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Carbon Emissions and Economic Growth in South Africa: A Quantile Regresison Analysis

B. Mapapu[1], Andrew Phiri[2]*

[1]Department of Economics, Faculty of Business and Economic Studies, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa, [2]Department of Economics, Faculty of Business and Economic Studies, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa. *Email: phiricandrew@gmail.com

ABSTRACT

Of recent carbon emissions have become an increasing concern for economies worldwide. In this study we investigate the relationship between carbon emissions and economic growth for the South African economy, one of the largest emitters of carbon dioxide worldwide. We employ the quantile regression methodology which is applied to annual data covering a period of 1970–2014. Our empirical results indicate that very low levels of carbon emissions are most beneficial towards economic growth. Our results thus encourage policymakers to continue to embark on energy efficiency programmes which specifically target lower levels of carbon pollution.

Keywords: Carbon Emissions, Economic Growth, Environmental Kuznets Curve, South Africa, Quantile Regressions
JEL Classifications: C13; C32; C51; Q43; Q53.

1. INTRODUCTION

Following the seminal works of Grossman and Krueger (1991; 1995) much empirical attention has been directed towards examining the relationship between environmental degradation and economic development, a phenomenon popularly dubbed as the environmental Kuznets curve relationship or hypothesis. Theoretically, the environmental Kuznets curve depicts that during the early stages of economic development, environmental degradation is a catalyst for improved economic development only up to certain level of development of which afterwards it begins to exert an adverse effect. Regardless of this hypothesized nonlinear, inverted U-shaped relationship between environmental degradation and economic development a bulk of the existing empirical literature has relied on linear econometric methodologies in examining the relationship between carbon emissions and economic growth Ang (2007), Ozturk and Acaravci (2010), Esteve and Tamarit (2012) and Cerdeira-Bento and Moutinho (2015), Shahbaz et al. (2015), Alam et al. (2016), Tang et al. (2016). The danger with this approach is that inaccurate conclusions concerning the Environmental Kuznets curve may have been deduced in the previous literature.

In our study, we examine the relationship between carbon emissions and economic growth for the South African economy over a period of 1971–2013. In deviating from the norm of linear estimation techniques, we choose the quantile regressions methodology as introduced by Koenker and Bassett (1978) as our mode of empirical investigation. We favour this technique since it examines the effects of regressor variables on the regress and at different quantile distributions. In adopting this method we are offered the unique advantage of being able to examine the effects of varying levels of carbon emissions on economic growth hence increasing the scope of policy relevance derived from our study. This becomes particularly significant towards an emerging economy like South Africa, whose heavy reliance on coal-based energy production has placed the country as the African continents number one carbon emitter. Knowing what effects carbon emissions exerts on economic growth is directly crucial towards South African policymakers as they are currently engaged in energy efficiency strategies aimed at reducing carbon pollution.

Empirically, our study further takes into consideration the fact that a majority of the existing empirical studies have been criticized on the premise of including both carbon emissions and energy/

electricity consumption as mutual regressors of economic growth hence violating the classical assumption of orthogonality between the regressors (Burnett et al., 2013). As a simple remedy to this multicollinearity problem, Burnett et al. (2013) advises researchers to exclude energy/electricity consumption from the estimated growth regressions and solely include carbon emissions and other growth determinants in the estimated regressions. We note that previous South African case studies have not followed in pursuit of this empirical rule Menyah and Wolde-Rufael (2010), Kohler (2013), Shahbaz et al. (2013a), Khobai and Le Roux (2017) hence providing a strong motivation for a fresh perspective on the subject matter. In our study, we take advantage of this empirical hiatus and in doing so, make a novel contribution to the literature.

Having provided the background and motivation to the study, the rest of the manuscript is arranged as follows. The following section of the paper presents the review of the previous literature whilst the third section outlines the quantile regressions methodology used in the empirical study. The description of the time series data as well as the empirical findings are presented in the fourth section of the paper. The paper is then concluded in the fifth section of the paper in the form of policy implications.

