Firm's Imperfect Compliance and Pollution Emissions: Theory and Evidence from South Africa

Abstract

Carbon emissions exacerbate global climate change. Transitioning away from coal is a cost-effective path to a low-carbon economy. Although many articles have considered the issue of manufacturers' production and emission of pollution. Few papers have discussed the impact of environmental tax and fuel tax on the cost of environmental degradation.This paper seeks to fill this gap by developing a theoretical model to discuss the relationship between environmental pollution and economic growth. Furthermore,in order to support the theoretical results and testify the relationship between carbon emissions and taxation, we take South Africa as a case for discussing the effect of environmental taxation and fuel levy on firms' carbon emissions.We show that the impact of environmental taxes on carbon dioxide emissions is greater than that of fuel taxes on carbon dioxide emissions . In addition, we find that the GDP level of South Africa is on the left of the inflection points of Kuznets Curve. In other words, the current growth of South Africa's economy is at the cost of worsening the environmental degradation.

JFL classification: H23, H26, P43,Q 53

Key words: Carbon emission, Environmental tax, Fuel levy, Kuznets curve

1.Introduction

In 1932, Pigou proposed the use of economic incentives to deal with externalities caused by pollution which show that the tax rate equivalent to the cost of the marginal damage caused by pollution (that is, the Pigouvian tax) would make the resource allocation of the society reach the Pareto optimality. Baumol and Oates (1988) further pointed out that in a perfectly competitive market, the Pigouvian tax can indeed internalize external effects and further correct externalities.Also, Heyes(2000), Macho-Stadler(2008) and Shiota(2008) show that enforcement policies do affect actual emissions. Sterner and Isaksson (2006) show that the Refunded emission payments (REP) scheme offers an interesting alternative to permits, particularly when the regulator wants a price-type instrument but does not want to place the full cost burden on the polluters.As we know, however, the REP scheme has its limitations, the basis of refunding in an REP scheme requires a common output, which can be hard to define. Requate (2006) and Williams (2017) consider governments have a variety of tools at their disposal, among which the emissions tax is publicly recognized as a central pillar. Nevertheless, Greenstone and Jack (2015) point out that many developing countries still maintain lax environmental policies, setting very low or even zero emissions taxes. Piciu and Trică (2012) suggest that the environmental taxes can be returned to polluters in the form of subsidies only under strict obligations.

Carbon emission in Africa has led to the premature deaths of 712,000 people every year. In South Africa's case, we think it is a critical need for South Africa-specific studies on the association between air pollution and environmental policy. In South Africa, after more than eight years in the making, the carbon tax is expected to take effect on 1 june 2019 and aims to price greenhouse gas emissions by obliging the polluter to internalise the external costs of emitting carbon, and contribute towards addressing the harm caused by such pollution.The design included a number of features to increase its acceptability and to limit the initial impact on South African economy. The proposed tax rate of R120 per tonne of carbon-dioxide -equivalent (tCO_2e) was intended to increase by 10% a year until 2020 (phase 1), when it would then be reviewed. Among the mechanisms proposed to make the tax more acceptable were an exemption for 60% of emissions by firms in all the covered sectors, additional tax-free emissions allocations for trade-exposed, energy-intensive sectors or those that had invested in efficiency measures, and allowing firms to utilise offsets to reduce a portion of their tax liabilities. In addition, the design of the carbon tax provides significant tax-free emissions allowances ranging from 60% to 95% for the first phase. This will provide South African business with sufficient time and flexibility to transition their activities through investments in energy efficiency, renewables and other low carbon measures.

