Research article

Environmental Kuznets curve hypothesis in a financial development and natural resource extraction context: evidence from Tunisia

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Abstract: This study investigates empirically the Environmental Kuznets Curve hypothesis within a financial development and natural resource extraction context for aggregate and sectoral carbon dioxide (CO_2) emissions in Tunisia. Using annual time-series data covering the period 1971–2016 it is found that financial development increases aggregate CO_2, CO_2 emissions from the transport sector, and CO_2 consumption from liquid fuel but reduces CO_2 emissions from manufacturing and construction as well as the residential and building. Natural resource extraction exerts upward pressure on CO_2 emissions from the manufacturing and construction sector as well as from the consumption of gaseous fuels whiles the contrary is found for CO_2 emissions. The existence of the EKC hypothesis or otherwise within the context of financial development and natural resources extraction is found to be dependent on the source of CO_2 emissions in Tunisia. The findings among other things imply the enforcement of stringent environmental laws that ensure environmental quality amidst natural resources extraction and financial development.

Key words: Environmental Kuznets curve; Tunisia; natural resource; CO_2; financial development

JEL codes: C13, D53, O13, O16, O44, P28, Q01

Abbreviations: lnCO: Log of aggregate carbon dioxide emission; lnGDP: Log of GDP per capita; lnGDP2: Log of the square of GDP per capita; lnNRE: Log of natural resource rent; lnFINDC: Log of financial sector domestic credit; lnFINPS: Log of financial credit to private sector; lnPOP: Log of total population; lnCOMC: Log of carbon dioxide emission from manufacturing industries and construction; lnCOL: Log of carbon dioxide emission from liquid fuel consumption; lnCOS: Log of carbon dioxide emission from solid fuel consumption; lnCOG: Log of carbon dioxide emission from gaseous fuel consumption; lnCOR: Log of carbon dioxide emission from residential buildings and commercial and public services; lnCOT: Log of carbon dioxide emission from transport sector

1. Introduction

Over the past decades, the life threatening global warming and climate change have gained global attention. Emissions of green house gases (GHGs) particularly, carbon dioxide have been identified to constitute a greater share of the causes of global warming and climate change. To tackle the problem of climate change, it has been argued there is the need to reduce the emission of GHGs otherwise long-run economic growth and national security will be negatively affected (White House 2016). In an effort towards this direction, discussions and subsequent empirical studies have been conducted on the relationship between economic activities (economic growth/development) and GHGs especially carbon dioxide. Earlier studies including Grossman and Krueger (1991), Grossman and Krueger (1995) and Stern et al. (1996) among others suggested an inverted U-shape relationship between economic activities and green house gases. It is this phenomenon that Panayotou (1993) has termed as Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis posits that, an initial stage of economic development is associated with a higher level of environmental degradation and pollution until a certain stage of economic development will gradually improve environmental quality. Since the seminal paper on the EKC hypothesis by Grossman and Krueger (1991) a plethora of studies have scrutinized the hypothesis with varied outcomes (Kwakwa and Adu, 2016). To deepen the understanding of the drivers of carbon dioxide emissions, subsequent studies have explored the effects of variables including financial development within the EKC framework (Ozatac et al., 2017; Pata, 2018; Nasreen and Anwar, 2015). However, the possible effect of a variable like natural resource extraction on the quality of environment has not received much attention. The objective of this study is to test the EKC hypothesis in a context of financial development and natural resource extraction using Tunisian data.

Tunisia offers an interesting case to study on many grounds. The country has been regarded as one of the economic success stories on the African continent for decades and its ability to register a GDP growth rate of 3.7% in 2010 after recovering from the 2009 economic crisis has been praised (African Development Bank [AfDB] 2011). It has also been one of the fastest growing economies in the Middle East and North Africa region (Fodha and Zaghdoud, 2010). Although the political disturbance in 2011 hampered economic growth in the country, government has targeted a 5 percent economic growth in 2020 (Laghmari and El-Tablawy, 2017). By recording 1.9% economic growth rate in 2017 as against 1% in 2016 and 1.1% in 2015 (World Bank 2018) there is an indication that efforts by the government seems to be working, although quite slow, towards the 2020 target. Nevertheless, the country is faced with environmental issues especially air pollution which reduction is paramount objective (M'raihi et al., 2015). For instance, Tunisia's carbon dioxide emission (kt) in 1971 which stood at 4,213.385 increased to 9,834.894 in 1981. Ten years later, carbon dioxide emission (kt) stood at 15,489.41 and as at 2014 the figure was almost doubled to 28,829.95 (World Development Indicator

(WDI) 2017). This environmental challenge may thwart the country's ability to ensure healthy lives and promote well-being for all at all ages as contained in the Sustainable Development Goals (SDGs)[1].

It appears from the above that expansion in the country's economic activities is not in tandem with the quality of environment as the EKC hypothesis would hint and that attention has not been paid to environmental implication of the country's economic growth. Since EKC hypothesis suggests economic growth will eventually reduce pollution it is imperative to test whether that holds in the case of Tunisia. Such a move is ultimately necessary for informed policy formulation to deal with the improper waste disposal and pollution challenges confronting Tunisia (Africa and the World 2018). Theoretically, the effect of financial development on environmental quality is not straight forward. The development of the financial sector helps to reduce carbon dioxide via the promotion of technological innovation (Mahalik and Mallick, 2014; Chang, 2015), reduction in the cost of environmental protection related investments (Stijn and Feijen, 2007) and the adoption of energy efficient technologies (Bello and Abimbola, 2010). On the other hand, financial development may increase emission of carbon dioxide by increasing energy consumption for economic activities (Mahalik and Mallick, 2014; Chang, 2015). Following the economic adjustment programme in 1986 and economic policies in the 2000s, Tunisia has witnessed a more liberalized financial sector (Ayadi and Mattoussi, 2014). The environmental effect of this development in the country is however not well known.

