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Examining the energy consumption and CO_2 emissions nexus in South Africa within the Environmental Kuznets Curve hypothesis framework

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Abstract
The increasing amount of carbon dioxide emissions over the past two decades remains a major important developmental concern. Incidentally, the growing commitment by South Africa to achieve greater economic expansion has culminated into consistent increase in economic activities which invariably entail ever-increasing energy consumption and its associated inevitable stern implications on the quality and sustainability of environment especially on CO2 emissions. Clearly, these emissions, which emanate from sources such as transport, residential and commercial activities inter alia, are attributable mainly to human activities that are directly linked with economic growth (activities) and development. Yet, to date, growth in scale of economic activities appears not to have been matched by a comparable growth in environmental protection policies. In the wake of economic expansion and industrial activities in South Africa coupled with rising mining activities, population and rapid urbanisation; energy consumption/demand could be expected to rise monotonically in the years ahead, a situation that could have severe adverse implications on the environment. In this study, a comprehensive analysis is conducted to understand the drivers of CO2 emissions and the potential existence of the EKC hypothesis for various sources of CO2 emissions in South Africa, one of Africa's industrialized economies.

Keywords: CO2 emissions; energy consumption; economic growth, Environmental Kuznets Curve; Autoregressive Lagged model; South Africa

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

1. Introduction

In recent years, South Africa's environmental pollution problems have become increasingly severe attracting wide global attention. This, according to Aboagye (2019), could be attributed to human economic activities which tend to have adverse effects on the overall ecosystem, and hence leading to severe environmental problems including global warming, floods, and adverse climate changes among others. Aboagye (2019) admits that if this deteriorating environmental quality is not well managed could lead to the loss of lives and substantial economic resources. Indeed, the quest by South Africa to expand its economy has culminated into the rise in the level of economic activities, coupled with rising industrialization and urbanization. These trends have been accompanied by increased energy consumption. This is perhaps due to the fact that almost every economic activity in the modern economy rely on energy-based resources. For instance, at the firm level, energy is needed by the transport sector, manufacturing sector, agricultural sector, mining sector,

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construction sector, and public and commercial services for their operations. Also, at the household level, energy provides a means for households to achieve basic economic needs from cooking, lighting, warming, heating and washing to entertainment. More so, the role of energy especially in the industrial, manufacturing, service and even the agricultural activities underscores its crucial link economic growth.

Zaleski (2001), Kwakwa (2012) and Kwakwa and Aboagye (2014) and Aboagye (2017) among others have also argued that energy consumption in developing economies is closely linked to deforestation, environmental degradation/pollution, adverse climate changes and depletion of natural resources. Abdulai and Ramcke (2009) further demonstrated that about a third of all energy consumed in developing countries like Ghana comes from wood, crop residues, straw and dung, which is often burned in poorly designed stoves within ill-ventilated huts and thus could be linked to environmental pollution and degradation (also see Kleemann and Abdulai, 2013; Halicioglu; 2009; Hamilton, 2000; Costantini and Martini, 2010; Costantini and Monni, 2008). Meanwhile, Aboagye (2017) suggested that against the backdrop of concerns about climate change and environmental degradation, it is imperative that an in-depth empirical examination is conducted to established clearly, the linkages that exist between energy consumption or its intensity and the environment

Furthermore, given the evidence that economic activities in many developing countries and the corresponding rise in energy use have coincided with the rise in environmental degradation (in the form of increased air and marine pollution, desertification and deforestation, loss of biological diversity and climate change), the hypothesized nexus between energy use and the environment requires a comprehensive empirical analysis to establish whether energy consumption and its intensity of use could be blamed for increased environmental degradation in South Africa. This worry is further exacerbated considering the fact that despite the large efforts made by different countries to increase the role of renewable energy, energy efficiency and energy conservation, fossil fuels still represent the dominant source of energy, representing about 80% of the total energy used globally (World Development Indicators, 2013). This worry is further heightened because 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). Furthermore, Odhiambo (2017) has consistently argued in spite of this observation, very few studies have been done in South Africa despite the fact that a number of studies have been conducted in both developed and developing countries in order to validate the environmental Kuznets curve (EKC) hypothesis.

1.1 Contribution and Originality

Although research on the relationship between energy consumption, emissions and economic growth is not new in South Africa (Kohler, 2013), no study specifically examines the nexus at the disaggregated levels. In this study we have not only examined nexus between energy consumption overall levels of $CO2$ but also $CO2$ emissions from varied sources such as $CO2$ emissions emanating from consumption of solid, liquid and gaseous fuels, $CO2$ emissions emanating from the manufacturing and construction, $CO2$ emissions emanating from the transport among others. Such critical disaggregated investigation is relevant in establishing how energy consumption contributes to specific sources of $CO2$ emissions so that policy could focus more on such linkages. This idea is consistent with Lean and Smyth (2013) observation that aggregated study aggregate are usually less useful for economic policy as they tend to lump up so many issues together and thereby hiding pertinent information (Aboagye and Nketiah-Amponsah, 2014). Foremost, the use of aggregated environmental sustainability data means that it is not possible to identify the effect of economic growth on specific $CO2$ emissions or environmental pollution (also see Sari et al., 2008). Furthermore, estimating the relationship between aggregated environmental sustainability and aggregated economic growth is of little or no value to policy makers when it comes to isolating the contribution that different components of the environmental endowment mix make to economic growth (Lean and Smyth, 2013).

2. Brief Literature Review

The bulk of extant literature on examining how the underlying drivers of environmental degradation has placed more emphasis on GDP and GDP growth. In South Africa, few studies have empirically discussed the impacts of energy consumption on environmental quality in different regions and income levels in the country. A few are discussed below.

Kwakwa, Alhassan and Aboagye (2018) 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 Kwakwa et al (2018) 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. The authors further established that 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. Finally, Kwakwa et al (2018) disclosed that 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. These findings among other things imply the enforcement of stringent environmental laws that ensure environmental quality amidst natural resources extraction and financial development.

