 4.5% and 5% over the last two decades (1990 to 2010), with a shift to services and to a lesser extent to industry. In 2012, the services sector accounted for nearly 60% of GDP, compared with 37.5% in 1989.

6.2. The change in Energy Intensity

The drop in energy intensity means that energy content in GDP is steadily decreasing in Tunisia as shown in Table 1.6 below.

Table-1.6. Average annual change in energy intensity and average value per period.

Period	Average annual evolution (%)	Average values (toe/1000 dinars)
1982-1986	-0,1%	0,403
1987-1991	0,8%	0,417
1992-1996	-0,6%	0,419
1997-2001	-0,2%	0,408
2002-2006	-3,5%	0,359
2008-2011	-5,9%	0,309
201-2012	+3,30%*	0,308

Source: ANME This increase is due to the value of 2012 which reached 0.313 toe / 1000 TND against 0.303. toe / 1000TND in 2011.

Primary energy intensity decreased by 25% between 1990 and 2013 (ANME) from 0.416 toe / 1000DT to 0.313 toe / 1000DT. Several factors may explain this decrease in energy intensity, such as:

- The contribution of energy efficiency policy, especially in the industrial sector.
- Structural changes in the economy (a strong increase in the contribution of energy-intensive industries to GDP and the growing tertiary sector of the Tunisian economy).
- Modernization of the industrial apparatus, mainly through the industry upgrading program.
- The strong progression of gas in the energy structure, leading to technological choices favoring greater energy efficiency, particularly in the electricity sector (better combustion efficiency of natural gas plants, introduction of the combined cycle).

The international comparison in Table 1.7 below shows that Tunisia is close to the world average but must make further efforts to reach the OECD average for primary energy intensity.

Table-1.7. Primary Energy Intensities in 2011: International Comparison in toe / 1000 USD (2005).

	Non-OECD of Europe and Eurasia	China	Africa	Middle East	Asia	Non-OECD of America	World	Tunisia	OECD
Primary energy intensity	0,74	0,6	0,55	0,51	0,47	0,26	0,25	**0,24**	0,14

Source : AIE/WEO 2013.

An analysis of energy indicators carried out in 2013 revealed that at the global level, this indicator has decreased by 1.6% per year on average between 1990 and 2006. Nearly two-thirds of the countries at the international level have lowered their energy intensity. 40% of countries register a regression of more than 1% per year, and a quarter of them a decline of more than 2% per year.

In another step, and to compare the national consumptions, we calculated the final energy intensity, defined as the ratio between the final consumption of the energy of each sector and its added value as shown in Figure 1.9 below. It measures the efficiency with which energy resources are used in each sector.

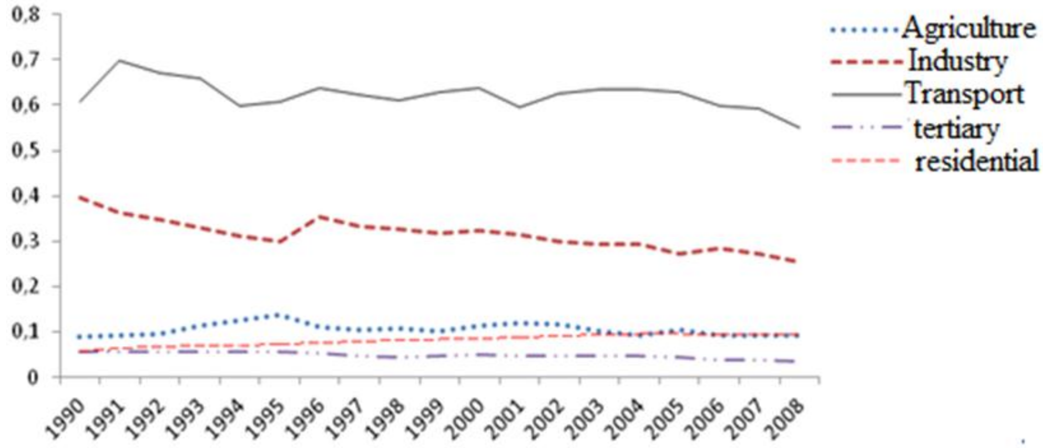

Figure-1.9. Energy intensity by sector in Tunisia, 1990-2008.
Source: ANME data, author's calculations.

Our calculations showed that the transport sector recorded the highest intensity relative to other sectors of the Tunisian economy during the entire period of 1990-2008, followed by manufacturing industries. The transport sector had an energy intensity higher than 0.6 during the '90s and even if it decreased to reach 0.55 toe per thousand Tunisian dinars in 2008, this sector remained the most energy-intensive sector relative to other sectors end use of energy. As for the manufacturing industries, they recorded a continuous decline in their final intensity to reach 0.25 toe / MDT in 2008 against 0.39 toe / MDT in 1990, a 36% decline during this period. The latter have therefore demonstrated a better control of their energy intensity.