Moreover, the potential harmful effect of natural resource extraction (Kwakwa et al., 2018) in Tunisia has not been explored. The country has its fair share of the gifts of nature as it is endowed with natural resources such as phosphates, petroleum, zinc, lead and iron ore. According to AZO mining (2012) Tunisia is the second and fifth leading producer of phosphate in Africa and the world respectively. It also has shale formations with an estimated 23 trillion cubic feet of recoverable gas and 1.5 billion barrels of recoverable oil (Energy Information Administration 2014). Extraction of the country's natural resource also contributes to the growth process of the economy. For instance between 1975 and 1985 the share of total natural resource rent to the country's economic growth ranged between 8.9% and 9.5%. The share again increased from 1.32% in 1998 to 11.17% in 2008 (WDI 2017). In the light of the above, this study is carried out to investigate the environmental Kuznets' curve hypothesis in a context of financial development and natural resource extraction.

This study is similar to recent studies that have econometrically estimated the environmental effect of natural resource and financial development. Key among such studies are Kwakwa et al. (2018), Balsalobre-Lorente (2018) and Osabuohien et al. (2014) that have analyzed the role of natural resources in carbon dioxide emission; and Adom et al. (2018) and Maji et al. (2017) that focused on the role of financial development in carbon dioxide emission. However, the point of departure from this study is that Kwakwa et al. (2018) investigated the effect of natural resource on per capita carbon emission; Balsalobre-Lorente et al. (2018) examined the effect of natural resource on per capita carbon emission within the EKC hypothesis; and Osabuohien et al. (2014) tested the EKC hypothesis (using per capita carbon dioxide emission) for oil and non-oil producing without estimating the effect of natural resource extraction on carbon emission. In this study, we extend the literature further to analyze the effect of natural resource extraction on per capita carbon dioxide emission and emissions from various source and sectors of Tunisia within the EKC hypothesis. The sectors analyzed in this study are carbon emission from solid, liquid and gas sources; CO_2 emission from residential buildings and commercial and public services; CO_2 emission from manufacturing and construction sector; and from

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[1]See all the SDGs at https://www.un.org/development/desa/disabilities/envision2030.html.

transport sector. This differentiates the current study from Adom et al. (2018) and Maji et al. (2016) that analyzed the emission effect of financial development on CO_2 emission but excluded some of the emission sources used in this study. Moreover, their analyses were not within the EKC framework. Then again, to the best of our knowledge, this is the first study to test the emission effect of financial development and natural resource extraction within a single framework, the EKC framework.

The study thus makes five main contributions to the literature. In the first place, it is the first study to examine the effect of natural resource extraction on carbon dioxide emission in Tunisia as previous studies in the Tunisian literature have not explored the natural resource extraction-carbon dioxide emission nexus for the country. For instance, Chebbi et al. (2009) examined the emission of trade and economic growth in Tunisia, while Fodha and Zaghdoud (2010) scrutinized the effect of income on carbon dioxide emission and sulfur dioxide for the country. In his work on Tunisia, Akin (2014) examined the impact of foreign trade, energy consumption and income on CO_2 emissions. Also, M'raihi et al. (2015) analyzed the effect of transportation issues on Tunisia's carbon dioxide emission; Sghari and Hammami (2016) investigated the linkages between economic growth, energy consumption and carbon emission in Tunisia; and Jebli and Belloumi (2017) assessed the causal relationships between combustible renewable and waste consumption and carbon dioxide emissions in Tunisia. The recent works on Tunisia by Amri (2018) tested the effect of total factor productivity, ICT, trade, financial development, and energy consumption on carbon dioxide emissions while Sekrafi and Sghaier (2018) tested the effect of corruption on carbon dioxide emissions.

The second contribution is that the study tests for the EKC hypothesis for various sources of carbon dioxide emission. Thirdly, the paper examines the effect of natural resource extraction on carbon dioxide emissions from various sectors. Further, the study analyses the effect of financial development on carbon emissions within the EKC framework. Lastly, the study becomes the first to test the EKC hypothesis with financial development and natural resources in single framework.

The rest of the paper proceeds as follows: section 2 does a review of the related literature; section 3 focuses on data and methodological issues; section 4 is on the analysis and discussion of the results; and section 5 concludes the study with policy implication.

2. Literature review

This section reviews the related literature on the theoretical arguments and empirical evidence on income-environment relationship, financial development-environment relationship and natural resource extraction-environment relationship.

2.1. Income-environment relationship

Theoretically, it is argued that economic growth increases with environmental degradation until a certain turning point beyond where economic growth reduces environmental degradation and pollution levels (Grossman and Krueger, 1993). This suggests that there is an inverted U-shaped relation between economic growth and environmental degradation. This observation is referred to as the Environmental Kuznets curve (EKC) hypothesis in the literature. The proposition under the EKC hypothesis is that economic growth has scale, composition and technical effects. Thus, in the early stage of development, the use of basic and inefficient technology in production degrades and pollutes the environment (i.e scale effects). As the economy transits to industrial

production, and then to the service sector, economic growth induces investment in sector that pollute less (i.e composition effect). Finally, at higher levels of economic growth there is a structural change towards more high-technology and service-oriented sector (i.e technical effect) (Hussen, 2005) which gradually reduce environmental degradation.