Similarly, Aboagye (2017) noted that the past few decades have witnessed continued rise in the level of degradation and pollution in developing and emerging economies culminating into intensification of the debate on the costs, benefits and longer-term implications of growth policies on the environment has intensified among stakeholders. He was quick to highlight that although economic expansion remains paramount in policy, ensuring environmental sustainability amidst the quest to stimulate growth in Ghana has assumed a central theme in its contemporary growth agenda. Exploring annual time series data spanning 1975–2015 Aboagye (2017) examined, in Ghana, the environmental impact of economic expansion within the standard Environmental Kuznets Curve (EKC) framework. The Autoregressive Distributed Lagged bounds approach to cointegration did not confirm the existence of EKC for any of the environmental indicators in the short run but was robustly established in the long run for CO_2 emissions and energy consumption. The author admitted that this conclusion implies that, given the long-run parameters of Ghana, beyond a certain income level, degradation emanating from energy consumption and CO_2emissions will eventually fall as the country's economy expands.

Codjoe and Dzanku (2009) have also shown a negative impact of economic expansion (through the structural adjustment programme, SAP) on deforestation in Ghana through both direct and indirect channels. Sharma (2011) using a panel dataset of 69 countries examined the determinants of CO_2 emissions for the period of 1985–2005; the sample is divided into sub-panels of high income, middle income, and low income, Sharma (2011) showed that trade openness, GDP per capita, and energy consumption have a positive influence on CO_2 emissions, whereas urbanization negatively affects CO_2 emissions for all the sub-samples. However, the overall sample results reveal that urbanization, trade openness, and per capita electric power consumption negatively influence CO_2 emissions, while GDP per capita and per capita total primary energy consumption have a positive impact on CO_2emissions.

The effect of foreign trade, income and energy consumption on environmental conditions was empirically examined by Kohler (2013).Using recent South African trade and

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energy data and modern econometric techniques to investigate this nexus, the author established the existence of a long run relationship between environmental quality, levels of per capita energy use and foreign trade in South Africa and that per capita energy use has a significant long run effect in raising the country's CO2 emission levels, but higher levels of trade act to reduce these emissions. Kohler (2013) further found Granger causality tests confirm the existence of a positive bidirectional relationship between per capita energy use and CO2 emissions. While a positive bidirectional causality between trade and income per capita and between trade and per capita energy use was also established. However, the study findings suggested that South African's trade liberalisation has not contributed to a long run growth in pollution-intensive activities nor higher emission levels.

In an attempt to examine the causal relationship between economic growth and CO2 emissions in South Africa, using the data from 1970 to 2007, Odhiambo (2009) found that it is economic growth that Granger-causes CO2 emissions in South Africa. While examining the causal relationship between CO2 emissions and economic growth in Kenya, Odhiambo (2017) found that, while economic growth Granger-causes CO2 emissions in the short run, in the long run there is no causal relationship between the two variables in Kenya. Similarly, Mapapu and Phiri (2017) examined the relationship between carbon emissions and economic growth for the South African economy within the EKC framework. Guided by the quantile regression methodology which is applied to annual data covering a period of 1970 to 2014 the authors found results that indicate that very low levels of carbon emissions are most beneficial towards economic growth. Mapapu and Phiri (2017) were thus quick to admit policy must to continue to embark on energy efficiency programmes which specifically target lower levels of carbon pollution. More so, Menyah and Wolde-Rufael (2010) studied the CO2 emission-economic growth in South Africa for the period spanning 1965-2007 and using the ARDL approach to cointegration found the nexus to be positive. Shahbaz et al. (2013) found the same results for South Africa though an ARDL estimation for almost the same period but the nexus turns negative at higher levels of economic growth. Khobai and Le Roux (2017) econometrically used the VECM methods on annual time series data from 1971-2013 to estimate a positive link between CO2 emissions and economic growth in South Africa.

Kwakwa et al. (2018) empirically established that natural resource extraction has several implications for the quality of the environment and that continuous extraction of natural resources put greater pressure on the environment and can contribute to environmental degradation possibly through the increase use of inputs that need energy for extraction and also through indiscriminate disposal of toxic waste into the environment. In Ghana, Kwakwa et al. (2018), within the Stochastic Impacts by Regression on Population, Affluence and Technology framework observed that there is a long-run positive relationship between carbon dioxide emission and natural resource extraction Fatawu and Allan (2014) and Hilson (2002) actually explored the effect of natural resources extraction on the environment (i.e. land, water and air) in Ghana and argued that extraction of resources degrades the environment. Even though Balsalobre-Lorente et al. (2015) could not examined the effect of natural resource extraction on carbon dioxide emission from various sources and sectors, they sufficiently investigated the EKC hypothesis in the European Union (Germany, France, Italy, Spain and United Kingdom) by incorporating natural resource abundance and extraction for which they established that natural resources in itself improve environmental quality.

Mabey and McNalley (1999) have further argued that FDI (especially from advanced economies to developing economies) is usually accompanied by improved technology which enhances production efficiency compared to domestic investment which often uses crude production technology. Xing and Kolstad (2002) also found weak evidence for the pollution haven hypothesis which asserts that developing countries tend to utilize lax environmental regulations as a strategy to attract dirty industries from developed countries. He (2006) examined the FDI-environment nexus between 1994 and 2001 using panel data on 29 Chinese provinces' industrial SO2 emissions. Employing a system Generalized Method of Moment to study the dynamism of the environment the author reported that an increase in FDI inflows results in a moderate deterioration of environmental quality. Also, Sharma (2011) in a study on the determinants of carbon dioxide emissions among 69 countries found among other things that urbanization has a negative impact on CO2emissions in high income, middle income and low-income panels. Wang et al. (2013) found that factors such as population, urbanization level, GDP per capita, industrialization level and service level, can cause an increase in CO2 emissions.

