Economic Growth and Air Pollution in Metropolitan Cities of Nigeria

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Abstract

There is an increasing consensus that environmental pollution has an inverted-U relationship with economic development. That is, economic development may initially lead to increased pollution but eventually bring about cleaner environment, hypothesis wasalso analyzed in studies using regional data within a country, and the air pollution data are from the 1999 Annual Report of Ambient Air Quality in *Nigeria* by the Ministry of Environment. The reason is that many of the observations are not available and are highly unreliable, mainly because those are the early years of pollution monitoring usingreceptors for the first time. The six metropolitan cities have 57 observation sites over 31 local districts. The results shows that carbon monoxide (CO) and total suspended particulates (TSP) had inverted-Urelationship with city income. The same kind of relationship, however, was not found in sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3), it also show that SO_2, NO_2, TSP and CO have inverted-U relationships with regionalincome.Turning points estimated in this paper are lower than some other particular cities of Nigeria, they estimated about 10 million won and 13 million won for SO_2 and NO_2, respectively. However, the air quality data investigated in this paper are qualitatively different. Many researchers in the field of urbanair pollution report that the estimated turning points tend to be lower for the concentration data than for the emission data

Keywords: *sulphur dioxide,nitrogen dioxide,income, air pollution Nigeria.*

Introduction

There is an increasing consensus that environmental pollution has an inverted-U relationship with economic development. That is, economic development may initially lead to increased pollution, but eventually bring about cleaner environment, at least for certain types of pollutants. Holtz-Eakin and Selden (1992), Selden and Song (1994), Shafik (1994) and Grossman and Krueger (1995) confirmed the relationship using cross-country data on environmental quality.

The inverted-U, or environmental Kuznets curve, hypothesis was also analyzed in studies using regional data within a country, such as Brooks and Sethi (1997) and Wu (1998). Brooks and Sethi (1997) examined the relationship between air pollution and socio-economic characteristics of

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the U.S. communities. They found that air toxic release showed an inverted-U relationship with the median community income. Wu (1998) studied the environmental quality of 23 cities of Taiwan from 1982 to 1995 and found the inverted-U relationship as well.

In Nigeria, we identified two studies which investigated the relationship between income and pollution using regional data. Lee and Lee (1996) investigated air pollution of 42 observation sites over 5 cities from 1985 to 1992. They found that carbon monoxide (CO) and total suspended particulates (TSP) had inverted-Urelationship with city income. The same kind of relationship, however, was not found in sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3). Kim and Chung (1998) studied the relationship between per capita air pollutant emission and regional income of Lagos, Port Harcourt, and Abuja from 1980 to 1995. They found that SO_2, NO_2, TSP and CO have inverted-U relationships with regional income.

These two papers, however, are different in many ways. Lee and Lee (1996) explain pollution concentration, while Kim and Chung(1998) use total emission of pollutants. The former covers many cities over the country, while the latter do only three regions around the capital city. The most striking difference isthat they drew different conclusions on testing the environmental Kuznets curve hypothesis for such major pollutants as SO_2 andNO_2.

Their different observations motivated our paper. We will examine the relationship between income and the two air pollutants and evaluate the proposed inverted-U hypothesis. The paper is organized as follows. In the next section, we describe a simple model that can explain the effect of economic development on air pollution. Section III explains the data. Section IV discusses regression results. Concluding remarks follow in the final section.

The Model

There is an extensive theoretical literature on pollution and economic development, which includes early works by Keeler, Spence and Zeckhauser (1972), Foster(1973), Gruver (1976), as well as more recent papers by Tahvonen and Kuuluvainen (1991), Huang and Cai (1994), Bovenberg and Smulders (1995), Michel and Rotillon (1995), Withagen (1995), Selden and Song (1995) and Jo (1999) among others. The following model, even in its simplest form, should be sufficient in explaining the inverted-U relationship between air pollution and economic development.

Suppose that, as in Foster(1973), pollution is a function of the pollution often depends on the stock of pollution carried over from the past. The above form is more appropriate because air pollution is the subject of this paper. It is assumed that pollution increases as more capitalis employed and decreases as abatement expenditure increase.