Based on this concept, there have been extant empirical studies on the nexus between economic growth and environment degradation but with mixed and inconclusive results. Some studies confirmed the EKC hypothesis with an inverted U-shaped relationship between economic growth and environmental degradation (Shahbaz et al., 2012; Tiwari et al., 2013; Alam et al., 2016; Al-Mulali and Ozturk, 2016; Kwakwa and Adu, 2016; Sinha and Sen, 2016; Aboagye, 2017; Boopen and Vinesh, 2011; Shahbaz et al., 2018; Sinha and Shahbaz, 2018; Dong et al., 2018). In contrast, other studies reported non-existence of EKC, arguing that increase economic growth reduces environmental quality (Nassani et al., 2017; Dogan and Ozturk, 2017; Pal and Mitra, 2017; Sinha et al., 2017; Balsalobre-Lorente et al., 2018; Onafowora and Owoye, 2014). The above studies are a mixture of panel or a group of countries studies and single country studies. For instance, Alam et al. (2016) examined the effect of economic growth on per capita carbon dioxide emissions in China, India, Brazil and Indonesia and confirmed the EKC hypothesis. Also, Al-Mulali and Ozturk (2016) relied on panel data for 27 advanced countries in their studies which confirmed the presence of EKC hypothesis. Kwakwa and Adu (2016) also found the EKC hypothesis holds for sub-Saharan African countries. Similarly, Sinha and Sen (2016) validated the existence of EKC hypothesis for BRIC countries. Contrarily, Pal and Mitra (2017) and Sinha et al. (2017) reported an N-shaped relationship between economic growth and environmental degradation for India and China and N-11 countries respectively. Recent evidence from BRICS countries by Nassani et al. (2017) revealed a U-shaped relationship between economic growth and CO_2 emissions, which is a departure from the EKC hypothesis. Tiwari et al. (2013) and Shahbaz et al. (2012) validated the existence of EKC hypothesis for India and Pakistan respectively. In addition, Sinha and Shahbaz (2018) and Aboagye (2017) confirmed the EKC hypothesis for the Indian and Ghanaian economy respectively. Also, Dogan and Ozturk (2017) did not establish the EKC hypothesis for the USA.

2.2. Financial development-environment relationship

In the economic literature on financial development, views on the relationship between financial development and environmental degradation are mixed. On one hand, financial development promotes technological innovation which helps to reduce CO_2 emissions (Mahalik and Mallick, 2014; Chang, 2015; Sadorsky, 2011). Further, Tamazian et al. (2009), Jalil and Faridun (2011) and Shahbaz et al. (2013) have argued that financial development may improve environmental quality when firms are encouraged by their financiers (i.e. financial institutions) to invest in eco-friendly technology which reduces CO_2 emissions. Contrary to the above views is the idea that financial development may increase emission of carbon dioxide by increasing energy consumption for economic activities. This is because financial development allows individuals and firms to obtain capital which enables them afford energy consumption appliance thereby increasing carbon emissions (Mahalik and Mallick, 2014; Chang, 2015). Motivated by this fact, various empirical studies have examined the nexus between financial development and environmental degradation with mixed results. Empirically, Ziaei (2015) using European, East Asian and Oceania countries data reported positive effect of shock market development on aggregate CO_2 emissions. In a related study

in BRICS countries, Nassani et al. (2017) also found that financial development increases nitrous oxide emissions. Contrarily, Dogan and Seker (2016) reported that financial development leads to a significant decrease in CO_2 emissions in 23 renewable energy countries. Also Xiong and Qi (2016) found evidence to prove that financial development decreases carbon dioxide emissions in China.

Unlike these studies which focused on aggregate emissions, other studies attempt to examine the relationship between various sources of carbon dioxide emissions and financial development. For instance, Alper and Onur (2016) investigated the relationship between financial development and sources of carbon dioxide emissions in China and found financial development to decrease CO_2 emissions from liquid fuel consumption, residential and commercial buildings and public services. Maji et al. (2017) in a related study on the impacts of financial development on sectoral carbon dioxide emissions in Malaysia found financial development increases CO_2 emissions from the transportation and gas sectors but decreases CO_2 emissions from the manufacturing and construction sector. In Ghana, Adom et al. (2018) assessed the drivers of potential and actual CO_2 emissions and reported that financial development reduces actual and potential CO_2 emissions in the transport, residential building, commercial and public and other sectors.

2.3. Natural resource extraction-environment relationship

Kwakwa et al. (2018) have noted that natural resource extraction has several implications for the quality of the environment. Continuous extraction of natural resources put greater pressure on the environment and can contribute to environmental degradation. This could be observed through the increase use of inputs that need energy for extraction and also through indiscriminate disposal of toxic waste into the environment (Hilson, 2002). Some studies have been conducted to examine the relationship between natural resource extraction and environmental degradation. For instance in Ghana, Fatawu and Allan (2014) and Hilson (2002) explore the effect of natural resources extraction on the environment (i.e land, water and air) and argued that extraction of resources degrades the environment. However, these empirical studies did not employ any econometric tool, but were mainly descriptive. In order to fill the knowledge gap and produce more robust results some scholars have used various econometric techniques to investigate the natural resource extraction-environmental degradation nexus. For instance, Kwakwa et al. (2018) examined the effect of natural resources extraction on carbon dioxide emissions in Ghana within the Stochastic Impacts by Regression on Population, Affluence and Technology framework. They observed that there is a long-run positive relationship between carbon dioxide emission and natural resource extraction. Balsalobre-Lorente et al. (2018) investigated the EKC hypothesis in the European Union (Germany, France, Italy, Spain and United Kingdom) by incorporating additional variables including natural resource abundance. They reported that natural resources improve environmental quality. However, the above studies failed to analyse the effect of natural resource extraction on carbon dioxide emission from various sources and sectors which this paper sought to do.

3. Method and data

This section deals with the methodological issues of the study under sub sections of theoretical and empirical specification, econometric method, and data source and description.

3.1. Theoretical and empirical model

Motivated by the EKC hypothesis, the base line model that expresses the relationship between environmental degradation and economic development is depicted as;

$$CO_{2t} = GDP_t * GDP_t^2 * \varepsilon_t \tag{1}$$

where CO_{2t} is carbon dioxide emission which represents environmental degradation, t represents time, * denotes the multiplication sign and ε is the stochastic error term. *GDP* is income and GDP^2 is income squared to depict a quadratic relationship.