2. A REVIEW OF THE ASSOCAITED LITERATURE

Theoretically, Antweiler et al. (2001), Coxhead (2003) and Ang et al. (2007) all postulate that the assumed relationship between environmental deregulation/pollution and economic development (i.e., the Environmental Kuznets curve) can be explained by three factors. Firstly, there is the scale effect which occurs as pollution increases with the size of the economy. Secondly, there is the composition effect which refers to the change in the production structure of an economy from agricultural based to industry and service based which results in the reallocation of resources. Lastly, there is the production techniques which indicates that improved technology in production may reduce the amount of pollutant emissions per unit of production. Empirically, a vast majority of the existing academic literature concerned with examining the environmental Kuznets curve, have opted to investigate the relationship between carbon emissions and economic growth as a means of empirically examining the environmental Kuznets curve for different economies, using different time periods as well as a variety of econometric tools. In providing a review of the associated literature, we conveniently generalize the studies into two classifications of empirical works, namely, studies who focus on developed or industrialized countries and those studies who focus on developing or emerging countries.

The first group of studies, which are those studies which have examined the relationship between carbon emissions and economic growth for developed or industrialized economies include the works of Ang (2007) for France; Ozturk and Acaravci (2010) for Turkey; Menyah and Wolde-Rufael (2010a) for the US; Esteve and Tamarit (2012) for Spain as well as Cerdeira-Bento and Moutinho (2015) for Italy. Whilst the studies of Ang (2007); Menyah and Wolde-Rufael (2010a) and Esteve and Tamarit (2012) advocate for a positive relationship between the time series, the works of Ozturk and Acaravci (2010) and Cerdeira-Bento and Moutinho (2015) both find a negative emissions-growth relationship. It should be noted that cording to theory it is more probable to find a negative relationship between emissions and economic growth since industrialized economies, are by definition, countries who are at advanced stages of development. Given the mixed results obtained from the review of developed or industrialized economies, the debate concerning these countries remains open to further deliberation.

On the other hand the papers published by Menyah and Wolde-Rufael (2010b) for the South Africa, Kohler (2013) for South Africa; Shahbaz et al. (2012) for South Africa for Pakistan; Shahbaz et al. (2013) for South Africa; Shahbaz et al. (2013) for Indonesia; Shahbaz et al. (2013) for Romania; Farhani et al. (2014) for Tunisia; Begum et al. (2015) for Malaysia; Rafindadi (2016) for Nigeria; Khobai and Le Roux (2017) and Ahmad et al. (2017) for Croatia suffice as those concerned with examining the emissions-growth relationship for developing countries, with the studies of Kohler (2013), Shahbaz et al. (2013b), Khobai and Le Roux (2017) exclusively focusing on the South African economy. In summarizing these studies we note that whilst the works of Shahbaz et al. (2013c), Rafindadi (2016) and Khobai and Le Roux (2017) advocate for a positive emissions-growth relationship, however, the remaining reviewed studies for developing countries mutually find a positive emissions-growth relations at low levels which turns negative at higher levels. These later group of studies are able to capture a nonlinear carbon emissions-growth relationship by including a squared term on the GDP variable which is intended to capture possibly nonlinear dynamics. However, as pointed out by Narayan et al. (2016) including both GDP and the squared term of GDP in the same regression would make the econometric model to suffer from the issue of multicollinearity. In contrast, the quantile regressions methodology applied in our current study naturally captures any nonlinearity hence the inclusion of the "squared carbon emissions" term is not necessary and hence circumvents the issue of multicollinearity. Nevertheless, a comprehensive summary of the reviewed studies are presented in Table 1.