In a related study, Abdulai and Ramcke (2009), Cole and Elliott (2001) and Dasgupta et al. (2002) found that there are signs that trade liberalization might be harmful to poor countries considering the adverse effect of trade openness on the environment of poor countries. Antweiler et al. (2001), however, found the contrary to exist. Coderoni and Esposti (2011) further established a two-way and bidirectional impact of agriculture on the environment which may help advance the "Agricultural Environmental Kuznets Curve". They point out that on the one hand, agricultural activities lead to pollution of water bodies, deforestation, loss of biodiversity, alteration of habitat and emission of Green House Gases whiles on the other hand, agriculture also provide a sink for Green House Gases, prevents and controls floods and helps in conserving biodiversity. Dogan and Turkekul (2016) used the autoregressive distributed lags (ARDL) approach in the USA during 1960–2010 and investigate the impact of energy consumption (alongside urbanization and trade openness) on carbon emissions. The outcome shows that urbanization and energy consumption negatively influence the quality of the environment, while trade openness enhances environmental quality. This study also failed to ratify the validity of the environmental Kuznets curve (EKC) hypothesis in the USA. Agras and Chapman (1997, 1999) estimate energy prices as a significant factor affecting both CO2 emissions and energy consumption despite the fact that no EKC-pattern arises. The authors place emphasis on the oil shocks in the 1970's that led to shifts in the energy mix

2.1 Some stylized facts

South Africa offers an interesting and compelling case to study on many grounds. The country has been regarded as one of the economic success stories on the African continent for decades According to available statistics, South Africa is the world's most carbon-intensive non-oil-producing developing country, measured in per capita CO2 equivalent emissions in 2010, and excluding island states (Environmental Impact Assessment, EIA, 2010). In fact, it is the largest emitter of GHGs in Africa, with 42% of the continent's emissions coming from South Africa alone. South Africa is also a bigger emitter of CO2 than all other Sub-Saharan African (SSA) countries combined (EIA, 2010).

South Africa's carbon dioxide emission (kt) in 1960 which stood at 97934.569 increased to 149763.947 in 1970. Ten years later, carbon dioxide emission (kt) was almost doubled to 280749.187 and between 2009 and 2015, average carbon dioxide emission (kt) stood at an incredibly high value of 503112.4 (World Development Indicator). South Africa's total GHG emissions in 2000 were estimated to be 461 million tons CO2 equivalent of which, 83% of emissions were associated with energy supply and consumption, 7% from industrial processes, 8% from agriculture, and 2% from waste (Department of Environmental Affairs, DEA, 2010). Evidently, the energy sector is therefore by far the largest sector responsible for emissions in South Africa at 380,988Gg CO2e with the sector's combustion of fuel producing 81% of the sector's emissions and fugitive emissions from fuel contributing the remaining 19% (DEA, 2010). Kohler (2013) has revealed that factors which have contributed to South

Africa's enormous energy related emissions include but not limited to the deliberate strategy by the pre-democratic government prior to 1994 of encouraging investment in energy-intensive industries, including aluminium and other non-ferrous metal beneficiation (the so called 'mineral-energy complex' identified by Fine and Rustomjee (1996); and the carbon-intensity of a largely (90 percent +) coal-based electricity generation base (EIA, 2010). The above evidence implies that since most of South Africa's energy needs are met by burning fossil fuels, a strong link between energy consumption and $CO2$ emissions, as well as the other forms of environmental pollution is to be expected. This fact makes South Africa vulnerable to energy consumption-induced environmental degradation and thus make energy consumption one of the most important factors that can explain the Environmental Kuznets Curve (EKC) in case of South Africa.

3. Methods and Data

3.1 Theoretical framework and model specification

The increasing amount of carbon dioxide emissions over the past two decades (Boopen and Vinesh, 2011) 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. In this study, a comprehensive analysis is conducted to understand the potential existence linkages between energy consumption and some prominent sources of $CO2$ emissions within the EKC hypothesis framework in South Africa. Understanding the linkages between sources of pollution is critical to developing a robust framework capable of estimating the energy-pollution nexus. For instance, $CO2$ is undoubtedly considered as a major component of total Greenhouse gases (GHGs) which are required to keep the Earth's temperature at levels so as to sustain life. However, increasing amounts of GHG emissions due to rise in $CO2$ emission emanating mainly from man-made activities, such as burning fossil fuels, absorb heat and cause global warming, giving rise to changes in the climate system. The Intergovernmental Panel on Climate Change (IPCC) (2007) confirmed that $CO2$ emissions are responsible for almost 60% and 80% of GHGs. These $CO2$ emissions often stem from human activities such as burning of fossil fuels, food farming, logging, mining and the manufacture of cement among others.

Also, energy consumption plays major role in the industrialization and economic expansion agenda of South Africa and this invariably led to substantial rise in the levels of energy consumption. Saboori and Soleymani (2011) revealed that the main part of the increase in $CO2$emissions can be attributed to energy consumption especially, fossil fuels burning such as oil, gas and coal. Kwakwa and Aboagye (2014) revealed that energy resources are increasingly becoming the most important and indispensable input for both production and consumption. Aboagye (2019) further argued that the role of energy especially in the industrial, manufacturing, service and even the agricultural activities underscores its crucial link economic growth. Indeed, Aboagye (2017) revealed that that energy-based resources and inputs constitute major components of industrial raw materials in both developed and developing countries and tend to be critical to sustainable economic development. However, higher level of energy consumption may promote environmental degradation more especially in countries with poor environmental awareness and concern. Thus, in the wake of rising population coupled with rapid urbanisation and industrial activities in South Africa, energy consumption/demand could be expected to increase monotonically in the years ahead. Whiles this trend is necessary for economic expansion, a rather major point of worry is the stern implications energy consumption could potentially have on the quality of the environment.