Given that the aim of this study was to examine the effect of financial development and natural resource extraction on per capita carbon dioxide emission and emissions from various source and sectors of Tunisia within the EKC hypothesis, the base line equation (1) is extended to include financial development (FIN), and natural resource extraction (NRE). Owing to the rising population pressure in the country the study controlled for population growth. Population growth is a major driver of environmental degradation (O'Niel et al., 2012; Raupach et al., 2007). It increases production and consumption of resources which put pressure on the environment that may reduce the quality of the environment (Casey and Galor, 2017; Yeh and Liao, 2017; Behera and Vishnu, 2011). To ascertain the existence of EKC hypothesis for the various sectors in Tunisia, carbon dioxide emission from solid fuel consumption, liquid fuel consumption, gas fuel consumption, residential buildings and commercial and public services; manufacturing and construction sector; and transport sector were taken into consideration. This therefore modifies equation (1) to equation (2):

$$CO_{2it} = GDP_t * GDP_t^2 * FIN_t * POP_t * NRE_t * \varepsilon_t \tag{2}$$

where i, represents the CO_2 emissions from different sources and sectors. Also, assuming a Cobb-Douglas production function with output produced measured as carbon dioxide emissions from various sources and sector and the drivers of environmental degradation as inputs, the production function is expressed as;

$$CO_{2it} = A * GDP_t^{\beta_1} * GDP_t^{2\beta_2} * FIN_t^{\delta} * POP_t^{\gamma} * NRE_t^{\phi} * e^{\varepsilon_t} \tag{3}$$

where A is the technological change. Taking a log transformation of equation (3) gives equation (4);

$$\ln CO_{2it} = a_i + \beta_1 \ln GDP_t + \beta_2 \ln GDP_t^2 + \delta \ln FIN_t + \gamma \ln POP_t + \phi \ln NRE_t + \varepsilon_t \tag{4}$$

where α_i= lnA and the variables are as previously defined.

3.2. Econometric method

In time series analysis the first step in estimating equation (4) is to test for stationarity of the variables. This test is crucial since an analysis with non-stationary variables generate spurious results. In this study, the stationarity (i.e. unit root) property of the selected variables in equation (4) was

examined using the famous Augmented Dickey-Fuller (ADF) and the Phillips-Perron tests developed by Dickey and Fuller (1979) and Phillips and Perron (1988). Since the ADF and PP approaches can be biased in the presence of structural breaks in the time series, the Zivot and Andrews (ZA) (1992) test which is capable of providing robust results in the presence of structural break is employed to complement the results of ADF and PP tests.

After the stationarity test, the long-run relationships of the variables were examined using the cointegration test based on the Engle-Granger and the Phillips-Ouliaris Tests. Lastly, the drivers of carbon dioxide emissions from equation (4) was estimated using the Park (1992), canonical cointegration regression (CCR). The CCR is superior over other techniques such as the Johansen (1988) and Johansen and Juselius (1990) approach since unlike the Johansen approach, the CCR approach produces efficient results when the variables are integrated of different orders. It is this reason that the CCR was chosen.

3.3. Data source and description

The annual time-series data of selected indicators covering the period 1971–2016 used for study were accessed from WDI, (2017). One of the dependent variable, aggregate carbon dioxide (CO) is measured by carbon dioxide emissions (kt). The various polluting sources used as dependent variables are as follows: emissions from transport sector (% of total fuel combustion) [COT], solid fuel consumption (kt) [COS], gaseous fuel consumption (kt) [COG], liquid fuel consumption (kt) [COL], manufacturing industries and construction (% of total fuel combustion)[COMC], and residential buildings and commercial and public services (% of total fuel combustion)[COR]. GDP per capita is used to denote income while natural resource extraction is proxied by total natural resource rent (% GDP). For sensitive analysis, financial development is measured by financial sector domestic credit (% GDP) [FINDC], and financial credit to private sector (% GDP) [FINPS]. Finally, population is measured as total population.

4. Results and discussion

This section discusses the results of the study under sub sections stationary and cointegration test, structural test, long-run determinants of total energy consumption and energy intensity, and asymmetric analysis of the drivers of total energy consumption and energy intensity.

4.1. Results for stationarity test and cointegration test

The results of the stationarity test have been reported in Table 1a and Table 1b below. From both ADF and PP tests it is seen that total carbon emission, population, CO_2 emissions from liquid fuel consumption and CO_2 emissions from gas consumption are intergrated of order zero while the remaining variables are integrated of the order one. The general indication is that all the variables are stationary either in levels or at first difference and that their usage in the estimation process will not lead to any spurious regression result. The results for the Zivot and Andrews (ZA) test which deals with structural breaks in unit root test is also embarked upon to confirm the stationarity of the variables and reported in Table 1b. The results also confirm that all the variables are stationary and hence their usage in the estimation process will not produce spurious results.

The cointegration results using the Engel-Granger and the Phillips-Ouliaris tests are reported in Table 2. One can infer from Table 2 that the variables are cointegrated and thus, a long-run relationship exists among the series. In that case income, natural resource extraction, financial development and population can be said to be the long-run forces of carbon dioxide emissions in Tunisia. It must be noted that to avoid inundating the work with many tables, the cointegration results that used Domestic credit to private sector (lnFINPS) which also confirmed a long-run relationship among the variables has not been reported here.

Table 1a. ADF and PP Unit root test results.