3. METHODOLOGY

Our baseline empirical model assumes the following functional form:

$$Y_t = \beta_0+\beta_i X_t+e_t \tag{1}$$

Where Y_t is the economic growth rates, X_t is a set of explanatory variables, β's represent the associated regression coefficients and e_t is a well behaved error term. Our main explanatory variable is carbon emissions (CO_{2t}) and the remainder of the conditioning variables are those primarily dictated by theoretical considerations based on the literature. For instance, our first conditioning variable is the investment variable (inv_t) which, according to classical theory is assumed to the engine of economic growth and is hence positive related to economic growth. Our second conditioning variable is the inflation rate (inf_t) and based on conventional growth theory is assumed to hinder economic growth and hence empirically exhibit a negative effect on economic growth. Our

Table 1: Summary of literature review

Author (s)	Country/countries	Time period	Methodology	Results
Ang (2007)	France	1960–2000	VECM	Positive relationship between CO2 and GDP
Ozturk and Acaravci (2010)	Turkey	1965–005	ARDL	Negative relationship between CO2 and GDP
Menyah and Wolde-Rufael (2010a)	US	1960–2007	VAR	Positive relationship between CO2 and GDP
Menyah and Wolde-Rufael (2010b)	South Africa	1965–2007	ARDL	Positive relationship between CO2 and GDP
Shahbaz et al. (2012)	Pakistan	1971–2009	ARDL	Positive relationship between CO2 and GDP at low levels which turns negative at higher levels
Kohler (2013)	South Africa	1960–2009	VECM and ARDL	Positive relationship between CO2 and GDP at low levels which turns negative at higher levels
Shahbaz et al. (2013b)	South Africa	1965–2008	ARDL	Positive relationship between CO2 and GDP at low levels which turns negative at higher levels
Shahbaz et al. (2013c)	Indonesia	1975–2011	VECM and ARDL	Positive relationship between CO2 and GDP
Shahbaz et al. (2013a)	Romania	1980–2010	ARDL	Positive relationship between CO2 and GDP at low levels which turns negative at higher levels
Farhani et al. (2014)	Tunisia	1971–2008	ARDL	Positive relationship between CO2 and GDP at low levels which turns negative at higher levels
Cerdeira-Bento and Moutinho (2015)	Italy	1960–2011	ARDL	Negative relationship between CO2 and GDP
Begum et al. (2015)	Malaysia	1970–2009	ARDL	Insignificant relationship between CO2 and GDP at low levels which turns negative at higher levels
Rafindadi (2016)	Nigeria	1971–2011	VECM and ARDL	Positive relationship between CO2 and GDP
Khobai and Le Roux (2017)	South Africa	1971–2013	\VECM	Positive relationship between CO2 and GDP
Ahmad et al. (2017)	Croatia	1992–2011	ARDL	Positive relationship between CO2 and GDP at low levels which turns negative at higher levels

ARDL: Autoregressive distributive lag model, VECM: Vector error correction model, VAR: Vector autoregressive model

third variable is the employment variable (emp_t), which according to growth theory is assumed to be positively correlated with economic growth. Our last conditioning variables is the terms of trade variable (tot_t), which represents international trade and the open economy which is assumed to exert a positive influence on economic growth. Collectively, our baseline empirical specification can be expounded as follows:

$$Y_t = \beta_0+\beta_1CO_{2t}+\beta_2INV_t+\beta_3INF_t+\beta_4EMP_t+\beta_5TOT_t+e_t \quad (2)$$

From regression (1) in conjunction with regression (2), the conventional OLS estimates would be obtained by finding the vector β_i that minimizes the sum of squares residual i.e.,,

$$\min_{\beta\in R^k}[\sum_{i\in\{i:y_i\geq x_i\beta\}}(y_i - x_i'\beta)^2 \quad (3)$$

In contrast, the quantile regression approach adopted in our study is a generalization of the median regression analysis to other quantiles. In particular, the mean average deviations (MAD) estimator can be computed as:

$$\min_{\beta\in R^k}[\sum_{i\in\{i:y_i\geq x_i\beta\}}/y_i - x_i'\beta/]^2 \quad (4)$$

Of which the MAD estimate depicted in regression (4) can be re-specified as:

$$\min_{\beta\in R^k}[\sum_{i\in\{i:y_i\geq x_i\beta\}}\tau / y_i - x_i'\beta/+\sum_{i\in\{i:y_i\geq x_i\beta\}}(1-\tau)/ y_i - x_i'\beta/] \quad (5)$$

Where τ represents the τ^{th} quantile and is specifically set at 0.5 for the MAD estimator. The general intuition of the quantile regression estimates is to use varying values of τ bound between 0 and 1 hence yielding the regression quantiles for varying distributions of GDP growth given the set of explanatory variables contained in the vector X. In our study we opt to use 9 quantiles with intervals of 0.1 between the quantiles i.e., τ = {0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8 and 0.9}.