This paper is organized as follows. In section 1, we discuss the relationship between CO2 emissions and environmental tax and fuel levy in South Africa's case. Section 2, we explore the South Africa's Kuznet inflection point between income and its carbon dioxide emissions

2. Literature review

Tullock(1967) first put forward the hypothesis of double dividend. By levying environmental taxes on water resources, pollutants can be reduced. Panayotou(1997) sampled data from 30 countries from 1982 to 1994 and found that low-income policies had a positive effect on improving the environment. With the increase of income level, the effect became more obvious. However, the faster the economic growth, the higher the population density, the higher the environmental cost of economic growth. Harbaugh et al.(2002) show that the relationship between economic growth and environmental pollution is not only influenced by economic factors, but also by sample selection and research methods. Bruyu(1997) selected data from developed countries in the 1980s to study, which showed that changes in economic structure had no significant effect on SO2 emissions, but in the high-income stage, environmental policies formed by international agreements could well explain the negative correlation between environment and income.Grossman(1995) regards urban air pollution and oxygen content in river water as environmental indicators. Through regression analysis, it is concluded that economic growth causes deterioration of environmental indicators in the low-income stage, and improves with economic growth in a certain stage, and the inflection point occurs at the income level of $8,000 (some examples are Sherry 2008, David 2004, Gurluk 2009).Copeland(2004)), analyzed the relationship among economic growth, international trade and environmental pollution, and found that on the inverted U-shaped curve of economic growth and environmental pollution, international trade and capital flow had a great impact on environmental pollution. Llorca and Meunie(2009) obtained the N-curve relationship between SO2 emission and per capita income.

2. The Model

Aiming at the relationship between environmental pollution and economic growth, this paper establishes indirect utility functions as Eq.(1). In the formula, R represents real income, a_1, a_2, γ, δ represent constants. These constants are greater than 0, Z represents pollution emissions, and assumes that the marginal negative utility of pollution emissions remains unchanged. In order to eliminate the impact of structural effects, it is assumed that only one commodity model is used for analysis. Therefore, the national income function Y is expressed as Eq.(2):

$$\mathrm{V} = a_1 - a_2 \times e^{-\frac{R}{\delta}} - \gamma \times \mathrm{Z} \tag{1}$$

$$\mathrm{Y} = \mathrm{P} \times \lambda \times \mathrm{Z}^{\beta} \times F(\mathrm{k})^{1-\beta} \quad ;\mathrm{k} = \frac{K}{L} \tag{2}$$

In the formula, λ is the conversion coefficient, P is the commodity price, F(k) is the production function and β is the constant, then the marginal output value of pollution emission is equal to the demand of reverse pollution emission, which can be expressed as follows.

$$\Gamma^{\mathrm{D}} = \beta \times \mathrm{P} \times \lambda \times \mathrm{Z}^{\beta-1} \times F(\mathrm{k})^{1-\beta} = \frac{\beta}{Z} \times \mathrm{Y}$$

(3)

Also, the supply-utility function of pollutant emissions can be obtained as follows.

$$\Gamma^{\mathrm{S}} = -\frac{\mathrm{V}_Z}{\mathrm{V}_Y} = \frac{\gamma \times \Omega(P) \div \delta}{a_2} \times e^{\frac{R}{\delta}} \tag{4}$$

Through the supply-demand function, the expression of the environmental Kuznets curve can be obtained as Eq.(5) and Eq(6)

$$Z^* = \frac{\beta \times a_2 \times R}{\gamma \times \delta} \times e^{-\frac{R}{\delta}} \tag{5}$$

The following formula can be obtained by calculating the derivative of environmental pollution Z.

$$\frac{dZ}{dR} = \frac{\beta \times a_2}{\gamma \times \delta} \times (e^{-\frac{R}{\delta}} - \frac{1}{\delta} \times R \times e^{-\frac{R}{\delta}}) = \frac{(\delta - R)}{R \times \delta} \times Z \tag{6}$$

The inflection point of environmental pollution is $R = \delta$. When economic growth reaches the level of δ, environmental pollution can be alleviated. It means that people begin to pay attention to the issue of sustainable environmental management. Eq.(6) is a convergence function, and its value is greater than zero. If n positive convergence functions are added together, the function obtained should also be convergent. Based on the theoretical models derived from Eq.(1) to (6), we will use statistical methods to verify the existence of the Environmental Kuznets Curve and where the Environmental Kuznets Curve is located in South Africa's air pollution emissions and national income data over the past 27 years.