Preferences are represented by a utility function $U=u(c,p)$, where c is consumption. It is assumed that the marginal utility of pollution is negative and decreasing. Output is produced with labor and capital stock. Labor is supplied at a constant proportion of population which is assumed to be constant overtime. Then output, y, can be expressed as a function of capital only, $y = f(k)$ Output is used δ for either consumption, abatement equation, $\dot{k}= i -\delta k$, where is a capital depreciation rate.

Following Solow (1956), investment is carried out at a constant fraction of income, $i = ø y$, where $ø$ is a gross saving rate.

Consider a hypothetical social planner who chooses paths for

$$f\,max\, e^{-\rho t}U(c,p(k,a))dt$$

subject to

$$fJ_0$$

to solve, $c+a=(1-ø)f(k), \quad forallt\geq 0,$ (1)

$\{c,a\}^{t=0}$a≥0, forallt≥0, (2)

∞

$\dot{k}=øf(k)-\delta k' \quad givenk0,$ (3)

where ρ is a time preference rate. The economy is completely described by state variables k and the time t. Optimal solutions, (c,a*), satisfy

$c+a=(1-ø)f(k)'$ (4)

$\partial u_{\geq}\partial u\partial p,$ (5)

$\partial c \qquad \partial p\partial a$

where the equality of equation (5) holds if a>0. Given *k*, consumption and abatement expenditure are allocated according to equation (4) and (5) so that the marginal utility of consumption equals the marginal benefit of abatement expenditure, and that consumption, abatement expenditure and investment meet the feasibility condition. If the consumption is low and abetment effects are minimal, then pollution abatement is likely to be zero and people consume all of disposable output less investment. In poor economies, even after people spend all their disposable income on buying consumption goods, the marginal utility of consumption may be still higher than the marginal benefit of abatement expenditure. For those economies, abatement expenditure is probably zero with the inequality solution of equation (5) until arriving a certain income level or having a huge technological improvement. Once they achieve those improvements, the optimal solution comes from the equality solution of equation (5) resulting a positive abatement expenditure.

The total effect of capital stock on pollution is

given by $$\frac{dp}{dk} + \frac{\partial pda}{\partial adk}$$

da. The marginal effect of capital stock on pollution,

$\frac{\partial p}{\partial k}$ is positive. When pollution abatement expenditure is positive, the total effects of capital stock on abatement, $\frac{da}{dk}$ is positive with an appropriate set of assumptions. However, the total effect of capital stock on pollution remains ambiguous. The same ambiguity holds for the relationship between income and pollution because income is simply a positive function of capital stock. The possibility of the inverted-U curve relationship between income and pollution is allowed for in the model but not necessarily predicted by the model.

The model can be modified to allow for exogenous population growth and technological progress. Jo(1999) gives an example of such cases. Population growth introduces population density into the model. The marginal effect of population density on pollution is positive. But since people may spend more on pollution abatement to reduce pollution, the total effect of population density on pollution however remains uncertain. Exogenous technology growth can be allowed to both output production and pollution abatement. The effect of output technology progress on pollution is negative. Output technology progress will bring more output with the same capital stock without further aggravating pollution. This extra output can be allocated to increase pollution abatement expenditure, thereby reducing pollution. The effect of pollution abatement technology progress is not definite. While the immediate effect of it is to reduce pollution, people may switch resources from pollution abatement to consumption and the total effect is ambiguous.

Technology is assumed to be common among all economies and it can be captured as a function of time. Since we cannot easily find good proxies for output and abatement technology, there is a practical reason to represent technology in this way. Time may capture other exogenous trends which are not in the model but affect pollution. Therefore, a care must be taken in interpreting the time effect. Introducing both population density and technology growth will change the quantitative effect of income on pollution but not its qualitative effect. That is, the possibility of the inverted-U curve relationship between income and pollution is allowed for in the model. Pollution can be written as a function of state variables, (k, t, n),where t represents technology, n is population density, and capital stock k can be substituted with income y by the inverse function. A specification of the empirical pollution function is,

$$p_{it} = \beta_1 + \beta_2 y_{it} + \beta_3 y_{it}^2 + \beta_4 t + \beta_5 n_{it} + \beta_6 z_i + \varepsilon_{it} \quad (6)$$