4. DATA AND EMPIRICAL RESULTS

4.1. Data Description

The empirical data used in our study has been collected from the World Bank online database and has been collected on an annual basis for a period ranging from 1970 to 2014. Our dataset particularly consist of economic growth (gdp), Carbon emissions (CO_2), CPI inflation (inf), gross domestic investment (inv), and terms of trade (tot) variables. Tables 2 and 3, present the descriptive statistics and the correlation matrices of the time series whereas Figure 1 presents a time series plots of the variables. Of particular interest from the descriptive statistics reported in Table 2 are the low GDP average of 2.63% which we note is well below the 6 percent target growth rate currently being embarked by policymakers. We also note that the average inflation rate over our study period is 9.62, a Figure which is above the 3–6% as stipulated by the South African Reserve Bank. Moreover, the low employment average of 1.75 is inherent characteristic of the South African economy, which is well known for her labour market deficiencies.

On the other end of the spectrum, the correlation matrix as depicted in Figure 2, tends to depict correlations which concur with those predicted by conventional growth theory. For instance, we note positive employment-growth and trade-growth relations which adheres to traditional economic theory. Similarly, the negative inflation-growth and emissions-growth relations are expected. However, the negative correlation established between investment and growth is a rather peculiar observation since investment is commonly perceived as the engine of economic growth. Nevertheless, this negative investment-growth correlation is not uncommon in the literature as recently advocated for in the study of Phiri (2017).

4.2. Empirical Estimates

In initiating our empirical analysis, we first provide the OLS estimates of the regression with the results being reported in Table 4. As can be observed, the coefficient on the carbon emissions variable produces a positive estimate which is statistically significant at all critical levels. Note that this result is in line with that presented in Shahbaz et al. (2013), Rafindadi (2016) and Khobai and Le Roux (2017). Also note that the coefficient on the inflation variable is negative and highly significant as expected and this particular finding concurs with that presented in Hodge (2006) for similar South African data. We further observe a positive coefficient estimate on the employment variable thus providing evidence of a positive employment-growth relationship as predicted by convention theory. On the other end of the spectrum, we note insignificant coefficients on both the investment and terms of trade variables which is contrary to conventional theory and yet concurs with that presented in the study of Phiri (2017) for South African data. Our reported results are reinforced by the partialled plots of GDP on the regressors as depicted in Figure 2.

However, as previously mentioned, the OLS estimates have been heavily criticized for constraining the coefficient on the regressand variables to be the same across different quantiles. Therefore, we proceed to present the empirical estimates of the quantile regressions which have been performed for 9 quantiles (i.e., 10^{th}, 20^{th}, 30^{th}, 40^{th}, 50^{th}, 60^{th}, 70^{th}, 80^{th} and 90^{th} quantiles) with the results been reported in Table 5. As can be observed, the coefficient estimates for the carbon dioxide variable are positive across all quantiles and are significant at a critical level of at least 5%. However, the positive effect of carbon emissions on GDP are amplified at the tail ends of distribution (i.e., very low and very high levels of carbon emissions) with the coefficients reducing as one moves from the extreme quantile (i.e., 10^{th} and 90^{th} quantiles) towards the centre quantile (50^{th} quantile) which incidentally happens to be the MAD estimate.

On the other hand, the coefficients on the inflation variable are negative and significant at all quantile levels with the negative effects of the inflation variable being more pronounced at lower quantiles and the coefficients becoming lower as one moves don the quantile levels hence signifying a diminishing negative effect of inflation on economic growth as one moves along the quantile levels. Concerning the employment variable we note a positive coefficient on the employment variable across all estimated quantiles which are statistically significant at all critical levels with the marginal positive effect of employment on economic growth diminishing as one moves up the different quantile levels. In lastly observing the coefficients obtained for the investment and terms of trade variables we note that all quantile estimates produce negative