3. Methodology and Analyses

Being carbon neutral is increasingly seen as good corporate or state social responsibility and a growing list of corporations, cities and states are announcing dates for when they intend to become fully neutral. As we know, most of South Africa's energy needs are directly derived from coal and most of coal consumed on the African continent is mined in South Africa. Thus, reducing carbon emissions while keeping a high pace of economic growth lies at the heart of South Africa's sustainable development plan.

However, it is worth discussing whether there is a causal relationship between the increase of CO2 caused by the government's raising the minimum emission standard of CO2 and environmental tax and fuel levy on polluters's carbon dioxide emissions. In contrast with the traditional method, we focus on examining the relationship between carbon emissions, environmental tax and fuel levy by using an empirical approach, where carbon emissions are measured in MtCO2, environmental tax and fuel levy are measured in ZAR millions, respectively. The data on carbon dioxide emissions came from The International Energy Agency, the environmental tax and fuel levy data collected from The National Treasury and SARS statistics

In the beginning the time evolution of carbon emissions, environmental tax and fuel levy in terms of levels (logarithms) are presented in Fig. 1, which shows the environmental tax series have an obvious increasing trend, and those sequences show that the mean values are varying in different periods, we then judge that the sequences are unstable.

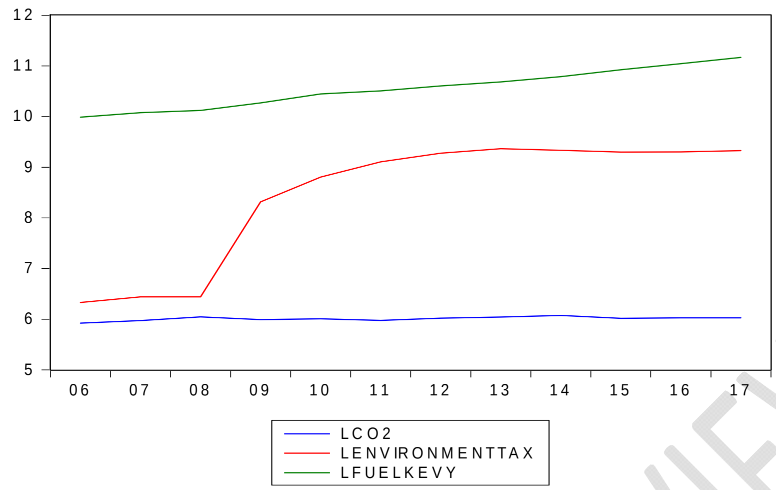

Fig.1 Time trend data on CO2 emissions,environmental tax, and fuel levy in logarithmic form for South Africa

We then test the cointegration approach among the carbon emissions, environmental tax and fuel levy for South Africa over a time period ranging from 2006 to 2017, determining whether the stochastic component contains a unit root or not. The results of unit root tests are presented in Table 1, which demonstrates that the LCO 2 appeared stationary at the first-differenced form under 5% significant level, depicting the logged variables are I(1), the LEnvironmentalTax and LFuellevy also appeared stationary at the first-differenced form under 5 % significant level, depicting the logged variables are also I(1). We then utilize the OLS regression method evaluating the relationship between LCO 2, LEnvironmentalTax and LFuellevy, the results are as follows:

$$LCO2=5.235428-0.001524LEnvironmentalTax+0.074901LFuellevy. \tag{7}$$

Table 1. Performance of unit root test of LCO2, LEnvironmental Tax and Lfuellevy

	1990 to 2017					
Variable	ln CO2		ln EnvironmentalTax		ln fuellevy	
	level	1st difference	level	1st difference	level	1st difference
ADF	- 1.347750	- 3.672751**	-1162135	-2.228849**	0.629275	-3.834209**
	(0.5517)	(0.0316)	(0.8591)	(0.0313)	(0.9828)	(0.3870)
PP	-3.204750	- 5.718489**	-0.553918	-5.696321**	-2.325449	-3.819368
	(0.1340)	(0.0062)	(09575)	(0.0064)	(0.39)	(0.0202)
KPSS	0.493548	0.177420**	0.163124	0.078848**	0.514265	0.167027**

Notes: Variables in logarithmic form ; ADF test and PP test,** stand for rejection of null hypothesis at 5% significance level, KPSS test, ** stand for acceptance of null hypothesis at 5%

significance level.