Series	Augmented Dickey-Fuller test		Phillips-Perron test	
	At level	At first difference	At level	At first difference
lnCO	−3.6852***	NA	−4.5328***	NA
lnGDP	−1.5727	−6.7033***	−1.5767	−6.7395***
lnNRE	−2.8225	−6.2382***	−2.7826	−6.2462***
lnFINDC	−1.3216	−5.9116***	−1.4091	−5.9116***
lnFINPS	−1.7271	−6.1250***	−1.7271	−6.1187***
lnPOP	−2.7568*	NA	−3.9670***	NA
lnCOMC	−2.0857	−7.2563***	−1.9932	−8.6307***
lnCOL	−4.1082***	NA	−3.5116**	NA
lnCOS	−0.5021	−6.5447***	0.1535	−6.5233***
lnCOG	−7.3921***	NA	−4.2727***	NA
lnCOR	−0.8187	−6.3451***	−0.9309	−6.3475***
lnCOT	−1.8054	−5.8069***	−1.9876	−5.7429***

Note: ***, ** and * denotes 1%, 5% and 10% level of significance, respectively; NA means Not applicable.

Table 1b. ZA unit root test results.

Variable	ZA test statistic	Breakpoint	Model
lnCO	−4.2989*	1981	Break in trend
lnGDP	−5.0460***	1986	Break in intercept
lnNRE	−3.2270**	1991	Break in intercept
lnFINDC	−4.4389**	1981	Break in intercept
lnFINPS	−4.6699**	1981	Break in intercept
lnCOMC	−4.4728***	2003	Break in intercept
lnCOL	−3.1057***	2005	Break in trend
lnCOS	−2.9027***	2005	Break in intercept
lnCOG	−5.3047***	1984	Break in intercept
lnCOR	−2.2179*	1988	Break in intercept
lnCOT	−3.7528**	1991	Break in trend
lnPOP	−1.7287**	1985	Break in intercept

Note: ***, ** and * denotes 1%, 5% and 10% level of significance, respectively.

Table 2. Cointegration results.

Series	Engel-Granger test		Phillips-Ouliaris test	
	tau-statistic	z-statisitc	tau-statistic	z-statisitc
lnCO, lnGDP, lnGDP2, lnNRE, lnFINDC, lnPOP	−4.4922	−33.5423**	−5.2561	−28.1403
lnCOT, lnGDP, lnGDP2, lnNRE, lnFINDC, lnPOP	−4.8412*	−24.6337	−5.0457*	−29.9417*
lnCOS, lnGDP, lnGDP2, lnNRE, lnFINDC, lnPOP	−5.6637**	−32.3454**	−4.4190	−30.5265**
lnCOG, lnGDP, lnGDP2, lnNRE, lnFINDC, lnPOP	−6.1582**	−32.2210*	−6.1415**	−37.8074**
lnCOL, lnGDP, lnGDP2, lnNRE, lnFINDC, lnPOP	−5.1746**	107.6385	−5.4274**	−30.7054*
lnCOMC, lnGDP, lnGDP2, lnNRE, lnFINDC, lnPOP	−4.8612*	−25.8558	−5.0889*	−31.4308*
lnCOR, lnGDP, lnGDP2, lnNRE, lnFINDC, lnPOP	−5.6781**	−29.7198*	−5.7421**	−28.9719

Note: ***, ** and * denotes 1%, 5% and 10% level of significance, respectively.

4.2. Long-run determinants of CO_2 emissions

This section reveals the driving forces of aggregate CO_2 emissions and sectoral CO_2 emissions with emphasis on financial development and natural resource extraction within the standard EKC framework.

4.2.1. Drivers of aggregate CO_2 emissions

The results for the effects of income, financial development, natural resource extraction and population on aggregate CO_2 emissions are reported in Table 3. It is seen from Table 3 that population, income, and natural resource rent unambiguously increase carbon emissions in both models where financial development is measured as Domestic credit by financial sector and Domestic credit to private sector whiles for income square, the contrary is established. The above results further generally suggest a confirmation of the EKC hypothesis for Tunisia using per capita CO_2 since income has a positive coefficient while income square has a negative coefficient. This implies that, for Tunisia, aggregate CO_2 emissions could rise but it is expected to fall after a certain level of per capita income. These findings on CO_2 emissions and the EKC hypothesis are broadly consistent with Alam et al. (2016), Kwakwa and Adu (2016), Aboagye (2017), Shahbaz et al. (2018), Al-Mulali and Ozturk (2016), Aboagye (2017), Aboagye and Kwakwa (2016), Kwakwa et al. (2014) but contrasts with Nassani et al. (2017), Pal and Mitra (2017), Balsalobre-Lorente et al. (2017), Onafowora and Owoye (2014).

The significance of the financial sector development was sensitive to measurement as domestic credit provided by the financial sector exerts significant increasing effects on carbon emissions in model 1 while in model 2 domestic credit to private sector is not significant. The positive coefficient of the domestic credit by financial sector indicates that at the economic-wide

level, the improvement of the financial sector has rather expanded economic activity without the promotion of technological innovation to help reduce carbon dioxide emission which is in line with Xiong and Qi (2016), Dogan and Seker (2016), Maji et al. (2017) and Adom et al (2018), but it is in sharp contrast to Sadorsky (2011), Ziaei (2015) and Nassani et al. (2017). The differences in the outcome can be attributed to the differences in the socio-economic conditions that characterises the different countries of studies. The insignificant coefficient of credit to private sector suggests it has not exerted any impact on carbon dioxide emission. Also, an increase in natural resource rent is accompanied by an increase in CO_2 emissions. The positive relationship established confirms the argument and empirical evidence provided by Kwakwa et al. (2018). In addition, population is also found to cause CO_2 emissions levels to increase in Tunisia. This is not surprising since population growth put pressure on the environment through the increase in production and consumption and that may reduce the quality of the environment (Casey and Galor, 2017; Yeh and Liao, 2017; Behera and Vishnu, 2011).

Table 3. Results for aggregate CO_2 emissions.