It is worth-noting at this stage that the economic analysis of the rise and fall in environmental degradation is often examined within the standard Environmental Kuznets

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Curve (EKC) which in its original formulation sought to establish a causal relationship or otherwise between economic expansion and different indicators of environmental quality particularly, CO2 emissions. In the literature, the EKC has been extensively explored in the recent years for global, regional and country level analysis of the relationship between economic expansion and environmental pollution whiles controlling for other important drivers of environmental outcomes. In 1991, the EKC hypothesis was first, based on the inspiration of Kuznets (1955) on income and inequality, introduced by Grossman and Krueger for salient environmental indicators, including the carbon dioxide emissions as well. The reasoning behind the EKC though not empirically straight forward it is intuitively appealing. It posits that in the early stages of industrialization, pollution grows more rapidly because high priority is given to increasing material output, and people are more interested in income than environment. The rapid growth inevitably leads to higher natural resources intensity of usage and thus higher emissions of pollutants, which in turn worsens the environmental conditions. However, at the later stage of industrialization and expansion in the services sector of the economy and as income increases, the willingness and ability to pay for a clean environment increases by a greater proportion than income, regulatory institutions become more effective for the environment and pollution levels starts to fall (Kijima, Nishide and Ohyama, 2010). In fact, at this later stage of higher income growth people tend to practically demand for cleaner environment. This tends to suggest that instead of being a threat to the environment, economic growth could be compatible with environmental improvements in the long run as countries could eventually “grow themselves” out of their environmental problems. Succinctly, the EKC hypothesis stated an inverted U-shape relation between various indicators of environmental quality and per capita income. Under this hypothesis, carbon dioxide emission was usually explained by linear, quadratic or cubic polynomial functions of income per capita.

Traditional models of the EKC include an indicator of environmental degradation (such as per capita CO_2 emissions, SO_2, NOx, etc) as a function of the levels and squares of per capita income. However, recent studies have shown that these models suffer from omitted variable bias as the addition of more explanatory variables also bear significant effect on environmental quality. As argued by Harbaugh, et al. (2002), there is not much theoretical guidance for the correct specification of the EKC. This means that the EKC is merely an empirical phenomenon.

Admittedly the relationship between economic growth and pollution is very complex, depending upon a host of different factors. Among these are: the size of the economy, the sectoral structure (including the composition of energy demand), the vintage of the technology, the demand for environmental quality, the level (and quality) of environmental protection expenditures. All these aspects are interrelated[2] but clearly as previously established, energy consumption has been linked various forms of environmental degradation. Thus, the nexus between energy consumption and environmental degradation is examined within the ECK model which is primarily concerned about economic growth. In its basic formulation, the standard EKC hypothesis is given as follows.

$$ENV_t = \alpha_t + \beta_1 Y_t + \beta_2 Y_t^2 + \varepsilon_t \quad (1)$$

More so, the choice of an appropriate indicator of environmental degradation is problematic. This stems from the qualitative problems encountered in measuring environmental quality (Akbostanci, et al., 2009) as well as data availability. Hence different

[2] For example, countries with the same sectoral composition of output may have a different level of emissions if their capital stocks are different in terms of technological vintage. More generally, while the study of the impact of economic growth on the environment is a significant endeavour, the analysis of feedback effects of the environment on a country wellbeing is even more challenging a task.

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indicators have been employed in empirical literature on EKC. The study employs Carbon dioxide (CO2) emissions which according to World Bank (2007) and Intergovernmental Panel on Climate Change (IPCC) (2004) account for almost 60% and 80% of GHGs. Thus, equation (1) is reformulation as seen in equation (2) below.

$$CO_{2t} = \alpha_t + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 E_t + \beta_4 T_t + \beta_5 F_t + \beta_6 U_t + \beta_7 P_t + \beta_8 K_t + \beta_9 I_t + \varepsilon_t \text{ ------ (2)}$$

Given the focus of this paper, the fundamental CO2 emission model in equation (2), is estimated both at the aggregated and disaggregated levels. The principal among the disaggregated CO2 emissions are those emanating from manufacturing, industry and construction; transport; residential building, commercial and public sector as well as CO2 emissions from the consumption of solid, liquid and gaseous fuels.

Also, in equation (2)

Y= Income | *F = Foreign Direct Investment* | *K = Capital growth*
Y^2 = Income squared/intensity | *T = Trade openness* | *I = Industry sector*
E = Energy consumption | *P = Population growth* | *ε = white noise*

3.2 Data

The study uses annual time series dataset from the World Bank from 1980-2017 on South Africa. Data on all variables are obtained from the World Development indicators (WDI) of the World Bank (see http://data.worldbank.org/data-catalog/world-development-indicators). It is important to emphasize that in the WDI, sufficient data on the relevant environmental variables (i.e. CO2 emissions, and its disaggregated components) under study hardly exist. Despite the insufficiency of data, the study has extracted considerably consistent data for variables for the study. Sample period is thus limited essentially by data availability. Further, since CO2 emissions has many dimensions, each of which may respond to energy consumption and the other included economic variables differently, the use of various measures of CO2 emissions seems very appealing.

4. Results and discussions

4.1 Unit root and Cointegration results

The results of the unit root test as shown in Table 1 indicate that most the variables are non-stationary in levels even at 10% critical levels. In particular, apart from trade openness, agriculture, and capital growth which attained stationarity at level, all the variables are integrated of order one [I (1)]. It is also worth noting that all the environmental variables are also I (1) and this justifies the use of the ARDL bounds approach to investigate the existence of cointegration relationships between environmental degradation and the energy consumption in SA.

More so, since the variables are a mixture of I(0) and I(1) with regard to their integration order, the ARDL remains the most appropriate technique to use for the analysis (Pesaran et al.2001). Also, as reported in Table A1 to A6 (See Appendix A), the ARDL bounds tests indicate that there is a consistently and stable cointegration among the variables which implies a long-run relationship exists among the variables employed for the study during the sample period. In particular, it is evident from the ARDL bounds cointegration results reported by Table A1 to A6 that both the F-statistic and W-statistic estimated are higher than their respective upper bounds at 10%. Hence, the null hypothesis of no cointegration between the various sources of CO2 emissions and energy consumption has been rejected by both statistics. This further means that energy consumption and the selected CO2 emissions variables alongside with the set of other included explanatory variables are cointegrated in the long run and that energy consumption can be treated as the 'long-run forcing' variable explaining CO2 emissions (both aggregate and disaggregate levels).