Next, we check the residuals for a unit root. The residual used to test the cointegration relationship is as follows:

$$e = LCO2 - 5.235428 + 0.001524 LEnvironmentalTax - 0.074901 LFuellevy \qquad (8)$$

Eq.(8) indicates the t-statistic of the residual series is -3.486349(Prob*=0.0364), which is less than the critical value at 5% significant level, and thus reject the null hypothesis, indicating that the residual series has no unit root and is stationary at I(0). The estimation results represent a cointegration relationship between LCO2 emissions, LEnvironmentalTax and LFuellevy, error correction models(ECM) can then be analyzed.

In order to ensure that the random disturbance term in ECM become white noise, the model with lag terms is estimated first, and then we adjust the regression model. We find that the short-term elasticity of LCO2 to LEnvironmentalTax is -0.018906 and the short-term elasticity of LCO2 to LFuellevy is -0.051104. As can be seen from Eq.(9)

$$\Delta LCO2_t = \alpha + \sum_{i=0}^{2} \beta_i \Delta LCO2_{t-1} + \sum_{i=1}^{2} \gamma_i \Delta LENVIRONMENTALTAX_{t-i} + \sum_{i=1}^{2} \kappa_i \Delta LFUELLEVY_{t-1} + \lambda e_{t-1} + v_i$$

$$\begin{aligned} \Delta LCO2_t = {} & 0.009826 - 0.018906\,\Delta LENVIRONMENTALTAX - 0.051104\,\Delta LFUELLEVY + 1.130707\,\Delta LCO_{t-1} \\ & + 0.925546\,\Delta LCO_{t-2} - 2.316379\,e_{t-1} \end{aligned} \qquad (9)$$

4. Estimation Results

As indicated in table 1, which shows that LCO2 and Lenvironmentaltax and Lfuellevy are I(1) sequence. We then adopt Johansen Cointegration to test whether there exist a long-term equilibrium relationship between LCO2 and Lenvironmentaltax and Lfuellevy. In Table 2, Trace test result shows that there exists a set of cointegrating vectors at the 5% level, and Max-eigenvalue test also indicates the same result.

Table 2. Performance of Johansen Cointegration Test of LCO2, LEnvironmental tax and LFuellevy

		2006 to 2017		
H0	H1	Statistic	5% critical value	Prob**
Trace test				
None*		63.01094	29.79707	0.0000
At most 1*				
γ =0	$\gamma \geqq 1$	14.54274	15.49471	0.0692
Max-eigenvalue test				
None*		48.46820	21.13162	0.0000
At most 1*				
γ =0	$\gamma \geqq 1$	9.422608	14.26460	0.2527

Notes: γ denotes number of cointegrating equations; Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

Next, we discuss the interaction between environmental tax and fuel levy on carbon dioxide emissions and the level of their influence, respectively.Thus,we use (VAR) Vector Autoregressiond to explore the following hypotheses:

Hypothesis 1: Environmental tax and fuel levy both have a negative impact on CO2 emissions, but its impact gradually decreases over time.

Hypothesis 1 can be analyzed by using the generalized impulse method (Pesaran and Shin, 1998), Figure 2 shows that the adverse impact of environmental tax on carbon dioxide emissions reached its maximum in the second phase, and then gradually diminished after the tenth period.