A second observation drew our attention: unlike the other sectors, the residential sector recorded an increasing intensity throughout the period studied with a slight stability at the end of the period. This can be explained by the increase in the share of this sector in total fuel consumption which more than doubled from 11% in 1985 to 26% in 2008, and more than 30% in 2013 as shown in Table 1.8 below. This showed the importance of energy for this sector and encourages the authorities to diversify and intensify energy control measures in residential buildings.

Table-1.8. Share of each sector in total final fuel consumption in Tunisia.

%	1985	2008	2010	2011	2012	2013
Industry	38%	27%	28,2%	27,2%	28,6%	29,2%
Transport	38%	35%	32,5%	31,7%	30,3%	28,5%
Residential and Tertiairy	18%	33%	33,6%	35,4%	35,5%	36,4%
Agriculture and fishing	6%	5%	5,8%	5,7%	5,6%	5,9%

Source: ANME.

A third finding was that energy resources seem to be used more efficiently by all the sectors studied, especially during the 1990-2008. It should be noted that manufacturing industries were the only ones that have maintained a steady decline in their final intensity from 1990 to 2008 (with the exception of 1996). This can be explained by the desire of companies to adopt technologies that make it possible to use energy more efficiently and thus improve their energy productivity.

6.3. The change in the Pollution Coefficient

The variation in the pollution coefficient, also known as the CO2 intensity effect, is defined by the ratio between CO2 emissions and energy consumption. This indicator measures the quality of the fuels used and their change. This coefficient is also called the char effect (Andreoni and Galmarini, 2012).

We measured the volatility of emissions from fuels consumed by the period (petroleum products and natural gas) in order to capture changes in the quality of energy used by different sectors and their change over time as can be seen in Figure 1.10 and 1.11below.

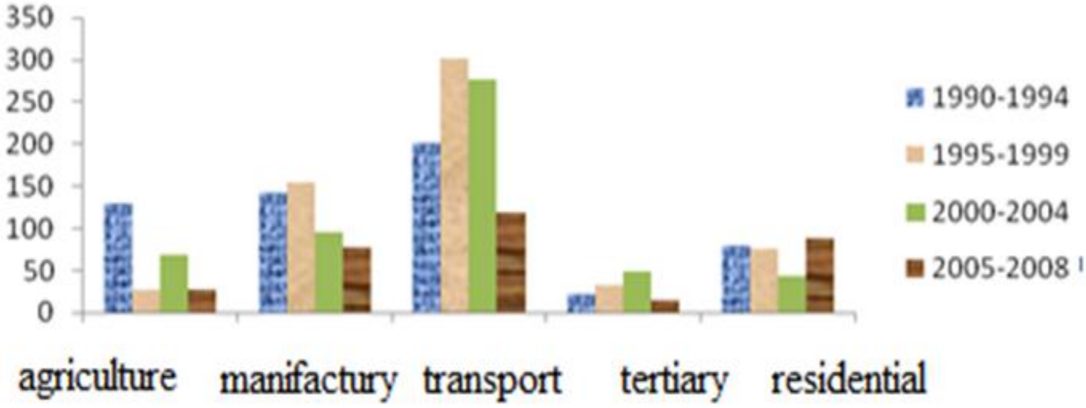

Figure-1.10. Volatility of carbon emissions due to the use of petroleum products by sector in Tunisia (in kte CO2).
Source: ANME data and author's calculations.

We noted that the transport sector was the most polluting sector relative to the other end sectors during all the sub-periods if we considered the use of petroleum products, followed by the manufacturing industries and then the residential sector as shown in Figure 1.10.

If we considered emissions from natural gas, we noted that it was the industrial sector that emitted more than the transport and residential sectors with increasing volatility, especially during the 2000s as shown in Figure 1.11.

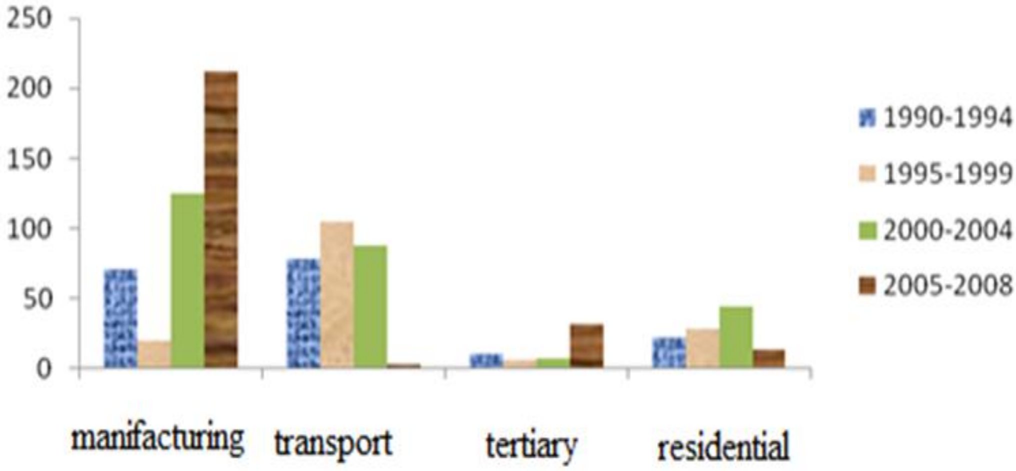

Figure-1.11. Volatility of carbon emissions due to the use of natural gas by sector in Tunisia (in kte CO2).
Source: ANME data and author's calculations.