Table 2: Descriptive statistics

???	gdp	CO_2	inf	inv	emp	tot
Mean	2.63	8.58	9.62	21.90	1.75	1.79
Median	2.95	8.70	9.37	20.75	1.30	2.10
Maximum	6.60	10.04	18.65	32.10	8.50	20.00
Minimum	−2.10	6.65	1.39	15.20	−4.30	−16.20
Std. dev.	2.27	0.93	4.21	5.06	2.68	6.44
Skewness	−0.43	-0.28	0.14	0.40	0.28	-0.01
Kurtosis	2.35	2.01	2.01	1.85	3.15	4.15
Jarque bera	2.15	2.38	1.94	3.61	0.62	2.44
Probability	0.34	0.30	0.38	0.16	0.73	0.30
observations	44	44	44	44	44	44

Table 3: Correlation matrix

	gdp	CO_2	inf	inv	emp	tot
gdp	1					
CO2	−0.20	1				
inf	−0.39	0.11	1			
inv	−0.03	−0.35	0.43	1		
emp	0.64	−0.25	0.18	0.37	1	
tot	0.17	−0.08	−0.14	−0.01	0.09	1

Table 4: OLS estimates

Variable	Coefficient	Standard error	t-stat	P value
CO_2	0.45	0.12	3.85	0.00***
Inf	−0.28	0.05	−5.59	0.00***
Inv	0.01	0.05	0.28	0.78
Emp	0.66	0.10	6.31	0.00***
Tot	0.01	0.03	0.52	0.60

***, **, * represent 1%, 5% and 10% significance levels, respectively

Table 5: Quantile regression estimation results

tau	CO_2		INF		INV		EMP		TOT	
	Coefficient	P value	Coefficient	P value	Coefficient	P value	Coefficient	P value	Coefficient	P value
0.1	0.52	0.00***	−0.30	0.00***	−0.09	0.29	0.79	0.00***	0.03	0.62
0.2	0.53	0.02**	−0.31	0.00***	−0.08	0.47	0.72	0.00***	0.04	0.54
0.3	0.51	0.00***	−0.22	0.00***	−0.08	0.43	0.72	0.00***	0.01	0.95
0.4	0.34	0.04*	−0.25	0.00***	0.04	0.51	0.63	0.00***	−0.05	0.30
0.5	0.36	0.02**	−0.28	0.00***	0.07	0.29	0.64	0.00***	0.03	0.59
0.6	0.41	0.01**	−0.29	0.00***	0.06	0.33	0.64	0.00***	0.03	0.66
0.7	0.44	0.00***	−0.25	0.01**	0.04	0.49	0.67	0.00***	0.02	0.71
0.8	0.43	0.00***	−0.22	0.06*	0.03	0.51	0.68	0.00***	0.05	0.35
0.9	0.43	0.00***	−0.16	0.00***	0.06	0.39	0.48	0.00***	0.05	0.34