Table 1: Unit root/Stationarity Test results

	Augmented Dickey-Fuller				*Phillips-Peron*				*Remarks and Decision*
	Levels		*First differences*		*Levels*		*First differences*		
Variables	*t-stat*	*Prob.*	*t-stats*	*Prob.*	*t-stat*	*Prob.*	*t-stat*	*Prob.*	
Agg. CO2 emissions	-2.21	0.28	-8.74	0.00	-2.25	0.29	-8.19	0.00	I(1)
CO2 from RBCP	-0.08	0.98	-6.97	0.00	-0.11	-1.04	-6.45	0.00	I(1)
CO2 from MIC	-1.41	0.65	-8.77	0.00	-1.41	0.69	-8.22	0.00	I(1)
CO2 from Transport	-1.58	0.57	-7.34	0.00	-1.76	0.52	-6.88	0.00	I(1)
CO2 from LFC	-0.86	0.84	-3.40	0.03	-0.85	0.90	-9.51	0.00	I(1)
CO2 from GFC	-1.41	0.65	-8.77	0.00	-1.41	0.69	-8.22	0.00	I(1)
CO2 from SFC	-0.67	0.88	-4.05	0.01	-1.91	0.45	-10.4	0.00	I(1)
Energy consumption	-0.08	0.98	-6.97	0.00	-0.11	-1.04	-6.45	0.00	I(1)
GDP per capita	-1.41	0.65	-8.77	0.00	-1.41	0.69	-8.22	0.00	I(1)
Foreign Direct Invest.	-1.58	0.57	-7.34	0.00	-1.76	0.52	-6.88	0.00	I(1)
Trade openness	-7.06	0.00	NA	NA	-1.68	0.56	-11.4	0.00	I(0)
Capital growth	-6.67	0.00	NA	NA	-0.68	0.94	-7.60	0.00	I(0)
Population growth	-0.67	0.88	-4.05	0.01	-1.91	0.45	-10.4	0.00	I(1)
Industry (% of GDP)	-7.33	0.00	-8.77	0.00	-1.41	0.69	-8.22	0.00	I(1)
Agric. (% of GDP)	-1.81	0.65	NA	NA	-0.42	0.99	-6.88	0.00	I(0)
	Null hypothesis: Unit root				Null hypothesis: Unit root				

4.2 Discussions main findings

After long run cointegration relationships have been properly established, the study then estimates the error correction mechanism (short run analysis) and compare the results with the long run dynamics of the phenomena. The discussion for CO2 emissions, is done at two levels namely; the aggregated level and at the sub-sectors level. The study first presents the short run findings, followed by discussion of the long run findings. The final discussion is centred on the test for the existence of valid causal relationships between the various sources of CO2 emissions (including its aggregate) and energy consumption.

4.2.1 Short run evidence

In the short run as reported by Tables B1, B2 and B3 (see Appendix B), it is evident that energy consumption is found to increase the level of overall CO2 emissions as well as all the six (6) disaggregated levels of CO2 emissions. Furthermore, No evidence of EKC is established for any of environmental degradation indicators employed in the study in the short run. Perhaps, the EKC for these environmental quality indicators could be a long run phenomenon. In the short run still, natural resources extraction, industry activities and population growth are also found to increase overall CO2 emissions, as well as CO2 emissions from transport sector and while capital growth, trade expansion and FDI are not statistically significant in the short run. This implies that, in the short run capital growth, trade expansion and FDI influx are not related to CO2 emissions and its disaggregated components.

In addition to the short run evidence, valid error correction mechanisms (ECM) exist for all environmental degradation variables which is additional evidence of the existence of a long-run relationship. These speed of convergence coefficients indicate that the model does not return immediately to its equilibrium state after a shock pushes it away from the steady state. In particular, the speed of adjustment for overall CO2 emissions with respect to energy consumption is 59.4.00% as reported in Table B1. In addition, ECM of about 51.1% was observed for CO2 emissions from Residential, Commercial and Public services while for

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CO2 emissions from Transport sector, error correction coefficient of approximately 69.6% is established. Also, in the CO2 emissions from Transport sector specification, the speed of adjustment to convergence was found to be 60.3% and that for the CO2 from Liquid fuel consumption model is 59.6% as reported in Table B2 respectively. Similarly, from Table B3, the study estimated an ECM term of 74.8% and 55.4% respectively for CO2 from Solid and Gaseous fuel consumption models. Clearly, this ECM coefficient suggests that the speed of convergence is advantageously high as it would take less than two years for these nexuses to be restored should there be any distortions in the time paths

4.2.2 Long run evidence

Energy consumption and Aggregated CO2 emissions

The evidence reported in Table 2 render support to the assertion that energy consumption in South Africa is linked with rise in the overall amount of CO2 emissions. In particular, given the elasticity coefficient on the energy consumption variable, a unit growth in SA's energy consumption is accompanied by a proportionate increase in CO2 emissions, by approximately 0.20%. This finding implies that energy consumption in South Africa could be blamed for both domestic and global air pollution. This finding is broadly consistent with Kwakwa et al. (2018), Aboagye (2017), Aboagye and Kwakwa (2016), Kwakwa et al. (2014), Dlamini and Joubert (1996) Wang et al (2013), Wang et al, (2011), Managi, Hibiki, and Tsurumi (2008), Bouvier (2004). The above results further generally suggest that a valid EKC exist for South Africa's overall CO2 emissions since income has a positive coefficient while income intensity (square) has a negative coefficient. This implies that, for South Africa, overall CO2 emissions (kt) could rise but it is expected to fall after a certain level of per capita income. This evidence on CO2 emissions (kt) and the EKC hypothesis is consistent with Kwakwa et al (2018), Aboagye (2017), Aboagye and Kwakwa (2016), Kwakwa et al. (2014) but contrasts. In addition, rapid population growth and industrial growth, agricultural activities as well extraction of natural resources further tend to contribute to the rise in overall CO2 emissions in South Africa.