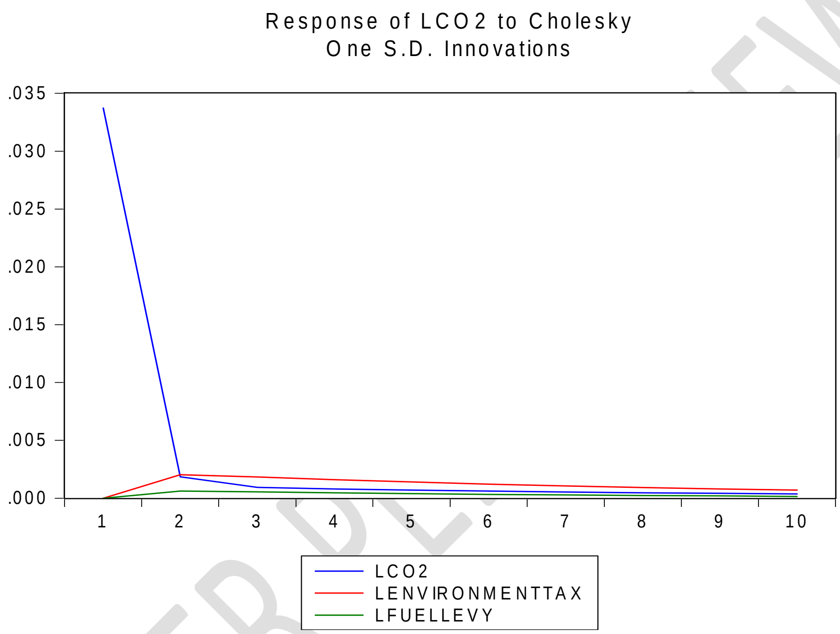

Fig.2 Impact of CO2, EnvironmentalTax and Fuellevy shock on CO2

Hypothesis 2: The correlation between environmental tax and CO2 emissions is higher than the correlation between fuel levy and CO2 emissions

Hypothesis 2 is explored using a generalized variance decomposition method(Koop et. al, 1996). Through the VAR model. Table 3 shows the unexpected impact variation of LEnvironmental Tax and LFuel levy on LCO2, respectively. At the beginning, the percentage of LCO2 explained by LEnvironmental tax and LFuel levy is extremely small, when looking forward to the forecast of 10 periods. LFuel levy could explain only 0.11% of the variation of LCO2 prediction errors. Comparatively, LEnvironmental tax could explain 1.41% of the variation of LCO2 prediction error, thus indicating that the environmental tax has a higher correlation with CO2 emissions.

Fuel levy is a kind of consumption tax. But even if fuel levy is levied, the market demand for oil products will not decrease significantly and thus the purpose of improving air pollution will not be achieved. Environmental tax is a tax levied on firms/polluters who directly produce air pollution, conforms to the polluter-pays principle. According to our empirical analysis, we show that the collection of environmental protection tax is more effective than the collection of fuel tax in reducing air pollution and improving environmental quality.

Another, air pollution is an important factor that causes the cost of environmental degradation. In this section, based on the theoretical models derived from Eq.(1) to (6), we use Kuznets curve to analyze the relationship between environmental degradation costs and economic variables in South Africa(some examples are Grossman et al., 1991; David, 2004; Sherry, 2008; Panayotou, 1997). Following is the establishment of a pollution emission loss model. Based on the KC curve, relevant variables are introduced.

Table 3. Variance Decomposition of LCO2

Period	S.E.	LCO2	LEnvironmentaltax	LFuellevy
1	0.033721	100.0000	0.000000	0.000000
2	0.033838	99.60687	0.360335	0.032794
3	0.033904	99.29391	0.648124	0.057963
4	0.033954	99.05782	0.866059	0.076126
5	0.033992	98.88001	1.030896	0.089098
6	0.034020	98.74621	1.155533	0.098258
7	0.034042	98.64567	1.249697	0.104630
8	0.034058	98.57028	1.320745	0.108980
9	0.034070	98.51387	1.374252	0.111875
10	0.034079	98.47181	1.414454	0.113739

$$\Delta \ln \mathrm{Loss}_t = \beta_1 \ln \mathrm{GDP}_t + \beta_2 (\ln \mathrm{GDP}_t)^2 + \beta_3 \ln \mathrm{EC}_t + \beta_4 \ln \mathrm{POP}_t + \beta_5 \ln \mathrm{NEX}_t + \beta_6 \ln \mathrm{ELC}_t + u_t \quad (10)$$

Eq(10), LnLoss indicates the cost of environmental degradation caused by air pollution, mainly related to carbon dioxide emissions. lnCO2 is the logarithm of energy from coal measured in Mt, lnGDP is the logarithm of gross national product measured in billion 2010 USD, and $(\ln GDP)^2$ using a quadratic form means that the cost rises at an increasing rate with the depreciation rate, lnEC is the logarithm of energy from coal measured in Mtoe , lnPOP is the logarithm of population measured in millions, lnNEX is is the logarithm of net export of energy measured in Mtoe, lnELC is the logarithm of electricity consumption measured in TWh. In table 4, model 2 adds EC variable on the basis of model 1, while other models add different variables separately. To illustrate the environmental degradation costs and economic variables. The analyses can be stated formally as Hypothesis 3.