***, **, * Represent 1%, 5% and 10% significance levels, respectively

Figure 1: Time series plots of the variables

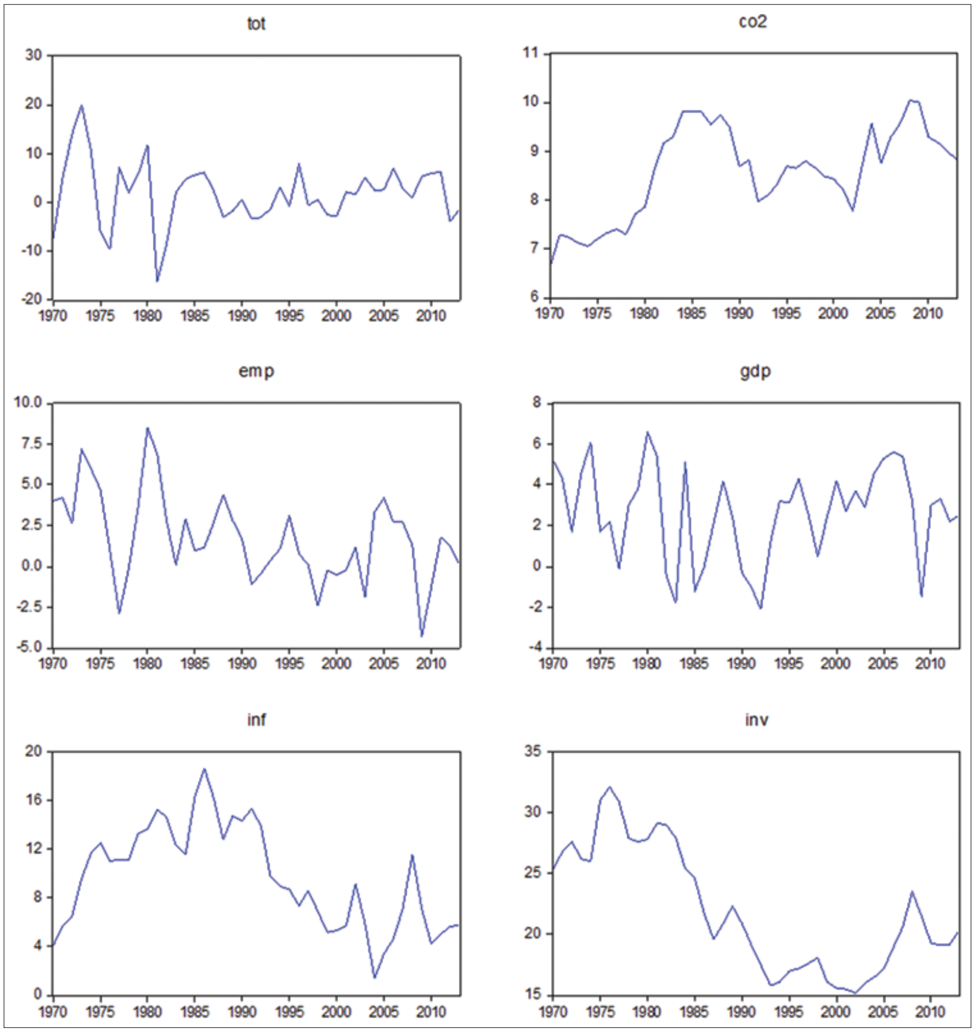


Table 6: Diagnostic tests on estimated quantile regression

Test	Statistic	P value	Decision
Ramsey RESET test	4.31	0.11	No specification error
Jarque-Bera (J-B)	2.28	0.31	Normal distributed regression

and insignificant coefficient estimates for the former variable while producing positive and insignificant estimates for the later variable. Note that these results closely emulate those obtained from the previous OLS estimates. The associated quantile process estimates are presented in Figure 3.