Table 2: Long run analysis of energy consumption and Aggregate CO2 emissions[3]

Regressors	*Coefficient*	*Standard Error*
Lag of dep. variable	0.032***	0.005
Energy consumption	0.204*	0.121
Income	0.184**	0.063
Income intensity	-0.040*	0.021
Trade openness	0.039**	0.019
Foreign Direct Investments	-0.062	0.182
Capital growth	-0.084*	0.051
Natural resource rent	0.057	0.014
Population growth	0.118*	0.063
Industry (% of GDP)	0.109**	0.044
Agric. (% of GDP)	0.104*	0.059
Constant	0.058	0.518
F - statistic	0.030	
Adjusted R^2	0.659	

[3] In all the results in Tables B1, B2, B3 and Tables from 6 – 8, Notes: *, **, *** respectively corresponds to 10%, 5% and 1% level of significance

Energy consumption and disaggregated CO2 emissions

CO2 emissions from Transport sector

Finding a positive and significant elasticity coefficient on energy consumption in the transport model suggests that an increase in energy consumption by the transport sector is responsible for the rise of CO2 emissions from Transport sector. Specifically, an elasticity coefficient of 0.382 was found for energy consumption. Thus, given that transport sector of South Africa relies extensively on energy of various forms, any expansion in the sector would imply greater energy consumption which inevitably results in increased CO2 emissions from Transport sector. In terms of the EKC hypothesis, evidence was found that the hypothesis holds in South Africa transport sector implying that an increase in income will lead to an eventual decline in carbon emission from the transport sector. This suggests that income growth supports energy efficiency in transport sector probably because of high demand for private transport services that may be associated with higher income. Both Kwakwa et al. (2018) and Adom et al. (2018) in particular have argued that there are no scale economies in the provision of environmental services in the transportation sector. Further, population growth and industrial growth, agricultural activities as well extraction of natural resources further tend to contribute to the rise in CO2 emissions from the Transport sector of South Africa.

CO2 emissions from Manufacturing, Industries and Commercial (MIC) services

More so, it is established from Table 3 that energy consumption tends to increase the level of CO2 emissions from manufacturing industries and construction, all the other things being equal. Elasticity coefficient of 0.224 is an indication that energy consumption in the sector cannot enhance the technical process of production in the sector and cause lower CO2 emissions. Remarkably, however, technological progress, measured by capital growth is observed to have statistically significant negative elasticity which implies that technological progress is a necessary catalyst to reducing CO2 emissions emanating from manufacturing industries and construction. In the sector also, the possible existence of the EKC hypothesis in the sector is robustly supported by the evidence. This implies that higher income levels have huge scale economies in the provision of environmental services in the sector even though this is actually contrast Kwakwa et al. (2018) and Adom et al. (2018). Additionally, natural resource extraction is found to increase CO2 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). Also, population growth is a robust driver of CO2 emissions from SA’s manufacturing industries and construction. Since population growth underlies both manufacturing and construction activities, these findings is consistent with expectation.

CO2 emissions from residential buildings and commercial and public (RBCP) services

Similarly, in Table where CO2 emissions from residential buildings and commercial and public services is examined, we find that energy consumption tends to put upward pressure on it. This is an indication that energy consumption does not enhance efficiency in the production process of the residential buildings and commercial and public services to lower CO2 emissions. The above results further generally suggest that a valid EKC exist for South Africa’s CO2 emissions from the RBCP services since income has a positive coefficient while income intensity (square) has a negative coefficient. This implies that, for South Africa, CO2 emissions from the RBCP services would eventually fall after a certain level of per capita income. This is supported by Kwakwa et al. (2018). Also, both natural resource extraction, and population growth tend to increase the level of CO2 emission from liquid fuel consumption in South Africa.

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Table 3: Long run analysis of energy consumption and disaggregated CO2 emissions

	Dependent variables					
	CO2 emissions from RBCP		*CO2 emissions from MIC*		*CO2 emissions from Transport sector*	
Regressors	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err
Lag of dep. variable	0.018	0.020	0.032	0.021	0.028	0.045
Energy consumption	0.182*	0.106	0.224*	0.092	0.382**	0.077
Income	0.184*	0.112	0.384**	0.212	0.352*	0.165
Income intensity	0.014**	0.006	0.040*	0.014	0.018*	0.005
Trade openness	0.116	0.083	0.139	0.132	0.190*	0.083
FDI	0.083	0.150	0.102	0.150	0.174	0.120
Capital growth	-0.104*	0.039	-0.122*	0.062	-0.184	0.164
Natural resource rent	0.098*	0.078	0.103*	0.051	0.178*	0.051
Population growth	0.158*	0.089	0.170*	0.089	0.228**	0.101
Industry (% of GDP)	0.130*	0.080	0.204*	0.119	0.188*	0.077
Agric. (% of GDP)	0.192*	0.104	0.104*	0.056	0.382*	0.111
Constant	0.026	0.483	0.014	0.009	0.066	0.453
F - statistic	0.003		0.007		0.043	
Adjusted R^2	0.778		0.691		0.667	

CO2 emissions from Liquid Fuel Consumption (LFC)

Table 4 reveals how CO2 emissions emanating from liquid fuel consumption is influenced by energy consumption. Evidently, neither of the two financial development variables influences CO2 emissions emanating from liquid fuel consumption. Hence, energy consumption does not systematically affect CO2 emissions emanating from liquid fuel consumption even though income, natural resource extraction, and population growth do. For instance, both natural resource extraction, and population growth tend to increase the level of CO2 emission from liquid fuel consumption in South Africa while a robust EKC is also established given that income and its square alternative starting with a positive sign. This implies that higher income levels do have scale economies in the provision of environmental services in liquid fuel reliant sectors of the South Africa economy.