Hypothesis 3: In table 4, model 1 expresses that not considering the effects of policies, the current economic development of South Africa has approached the left

end of the inflection point of the Kuznets curve.

In Table 4, we analyze the path of the coordinating the conflicts between economic growth and environmental pollution. Our empirical results show that not considering the effects of policies, the GDP level of South Africa is on the left of the inflection points of Kuznets curve. InTable 4, model 1 shows that the inflection point of the quadratic curve is 6.13, and the GDP of South Africa is 420 billion USD in 2016 based on 2010. The logarithmic value of 420 is 6.04. This proves that not considering the effects of policies, the current economic development of South Africa has approached the left end of the inflection point of the Kuznets curve. It means that increasing the domestic products including net exports can make the environment condition worse.

Nevertheless, from the results of Table 4, model 2, we can see that the regression coefficient of lnEC, energy from coal, is 0.0049, reaching a significant level of 1%. Due to the positive sign of the coefficient, it shows that the increase of LnEC can dramatically lift the cost of environmental degradation to a certain extent. In Table 4, model 6 shows that the cost of environmental degradation is negatively correlated with lnELC, electricity consumption in logarithmic form, reaching a significant level of 10%,revealing that the source of electricity consumption not came from coal-fired power generation, but also hydroelectric power, wind energy and natural gas.

Table 4 Regression analysis of environmental degradation cost

Independent variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
lnGDP	12.96364* (6.208422)	3.773657 (0.696761)	14.18636* (6.812107)	13.16644* (6.148074)	15.27784* (3.718701)	6.608958*** (1.769524)
$(\ln GDP)^2$	-1.056245* (-5.777492)	0.320307 (-0.584613)	-1.141393* (-6.371491)	-1.074742* (-5.726069)	-1.252545* (-3.563494)	-0.517988 (-1.629599)
ln EC		0.663706* (3.110537)				0.857076* (3.804819)
ln POP			-0.513972*** (-1.909694)			-0.249946 (-0.953709)
ln NEX				-0.010070 (-0.612448)		0.000195 (0.014658)
ln ELC					-0.133002 (-0.656844)	-0.367812*** (-1.850764)
AR(1)	1.498388* (8.497288)	1.190972* (5.395506)	1.323322* (7.056437)	1.574146* (7.341918)	1.314486* (5.952779)	
AR(2)	-0.510447*		-0.465848*	-0.565642**	-0.362335***	

	(-2.850285		(-2.859872)	(-2.540726)	(-1.731689)	
D-Wstat	1.918295	1.842529	1.601369	1.872873	1.386572	2.214722
Adjusted-R^2	0.994294	0.980583	0.976190	0.995093	0.972923	0.984124
γ * (inflection point of EKC)	6.136663	5.890687	6.214494	6.125395	6.098719	6.379450

Notes: Variables in logarithmic form ; *,**,*** stand for at 1%,5% and 10% significance level; The number in brackets is the t-statistic of the estimated parameter

5. Conclusions and Discussion

In comparison with traditional literature, the major findings of this study indicated the following results. Firstly, as noted in Figure 2 and Table 3, in South Africa's case, we show that the collection of environmental protection tax is more effective than the collection of fuel tax in reducing air pollution and improving environmental quality. Secondly, as noted in Table 4, we find that not considering the effects of government policies, the current economic development of South Africa has approached the left end of the inflection point of the Kuznets curve. It means that the further growth of economic scale will lead to the worsening of environmental quality. It is hoped that the formal analysis presented in this paper, even though it is based on a simple model, can be useful in improving developing countries' carbon pollution, and considered by decision-makers as a call to take relevant methods to mitigate emissions level without harming the economic growth.

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