4.3. Residual Diagnostics

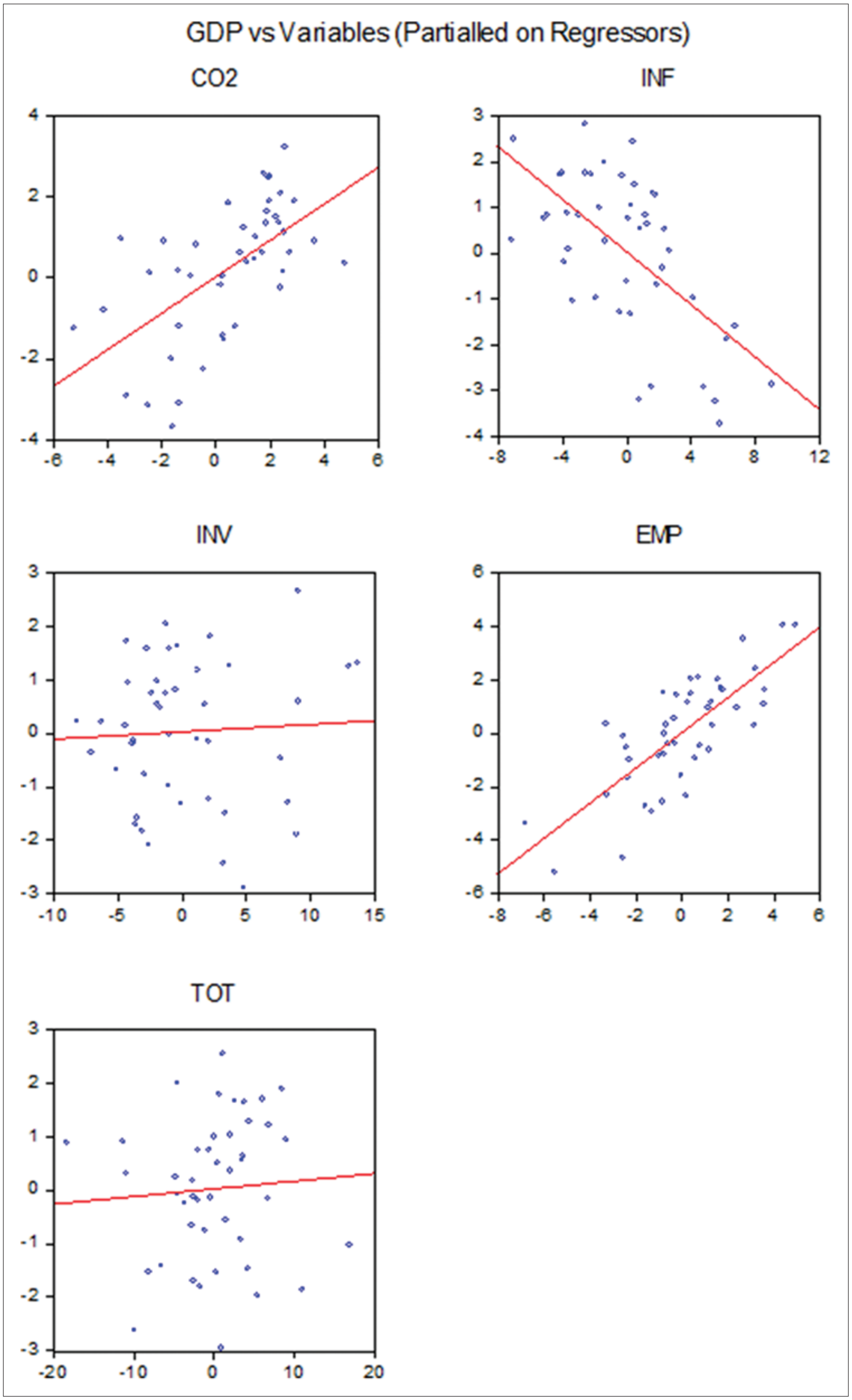
As a final step in our empirical analysis, we implement diagnostic test to our estimated regression. In particular, we implement two diagnostic tests, namely, Ramsey's RESET test for model misspecification and Jarque-Bera (J-B) goodness of fit test. The results of these diagnostic tests are reported in Table 6 and as can be seen our empirical estimates contain no specification errors and are normally distributed. We thus consider our obtained quantile regression estimates to be plausible.

5. CONCLUSION

The primary objective of this current study has been to evaluate the relationship between carbon emissions and economic growth in South Africa using annual data collected over a 44 years period spanning from 1970 to 2013. In differing from pervious empirical studies, we employ the quantile regression approach which provides the advantage of assuming parameter heterogeneity in analysing the effects of carbon emissions on economic growth. Moreover, we circumvent the possibility of multicollinearity within the estimated regression estimates by not including energy/electricity consumption alongside carbon emissions as regressors in the estimated growth model.

Our obtained empirical results confirm positive relationship between carbon emissions and economic growth, albeit, the positive effect being most magnified at extremely low or extremely high values and diminishing as one moves to centre values. We consider the overall positive relationship to be expected since South Africa is well known for her dependency on coal usage in producing energy for productive and consumption usage within different sectors of the economy. Hence given the country's current