Table 4: Long run analysis of Energy consumption and disaggregated CO2 emissions

	Dependent variables					
	CO2 from Liquid fuel consumption		CO2 from Gaseous fuel consumption		CO2 from Solid fuel consumption	
Regressors	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err
Lag of dep. variable	0.015	0.011	0.026	0.108	0.030*	0.016
Energy consumption	0.205*	0.111	0.343*	0.166	0.407**	0.170
Income	0.198*	0.097	0.317*	0.191	0.375*	0.219
Income intensity	0.023*	0.011	0.033	0.040	0.019*	0.012
Trade openness	0.132*	0.058	0.157*	0.092	0.096	0.085
FDI	-0.069	0.127	-0.165	0.127	-0.132	0.169
Capital growth	-0.151*	0.055	-0.215*	0.104	-0.032	0.053
Natural resource rent	0.130***	0.032	0.140	0.095	0.243*	0.104
Population growth	0.141*	0.085	0.203*	0.105	0.309*	0.124
Industry (% of GDP)	0.218*	0.119	0.168*	0.102	0.195*	0.107
Agric. (% of GDP)	0.158	0.151	0.086	0.151	0.151	0.115
Constant	0.021	0.338	0.112	0.426	0.070	0.468
F - statistic	0.027		0.006		0.000	
Adjusted R^2	0.780		0.793		0.633	

CO2 emissions from Gaseous Fuel Consumption (GFC)

The evidence reported in Table 4 render support to the assertion that energy consumption in South Africa is linked with rise in CO2 emissions from gaseous fuel consumption. In particular, given the elasticity coefficient on the energy consumption variable, a unit growth in SA's energy consumption is accompanied by a proportionate increase in CO2 emissions

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from gaseous fuel consumption, by approximately 0.40%. Further, an increase in both population growth and natural resource rent is associated with an increase in CO2 emissions from gas fuel consumption. Thus, the extraction of natural resources in South Africa is partly responsible for CO2 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). Also, its linkages with population could be because South Africa is still gas fuel dependent. Moreover, the EKC hypothesis is robustly established predicting that policies intended to stimulate growth into the South Africa economy would help the country grow out of CO2 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 South Africa economy.

CO2 emissions from Solid Fuel Consumption (SFC)

Similarly, regarding CO2 emissions from solid fuel consumption it is seen from Table 8 that the coefficients of energy consumption is positive and significant suggesting that that an increase in energy consumption in SA is responsible for the rise of CO2 emissions from solid fuel consumption. This finding is interesting in the sense that SA households and even firms tend to depend on solid fuels. Thus, given that transport sector of SA relies extensively on energy of various forms, any expansion in the sector would imply greater energy consumption which inevitably results in increased CO2 emissions from Transport sector. It is further observed that the coefficients of income and income square cast doubt on the existence of EKC for CO2 emissions from solid fuel consumption. Thus the results shows that initial income of level will reduce CO2 emissions from solid fuel consumption but beyond a certain level, CO2 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 CO2 emissions from solid fuel consumption. This outcome could have very stern implications for South Africa as the country attempts to grow out of environmental degradation (particularly, CO2 emissions from solid fuel consumption) through growth policies, Furthermore, expansion in natural resource rent and population are noted to have insignificant effect on CO2 emissions from solid fuel consumption. This is could be because the extractive sector and the general population do not rely heavily on solid fuel since electricity is readily available in South Africa.

4.3 Causality results

The Engel and Granger Causality (1987) test is employed to examine the existence of causal relationships between energy consumption and CO2 emissions indicators of environmental quality (i.e. CO2, and its disaggregate components) and the results of these estimations are reported in Table 5. It is noticeable that, there is unidirectional causality running from energy consumption to all the environmental degradation variables under examination in this study except for CO2 emissions from Gaseous fuels consumption. This further implies that the long run relationships established between energy consumption and most of the environmental degradation variables are actually causal and not a case of mere association. Given the motivation of the current study, the reverse of the causal relationships are however not examined. These findings are broadly consistent with Kwakwa et al. (2018), Aboagye (2017), Aboagye and Kwakwa (2016), Kwakwa et al. (2014) among others.

5. Conclusions

Without doubt, energy is a strategic resource that influences the outcomes of economic development as well as cleaning and polluting environment to the extent that no matter the way energy it is used (such as power generation, industrial use, transportation, and residential use), it constitutes a basis for economic growth and prosperity. In fact, as revealed by Kohler (2013), if South Africa's greenhouse gas (GHG) emissions are compared on a global scale, it is immediately clear that the country is one of the world's most carbon-intensive economies

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As South Africa's grows and wealth increases, demand for energy-based inputs increases as well. The rapid growing demand for energy and the heavy dependence of South Africa's on energy indicate that energy could be a major problem in the next century. Another major point of concern relates to detrimental effect energy consumption in the country can potentially have on the environment given that 83% of South Africa's CO2 emissions were associated with energy supply and consumption. The main finding of this empirical study is that energy consumption in South Africa could be blamed for various sources of CO2 emissions. In addition, the EKC hypothesis is robustly established for all the forms of CO2 emissions investigated except for emissions from solid fuels consumption implying the economic expansion or increase in wealth could guarantee that South Africa's escape from CO2 emissions. The study also established a unidirectional causality running from energy consumption to all the various sources of CO2 emissions under examination except for emissions from gaseous fuels consumption. Other findings emerging from the study are that rapid urbanisation and population growth are associated with a rise in CO2 emissions. The influx of FDI is also associated with a fall in CO2 emission. Also, capital growth which is employed to proxy for technological advancement is found to reduce CO2 emissions (air pollution).

Table 5: Engel and Granger Causality

Null Hypotheses	F-Statistic	P-values	Remarks
Energy consumption does not Granger Cause Aggregate CO_2 emissions	6.9353	0.0057	Causality
Energy consumption does not Granger Cause CO_2 emissions from Residential buildings, Commercial and Public services	4.2126	0.0098	Causality
Energy consumption does not Granger Cause CO_2 emissions from Manufacturing, Industries and Constructions	6.16052	0.0064	Causality
Energy consumption does not Granger Cause CO_2 emissions from Transport sector	5.1506	0.0091	Causality
Energy consumption does not Granger Cause CO_2 emissions from Liquid fuels consumption	7.4164	0.0038	Causality
Energy consumption does not Granger Cause CO_2 emissions from Gaseous fuels consumption	0.3328	0.7822	No Causality
Energy consumption does not Granger Cause CO_2 emissions from Solid fuels consumption	5.0866	0.0093	Causality