Variable	Model 1		Model 2	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Population	1.450255***	6.100089	1.555061***	6.030289
Per capita Income	5.907481**	2.632478	5.017499**	2.136285
Per capita income square	−0.343618**	−2.531700	−0.290486**	−2.039672
Natural Resource Rent	0.031051*	1.712717	0.040432**	2.201462
Domestic credit by financial sector	0.217061*	1.946924		
Domestic credit to private sector			0.122374	1.024480
Constant	−39.6476***	−5.951828	−37.2162***	−5.115056
R−squared	0.992598		0.991826	
Adjusted R−squared	0.991598		0.990722	

Note: ***, ** and * denotes 1%, 5% and 10% level of significance, respectively.

4.2.2. CO_2 emissions from transport sector

The results for CO_2 emissions from transport are reported in Table 4. The findings are that population growth reduces CO_2 emissions from transport in both Model 1 and Model 2, while income square and natural resource rent are respectively found to increase and reduce emission in the transport sector in Model 2 alone. Also, Domestic credit to private sector is found to increase emission in this sector (Model 2). The deductions are that the EKC hypothesis does not hold in the transport sector for Tunisia and that an increase in income will lead to an increase in carbon emission from the transport sector. This suggests that income growth does not promote energy efficiency in transport sector probably because of high demand for private transport services that may be associated with higher income. Adom et al. (2018) in particular have argued that there are no scale economies in the provision of environmental services in the transportation sector.

Also obtaining a positive and significant effect of the domestic credit to private sector suggests that an increase in the domestic credit to private sector expands the private sector activities that rely on transport services which consumes energy hence, an increase in the carbon emission. This is similar to

the findings of Adom et al. (2018). An increase in the natural resource rent is seen to reduce CO_2 emissions from transport sector which contradicts Kwakwa et al. (2018). This could mean that the extraction industry in Tunisia is energy efficient regarding their transportation system.

Table 4. Results on CO_2 emissions from transport.

Variable	Model 1		Model 2	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Population	−0.763408**	−2.683053	−0.9413***	−3.555101
Per capita Income	−2.915171	−1.082054	−3.293168	−1.373369
Per capita income square	0.220368	1.352137	0.248325*	1.707743
Natural Resource Rent	−0.030903	−1.409460	−0.036312*	−1.905635
Financial sector Domestic credit	0.215	1.622736		
Domestic credit to private sector			0.309961**	2.532879
Constant	23.74***	2.967994	27.4719***	3.703641
R-squared	0.616		0.659542	
Adjusted R-squared	0.564		0.613534	

Note: ***, ** and * denotes 1%, 5% and 10% level of significance, respectively.

4.2.3. CO_2 emissions from solid fuel consumption

Regarding CO_2 emissions from solid fuel consumption it is seen from Table 5 that the coefficients of income and income square cast doubt on the existence of EKC hypothesis for CO_2 emissions from solid fuel consumption. Thus, the results show that initial income of level will reduce CO_2 emissions from solid fuel consumption but beyond a certain level, CO_2 emissions from solid fuel consumption will increase with income. This means a U-shape relationship contrary to an inverted U-shape relationship exist between income and CO_2 emissions from solid fuel consumption. This outcome could have very stern implications for Tunisia as the country attempts to grow out of environmental degradation (particularly, CO_2 emissions from solid fuel consumption) through growth policies. It is of no wonder that the country continues to struggle in the management of solid waste despite some impressive economic growth. Although this finding contradicts the evidence from Shahbaz et al. (2018), Al-Mulali and Ozturk (2016) and Aboagye (2017), it is possible to attribute this to the lack of effective commercial solid waste management as it is the case in some African countries (Adom et al. 2018).

Moreover, while the domestic credit provided by financial sector has significant reduction effect on CO_2 emissions from solid fuel consumption (Model 1), the domestic credit to the private sector has insignificant effect (Model 2). Although Tunisia has almost 100 percent access to electricity, it is possible that domestic credit provided by financial sector enables the reduction of solid fuel consumption thereby reducing the carbon dioxide emission unlike domestic credit to the private sector hence the insignificant effect. Growth in natural resource rent and population are noted to have insignificant effect on CO_2 emissions from solid fuel consumption. Probably it is because the extractive sector and the general population do not rely heavily on solid fuel since electricity is readily available.

Table 5. CO_2 emissions from solid fuel consumption.

Variable	Model 1		Model 2	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Population growth	0.603759	0.232674	−0.392793	−0.138591
Per capita Income	−89.61089***	−3.633739	−78.66482***	−3.077985
Per capita income square	5.369901***	3.599532	4.708890***	3.039889
Natural Resource Rent	−0.033092	−0.163843	−0.128273	−0.622384
Financial sector domestic credit	−2.579177**	−2.066195		
Domestic credit to private sector			−1.659703	−1.238591
Constant	375.2048***	5.136208	342.0804***	4.347345
R-squared	0.908597		0.899658	
Adjusted R-squared	0.896245		0.886099	

Note: ***, ** and * denotes 1%, 5% and 10% level of significance, respectively.

4.2.4. CO_2 emissions from gaseous fuel consumption

The results in Table 6 shows the nexus between financial development and CO_2 emissions from the consumption of gaseous fuel and it is marked that both financial development variables do not have any statistically significant impact on the level of CO_2 emissions from gaseous fuel consumption. This suggests that neither financial sector domestic credit nor domestic credit to private sector has translated into the consumption of gas fuel in ways that can reduce the associated CO_2 emissions. It is either such credits to the private sector involved in provision of gas fuel have not developed technologies sophisticated enough to influence a fall in CO_2 emission per every consumption of gas fuel or that there are some consumption efficiency constraints in the country. Further, while an increase in natural resource rent is associated with an increase in CO_2 emissions from gas fuel consumption, population growth does not influence the level of CO_2 emissions from solid fuel consumption. Thus, the extraction of natural resources in Tunisia is partly responsible for CO_2 emissions from gaseous fuel consumption probably because of its usefulness as fuel for heavy duty vehicles that are used in the sector. This supports Kwakwa et al. (2018). It is surprising that population does not influence CO_2 emissions emanating from gas fuel consumption since the country is still gas fuel dependent. Perhaps, it could be that the rise in population does not necessarily lead to the consumption of gas fuels that can potentially cause CO_2 emissions. Also, the EKC hypothesis is robustly established in both models. This stands to reason that policies intended to stimulate growth into the Tunisian economy would help the country grow out of CO_2 emissions from gaseous fuel consumption. Thus, higher income levels translate into economies of scale in the provision of environmental services in gaseous fuel reliant sectors of the Tunisian economy.