6.4. The change of the Energy Mix

The production of primary energy is mainly based on crude oil and natural gas in the country with45% and 39% respectively of the total primary energy production in 2013 (ANME). But while the share of crude oil had declined and was offset by an almost identical increase in natural gas, biomass had been allocated a share of 15% in 2013 and renewable energies a rather modest share of 1%.

However, forecasts indicated that energy production would fall by 5% per year against an increase in demand of 6% per year. This is why we seek to diversify and optimize the use of different energy sources, particularly electricity generation. Giving a larger share to renewable energies is one of the objectives of the Tunisian authorities.

6.5. The evolution of the Population

Since the beginning of the 1960s, Tunisia's economic and social development policy has been based on the idea that demographic pressure is a constraint that must be mastered in order to meet the basic needs of the population in the areas education, health and employment. The family planning program has yielded significant results in

Tunisia since the rate of population growth has decreased from 3% in 1966 to 0.94% in 2004. Thus, the population did not exceed 10 million in 2005 and the number of inhabitants did not reach 12 million in 2013 as shown in Figure 1.12.

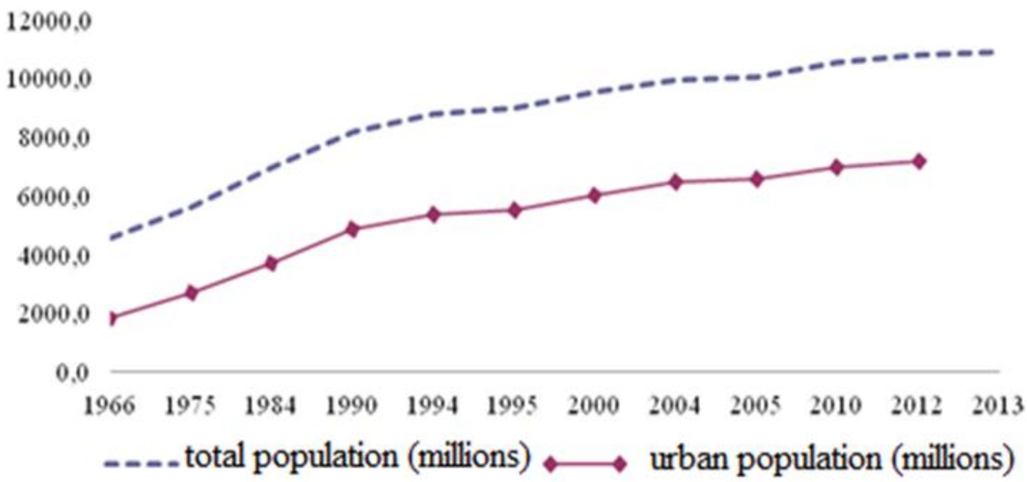

Figure-1.12. Evolution of the population in Tunisia 1966-2013[7].

Source: National Institute of Statistics.

The mastery of demography has also transformed the age pyramid in the country. Thus, the under 15 age group represented almost half of the population in the mid-1960s, and then increased to 27% of the population in 2004 and even fewer (20%) from 2010. The 15-59 age groups have steadily increased to 68% in 2010: this reflects an aging of the Tunisian population.

7. CONCLUSION

Our observation of the Tunisian case showed that there was a marked volatility of CO2 emissions during the period 1970-2010. We tried to check the U shape of the Kuznets curve for the case of Tunisia during 1970-2010, and our results showed that the country is in a phase where an increase in GDP is accompanied by a deterioration of the environment. We have analyzed the Environmental Kuznets Curve for the case of Tunisia, and we have found that the country has not yet reached the threshold of development from which economic growth is accompanied by a reduction of pollutant emissions.

We then sought to identify factors that contributed to increasing pollutant emissions from energy consumption. We noted six factors: change in activity, change in economic structure, change in energy intensity, change in pollution coefficient, change in energy mix, and population change. We conducted a long-term analysis of the growth of CO2 emissions in the case of Tunisia by describing its volatility and indicating the stylized facts that mark this environmental indicator over time. This analysis was followed by a descriptive study of the relationship between energy consumption and environmental degradation in Tunisia over the last decades. Then we checked the U-shape of Kuznets for the country. Finally, we outlined the factors that contributed to increasing pollutant emissions from energy consumption.

Funding: This study received no specific financial support.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

7 This graph is borrowed from Abdessalem (2014).

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