Given that energy consumption account for a large proportion of CO2 emissions which also remains a dominant component of total anthropogenic greenhouse gas (GHG) emissions, environmentally sustainable economy is therefore important growth agenda of South Africa in order to preserve the long term interest of the communities who depend on the growth of the economy as well as the communities whose livelihood are affected because of pollution. It is very urgent to frame some strategies towards achieving the sustainable development in South Africa. In terms of policy, given that energy consumption is to be blamed for environmental degradation as revealed by the study, reducing the pernicious effect of energy consumption on the environment could be possible by making energy consumption reduction, increases in renewable energy sources/consumption and energy efficiency improvement absolute priorities in South Africa even in the context of a green economy and sustainable development. More so, following the other findings of the study, increasing the attractiveness the South African economy to FDI and the adoption of progressive technology are necessary catalyst to enhance the quality of the environment by reducing CO2 emissions, water pollution as well as. Thus, even while policy battles to control environmentally harmful energy consumption sources, FDI and the adoption of progressive technology could be embraced to forestall the continual rise in the level of CO2 emissions in South Africa.

6. Appendices

Table A1: CO2 emissions

	95%		*90%*	
F-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
6.432	4.506	7.070	3.523	5.784
W-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
38.587	27.067	41.768	21.493	34.709

Table A2: CO2 emissions from RBCP services

	95%		*90%*	
F-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
3.626	2.540	3.985	1.986	3.260
W-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
21.469	15.059	23.238	11.958	19.311

Table A3: CO2 emissions from manufacturing industries and construction (MIC)

	95%		*90%*	
F-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
6.447	2.507	3.933	1.960	4.376
W-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
35.269	13.732	21.191	10.905	23.949

Table A3: CO2 emissions from liquid fuel consumption (LFC)

	95%		*90%*	
F-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
6.248	2.430	3.812	1.900	4.241
W-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
37.484	14.595	22.522	11.590	25.454

Table A4: CO2 emissions from gaseous fuel consumption (GFC)

	95%		*90%*	
F-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
5.169	2.010	3.154	1.572	3.509
W-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
31.009	12.074	18.632	9.588	21.057

Table A5: CO2 emissions from solid fuel consumption (SFC)

	95%		*90%*	
F-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
4.544	1.767	2.772	1.382	3.085
W-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
27.261	10.614	16.380	8.429	18.512

Table A6: CO2 emissions from transport

	95%		90%	
F-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
4.828	1.877	2.946	1.468	3.277
W-statistic	Lower Bound	Upper Bound	Lower Bound	Upper Bound
28.965	11.278	17.403	8.956	19.669

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Appendix B: Short run Analysis

Table B1: Short run analysis for energy consumption and aggregate CO2 emissions

Regressors	*Coefficient*	*Standard Error*
Lag of dep. variable	0.004	0.054
Energy consumption	0.097*	0.041
Income	0.018*	0.011
Income intensity	0.065	0.053
Trade openness	0.013*	0.007
Foreign Direct Investments	0.031	0.035
Capital growth	0.078	0.785
Natural resource rent	-0.045	0.066
Population growth	-0.555	0.737
Industry (% of GDP)	0.086**	0.006
Agric. (% of GDP)	0.063**	0.023
Error Correction term	0.594*	0.301
Constant	0.069	0.104
F - Statistic	0.007	
Adjusted R^2	0.721	

Table B2: Short run analysis for energy consumption and (Disaggregate CO_2 emissions)

	Dependent variables					
Regressors	*CO2 emissions from Residential, Commercial and Public services*		*CO2 emissions from Manufacturing and Construction*		*CO2 emissions from Transport sector*	
	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err
Lag of dep. variable	0.002	0.050	0.106**	0.050	0.104*	0.050
Energy consumption	0.009	0.010	0.092**	0.040	0.097**	0.021
Income	0.033	0.049	0.033	0.049	0.102	0.117
Income intensity	0.008	0.093	0.006	0.093	0.009	0.095
Trade openness	0.051*	0.032	0.051**	0.032	0.066*	0.035
FDI	0.040	0.727	-0.023	-0.061	-0.075	0.076
Capital growth	-0.023	-0.061	-0.283	-0.682	-0.039	0.049
Natural resource rent	-0.283	-0.682	0.032	0.021	0.044	0.079
Population growth	0.095*	0.061	0.051**	0.013	0.093**	0.042
Industry (% of GDP)	0.074**	0.021	0.035	0.096	0.084*	0.067
Agric. (% of GDP)	0.051	0.038	0.079	0.060	0.079	0.093
Error Correction term	0.511**	0.202	0.696**	0.067	0.603**	0.063
Constant	0.090	0.34	0.291	0.345	0.389**	0.395
F - Statistic	0.000		0.044		0.003	
Adjusted R^2	0.652		0.521		0.620	

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Table B3: Short run analysis for energy consumption and (Disaggregate CO_2 emissions)

Regressors	*Dependent variables*					
	CO2 from Liquid fuel consumption		*CO2 from Gaseous fuel consumption*		*CO2 from Solid fuel consumption*	
	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err
Lag of dep. variable	0.007***	0.001	0.002	0.050	0.056	0.054
Energy consumption	0.104*	0.052	0.092**	0.040	0.096*	0.053
Income	0.096***	0.025	0.033	0.049	0.020	0.126
Income intensity	0.005	0.277	0.185*	0.093	0.004	0.102
Trade openness	0.052	0.038	0.051	0.032	0.060	0.038
FDI	-0.050	0.293	0.396	0.727	0.093	0.105
Capital growth	0.049	0.043	-0.023	-0.061	-0.044	-0.083
Natural resource rent	0.062	-0.210	-0.283	-0.682	-0.075	-0.053
Population growth	0.079***	0.022	0.095**	0.048	0.062*	0.033
Industry (% of GDP)	0.051	0.024	0.032**	0.013	0.108**	0.054
Agric. (% of GDP)	0.095	0.059	0.051	0.038	0.152*	0.089
Error Correction term	0.596*	0.362	0.554***	0.096	0.748**	0.372
Constant	0.155	0.325	0.013	0.480	0.112	0.426
F - Statistic	0.000		0.044		0.007	
Adjusted R^2	0.575		0.619		0.767	

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