4.2.5. CO_2 emissions from liquid fuel consumption

Table 7 reveals how CO_2 emissions emanating from liquid fuel consumption is influenced by income, financial development, natural resource extraction, and population growth. The CO_2 emission from liquid fuel consumption is found to increase as natural resource extraction and population increase. Evidently, neither of the two financial development variables influences CO_2 emissions emanating from liquid fuel consumption. Hence, financial development does not systematically affect

CO_2 emissions from liquid fuel consumption, an indication that financial development cannot enhance the technical process of production in sectors in Tunisia that rely on liquid fuel.

Table 6. CO_2 emissions from gaseous fuel consumption.

Variable	Model 1		Model 2	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Population growth	3.224288*	1.774664	2.443061	1.337295
Per capita Income	64.61078***	3.740075	66.02492***	3.957871
Per capita income square	−3.9828***	−3.813705	−4.056174***	−4.013623
Natural Resource Rent	0.359372*	2.537083	0.307597**	2.302715
Financial sector domestic credit	−0.265418	−0.318191		
Domestic credit to private sector			0.414780	0.505466
Constant	−304.35***	−5.965367	−301.1970***	−5.894293
R-squared	0.920756		0.920936	
Adjusted R-squared	0.910048		0.910252	

Note: ***, ** and * denotes 1%, 5% and 10% level of significance, respectively.

Table 7. CO_2 emissions from liquid fuel consumption.

Variable	Model 1		Model 2	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Population growth	0.811402*	1.936983	0.973276*	2.348847
Per capita Income	15.40278***	3.869833	15.24492***	4.005674
Per capita income square	−0.960654***	−3.989130	−0.954345***	−4.134527
Natural Resource Rent	0.025925	0.807581	0.036207	1.217351
Financial sector domestic credit	0.064943	0.330141		
Domestic credit to private sector			−0.075717	−0.39589
Constant	−65.77538***	−5.559139	−66.94230***	−5.67866
R-squared	0.949262		0.947776	
Adjusted R-squared	0.942405		0.940718	

Note: ***, ** and * denotes 1%, 5% and 10% level of significance, respectively.

Notwithstanding, given that the coefficients on income and its square are statistically significant in both models and positively and negatively signed respectively, the argument for EKC hypothesis is strongly supported for CO_2 emissions from liquid fuel consumption. This implies that higher income levels do have scale economies in the provision of environmental services in liquid fuel reliant sectors of the Tunisian economy which is in line with Shahbaz et al. (2018) and Al-Mulali and Ozturk (2016).

4.2.6. CO_2 emissions from manufacturing industries and construction

It is established from Table 8 that apart from domestic credit to private sector which tends to increase the level of degradation and natural resource extraction which increases CO_2 emissions from manufacturing industries and construction, all the other regressors are not statistically significant.

Table 8. CO_2 emissions from manufacturing industries and construction.

Variable	Model 1		Model 2	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Population growth	0.200646	0.482348	0.377576	0.930919
Per capita Income	−4.545863	−1.154909	−3.807340	−1.035137
Per capita income square	0.268583	1.127914	0.217702	0.975956
Natural Resource Rent	0.065111**	2.029145	0.068485**	2.335108
Financial sector domestic credit	−0.307130	−1.585114		
Domestic credit to private sector			−0.384700**	−2.055347
Constant	20.23917*	1.731169	15.03887*	1.320889
R-squared	0.609068		0.930919	
Adjusted R-squared	0.556239		0.120094	

Note: ***, ** and * denotes 1%, 5% and 10% level of significance, respectively.

The fact that domestic credit to private sector significantly reduces CO_2 emissions from manufacturing industries and construction is an indication that domestic credit to private sector can enhance the technical process of production in the sector and cause lower CO_2 emissions. Such an outcome corroborates the work of Maji et al. (2017) and Adom et al. (2018). Given that neither income nor its square is statistically significant, the possible existence of the EKC hypothesis in the manufacturing industries and construction sector is not supported by the evidence. This implies that higher income levels do not have scale economies in the provision of environmental services in the sector. This is actually in line with Adom et al. (2018). Again, population growth is not a driver of CO_2 emissions from manufacturing industries and construction. Since population growth underlies both manufacturing and construction activities, one would expect CO_2 emissions from the sector to be indirectly linked to population growth. The contrary effect is established here and it could be that in Tunisia, population growth may not have automatically triggered manufacturing and construction works that are CO_2 emission sensitive. Expansion in the natural resource extraction activities is found to increase CO_2 emissions from manufacturing industries and construction which could be attributed to the close linkage between the manufacturing sector and the extraction industry. Similar finding was reported by Kwakwa et al. (2018).

4.2.7. CO_2 emissions from residential buildings and commercial and public services

Finally, in Table 9 where CO_2 emissions from residential buildings and commercial and public services is used as a measure of environmental degradation we find that neither financial development variables tend to have a statistically significant impact on environmental degradation. This is an indication that financial development does not enhance efficiency in the production process of the residential buildings and commercial and public services to lower CO_2 emissions. In the work of Alper and Onur (2016) financial development is reported to have significant effect on CO_2 emissions from residential buildings and commercial and public services. Similar to the findings of Balsalobre-Lorente et al. (2018), an increase natural resource rent is noted to be accompanied by a decline in CO_2 emissions from residential buildings and commercial and public services.