Data and method

We investigate SO_2 and NO_2 concentration of Abuja, Lagos, Kaduna, Kano, Port Harcourt and Cross Rivers from 1989 to 1998. The air pollution data are from the 1999 Annual Report of Ambient Air Quality in Nigeria by the Ministry of Environment. Although the air quality has been monitored by the government since 1985, the data between 1985 and 1988 are not included in this study. The reason is that many of the observations are not available and are highly unreliable, mainly because those are the early years of pollution monitoring using receptors for the first time. The six metropolitan cities have 57 observation sites over 31 local districts. Air pollution data are unbalanced in that they are not available for the whole period for many observation sites. We use per capita real gross regional domestic product (GRDP) of metropolitan cities as a measure of real lncome.

The real GRDP data are obtained from various issues of Main Indicators of Cities, Kuns and Kus by Nigeria Bureau of Statistics Office. Population density variable data come from the same source, which are available up to a ku level. We also include the site dummy variables indicating the land use near the observation site (residential, commercial, industrial, and semi-industrialareas, with respect to green area) as control variables. The site dummy data are from 1999 Annual Report of Ambient Air Quality in Nigeria.

Table 1
Data Summary

	SO_2	NO_2	Income	Pop. Density
	(ppm)	(ppm)	(mil/cap)	(10,000/km2)
Mean	0.0238	0.0277	6.6444	1.3482
Median	0.0190	0.0280	6.4479	1.3943
Maximum	0.1240	0.0540	8.7916	3.5279
Minimum	0.0050	0.0090	4.1685	0.0376
Std.Dev.	0.0169	0.0085	1.1690	0.7979
N	369	362	570	528

Since both SO_2 and NO_2 have asymmetric distribution, showing multiplicative change, we use log(SO_2) and log(NO_2) in our estimation. We employ a random effect model in the estimation of the equation (6), taking into account the unbalanced nature of the panel data.

Results

A. Economic Development and Air Pollution

B. Equations (1) and (2) of <Table 2> show the random effect estimation of SO_2. P-values of coefficient estimates are reported in

Table 2

Random Effect Estimation of log(SO_2) and log(NO_2)

	log(SO2)		log(NO2)	
	(1)	(2)	(3)	(4)
Constant	353.6654	345.5437	35.6183	31.8888
	(0.0000)	(0.0000)	(0.0189)	(0.0360)
Income	1.1408		0.7139	
	(0.0000)		(0.0000)	
Income 2	-0.0830		-0.0422	
	(0.0000)		(0.0003)	
Logincome		14.3392		6.2852
		(0.0000)		(0.0008)
Logincome2		-3.7736		-1.4194
		(0.0000)		(0.0037)
Time	-0.1816	-0.1824	-0.0213	-0.0214
	(0.0000)	(0.0000)	(0.0056)	(0.0054)
Density	0.1681	0.1763	0.0907	0.0916
	(0.0004)	(0.0001)	(0.0007)	(0.0007)
Site 2	0.4818	0.4873	0.2470	0.2492
	(0.0002)	(0.0001)	(0.0001)	(0.0001)
Site 3	0.5217	0.5298	0.2466	0.2482
	(0.0005)	(0.0003)	(0.0007)	(0.0007)
Site 4	1.2057	1.2147	0.4114	0.4115
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Site 5	0.5879	0.5880	0.1986	0.2008
	(0.0010)	(0.0007)	(0.0227)	(0.0224)
N	352	352	346	346
Turning point	6.8706	6.6853	8.4515	9.1530
	(0.1500)	(0.1454)	(0.4683)	(1.0894)

Note: P-values are reported in parentheses. For the turning point estimation, however, the standard error is reported. parentheses. The positive coefficient on income and the negative on income squared of equation (1) tell us that there is an inverted-U relationship between SO_2 and income. Both effects are statistically significant.