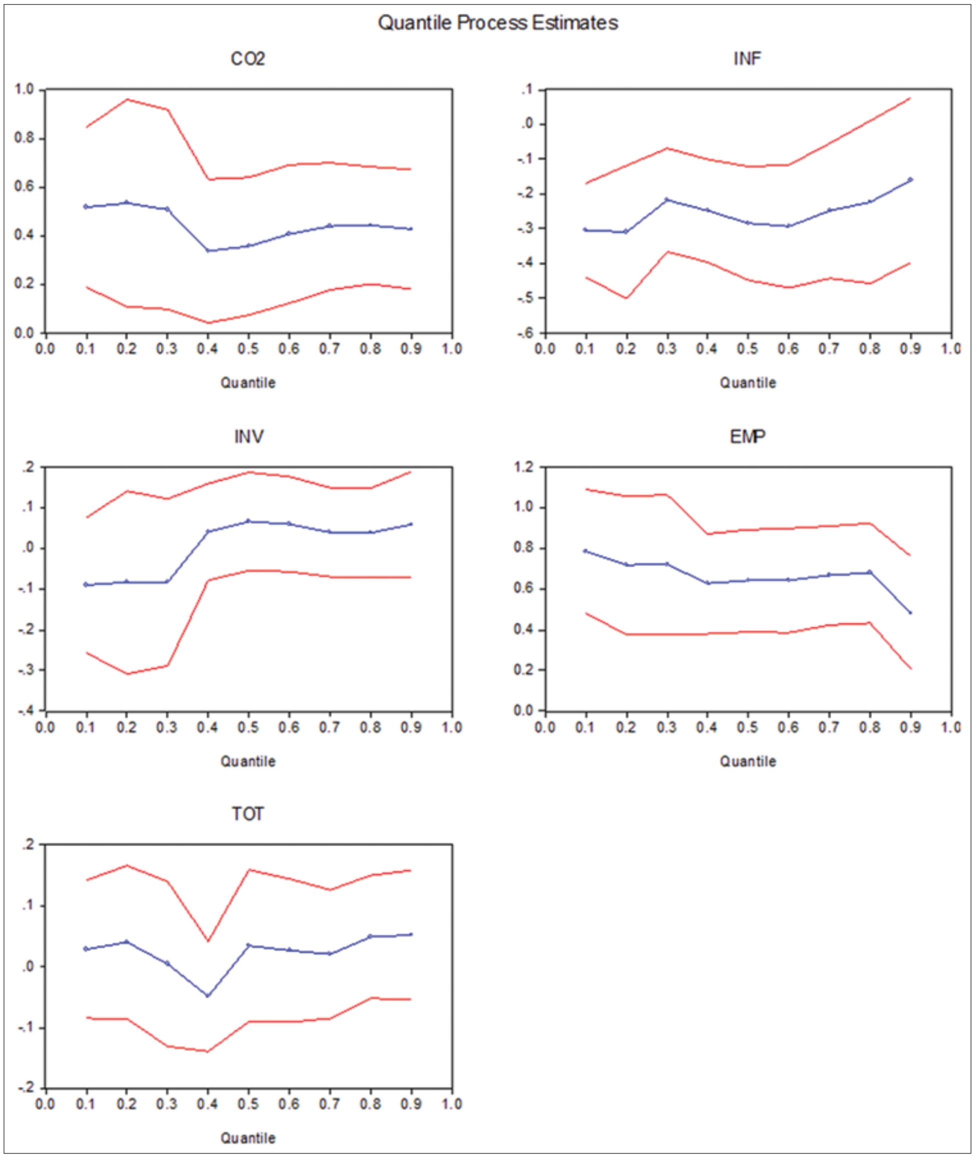
Figure 2: GDP versus other variables



stage/level of economic development increased electricity usage in South Africa would be accompanied with increased carbon emission as well as improved economic growth. However, our quantile estimates indicate that very low levels of carbon emissions are most beneficial for economic development through improved economic growth rates.

In effect our study bears important policy implication since policymakers have been embarking on energy efficiency programmes over the last decade and a half or so. Part and parcel of these energy efficiency programmes is to shift from coal-based energy production schemes to renewable energy sources which would exert a positive environmental effect in terms of greenhouse

Figure 3: Quantile process estimates



emissions. From a policy perspective, our results imply it would be in government's best interest to keep carbon emissions as low as possible to fulfil the macroeconomic policy objectives of improving both environmental degradation and long-run economic growth. Based on our study, government's current pursuit of energy programmes and strategies though increased renewable energy sources is thoroughly encouraged.

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