Table 9. CO$_2$ emissions from residential buildings and commercial and public services.

Variable	Model 1		Model 2	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Population growth	0.336046	0.891193	0.323900	0.843545
Per capita Income	12.30251***	3.476881	13.35245***	3.880938
Per capita income intensity	−0.803859***	−3.755732	−0.869339***	−4.168531
Natural Resource Rent	−0.077857**	−2.694620	−0.083307***	−3.023377
Financial sector domestic credit	−0.287879	−1.590017		
Domestic credit to private sector			−0.248168	−1.362743
Constant	−48.40324***	−4.603157	−52.59520***	−4.935743
R-squared	0.682151		0.667201	
Adjusted R-squared	0.639199		0.622228	

Note: ***, ** and * denotes 1%, 5% and 10% level of significance, respectively.

In terms of the EKC hypothesis, given that the coefficients on income and its intensity have positive and negative signs respectively, the EKC hypothesis is said to have been supported by available evidence produced by the study. This points toward that higher income levels translates into significant scale economies in the provision of environmental services in the residential buildings and commercial and public services sector and further suggests that Tunisia could grow out of CO$_2$ emissions from residential buildings and commercial and public services with growth policies as reported in some previous studies on carbon dioxide emissions (Kwakwa and Adu, 2016).

5. Concluding and policy recommendation

The increasing amount of carbon dioxide emissions over the past two to three decades remains a major important developmental concern. These emissions, which emanate from sources such as transport, residential and commercial activities *inter alia*, have been attributed mainly to human activities that are directly linked with economic growth (activities) and development. Efforts to reduce emission of CO$_2$ including the identification of the drivers of CO$_2$ are therefore critical to guarantee healthy lives and promote well-being for all ages as enshrined in the Sustainable Development Goals.

In this study, a comprehensive analysis was conducted to understand the potential existence of the EKC hypothesis for various sources of CO$_2$ emissions within the context of financial development and natural resources extraction in Tunisia. A major observation is that the existence of the EKC hypothesis or otherwise within the context of financial development and natural resources extraction is dependent on the source of CO$_2$ emissions. The study revealed that the EKC hypothesis was robustly established for aggregated CO$_2$ emissions as well as CO$_2$ emissions emanating from the consumption of gaseous and liquid fuels. Same results is also found for the residential and building sub-sectors while for the manufacturing and construction sector and the transport sectors no evidence of EKC was found. Perhaps, a major point of concern regarding the EKC relates to the U-shaped findings on solid fuels. This implies that CO$_2$ emissions emanating from the consumption of solid fuel would increase eventually as the Tunisian economy grows larger.

Also, the effect of financial development on CO_2 emission is noted to be largely depended on the source of emission and the measurement of financial development. For instance, whiles financial sector credit to the private sector tends to increase CO_2 emissions from the transport sector and consumption of liquid waste, the converse is established for CO_2 emissions from manufacturing and construction as well as the residential and building sub-sectors of the Tunisian economy. It is worth-noting that financial sector credit to the private sector has no systematic effect on CO_2 emissions from the consumption of solid and gaseous fuels. On the aggregate level however, financial sector credit to the private sector tends to increase CO_2 emissions.

Similarly, the effect of natural resources extraction (proxied by natural resource rent) on CO_2 emission is largely dependent on the source of emission. In fact, an increase in natural resources extraction is associated with increase in CO_2 emissions from the manufacturing and construction sector as well as from the consumption of gaseous fuels whiles the contrary is found for CO_2 emissions from transport as well as the residential and building sectors of the Tunisian economy. Again, the effect of natural resources extraction on CO_2 emissions from the consumption of solid and liquid fuels is not statistically significant. But on the whole, natural resources extraction tends to increase CO_2 emissions. Thus, natural resources extraction eventually increases CO_2 emissions. In addition, population is also found to cause CO_2 emissions levels emanating from gaseous and liquid fuels consumption to increase in Tunisia. In fact, population growth in Tunisia, is also significantly linked with rise in the overall level of CO_2 emissions.

Having identified the effects of income, population, financial development and natural resource extraction on CO_2 emissions in Tunisia, the policy implications and/or recommendations from the results to help control CO_2 emissions will be imperative for Tunisia to meet the SDGs 3. Similarly, controlling CO_2 emissions will also help Tunisia towards the attainment of SDGs 11, 12, 13 and 15 given their robust connection with CO_2 emissions. A remarkable policy implication from the EKC evidence is that Tunisia must never relent in its efforts to stimulate economic expansion because the findings confirm that Tunisia can actually grow out of overall CO_2 emissions through consistent income growth. Also, from a pure policy perspective, it is implied the enforcement of stringent environmental laws that ensure environmental quality amidst natural resources extraction in Tunisia is highly imperative to minimize or possibly halt and potentially reverse the tendency of causing more CO_2 emissions. In addition, efficient and high-technology driven extraction of natural resources capable of reducing CO_2 emission is needed to reduce environmental degradation. More so, financial development has not yet enhanced the technical process of production in   the transport sector of the economy and there are no scale economies in the use of liquid fuels as far as reducing CO_2 emissions is concerned. This suggests that neither financial sector domestic credit nor domestic credit to private sector has translated into the consumption of liquid fuel in ways that can reduce the associated CO_2 emissions. Thus, credits to the private sector involved in provision of transport services and liquid fuel must develop technologies sophisticated enough to influence a fall in CO_2 emission. From a policy perspective, it should be noted that increasing population growth in Tunisia is exerting pressure on environmental quality. However, because it may be difficult to control births, a radical shift from non-renewable to renewable energy sources may be beneficial to address increasing pressures on the environment.

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Conflict of interest

The authors declare no conflict of interest in this paper.

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