The coefficient on time is significantly negative. Technology and other exogenous effects related with time have worked to reduce SO_2 concentration. This result can be attributed to the fact that Nigerian Government has adopted policies for manufacturers to use low-sulfur energy sources and to invest in desulfurization facilities. The positive coefficient on density implies that the physical density effect on SO_2 concentration dominates the efforts of pollution abatement by residents, if any. All of site dummy variables are statistically significant and have intuitively correct signs. Compared to a green site, industrial and semi-industrial sites have more air pollution in the order. Commercial and residential sites have more air pollution than a green site, but less than an industrial site or a semi-industrial site.

For the turning point estimation, the standard error is reported in parentheses. The turning point estimate of income at whichSO_2 changes from increasing to decreasing is estimated about 6 to 7 million won with high significance. In equation (2), log income and log income squared are used to see a possible specification error. The estimation results remain the same. And a similar turning point is obtained by thees timation.

Equation (3) shows the estimation of NO_2. The qualitative results of NO_2 are the same. The concentration of NO_2 has an inverted-U relationship with economic development of metropolitan cities. The effects of time and density have a negative and a positive signs as before. All site dummy variables are significant. A difference is that a semi-industrial site has less NO_2 concentration than a residential site or a commercial site. It may be explained by the different emission sources of SO_2 and NO_2. The turning point estimated occurs around 8 to 9 million won. The qualitative results remain the same when log income and log income squared are used in the estimation in equation (4).

B. Model City effects

Each Metropolitan city has different regulatory performances in terms of maintaining environmental quality. Therefore, it is likely that the efficiencies of environmental policies are not the same among them. However, measuring the environmental policy efficiency is not an easy task. Instead, one may argue that the effects of environmental policies can be captured by city dummy variables in air pollution estimation.

<Table 3> shows the estimation of the two air pollution with extra city dummies in regressors. The 5 city dummies correspond to Abuja, Lagos, Port Harcourt, Kaduna and Kano with respect to Cross Rivers. SO_2 concentration is the highest in Taegu and NO_2 concentration is the highest in Abuja. Both SO_2 and NO_2 pollutants are the lowest in Kwangju. Some city dummy effects are not significant, however.

Inclusion of city dummies in the estimation does not change much both qualitative and quantitative effects of other variables. The only exception is a density variable. The estimated standard errors of the density variable are larger with city dummies. The effect of density becomes even insignificant in equation (6). It can be explained by the fact that a city dummy is closely related with density.

A city dummy variable captures anything that are related to the city, but they are not included in the estimation. Therefore, an extreme care must be taken in interpreting the effects of city dummy

Table 3
Random Effect Estimation of log(SO2) and log(NO2) with City Dummy Variables

	log(SO2)	log(NO2)
	(5)	(6)
Constant	364.3079	14.6385
	(0.0000)	(0.4321)
Income	1.2402	0.7754
	(0.0000)	(0.0000)
Income2	-0.0890	-0.0497
	(0.0000)	(0.0001)
Time	-0.1872	-0.0109
	(0.0000)	(0.2541)
Density	0.1208	-0.0181
	(0.0131)	(0.5574)
City 1	0.1326	0.3912
	(0.4085)	(0.0001)
City 2	0.2799	0.2030
	(0.0674)	(0.0234)
City 3	0.4516	0.2891
	(0.0049)	(0.0036)
City 4	0.1282	0.1705
	(0.4264)	(0.0716)
City 5	-0.3423	-0.1764
	(0.0348)	(0.0534)
Site 2	0.4509	0.2166
	(0.0000)	(0.0002)
Site 3	0.5332	0.3311
	(0.0000)	(0.0000)
Site 4	1.0009	0.3281
	(0.0000)	(0.0001)
Site 5	0.5820	0.1657
	(0.0000)	(0.0320)
N	352	346
Turning point	6.9709	7.7984
	(0.1518)	(0.3246)

Note: P-values are reported in parentheses. For the turning point estimation, however, the standard error is reported variables.

It would be informative to graphically demonstrate the fitting performance of the estimated pollution function on a certain observation site and illustrate how the estimation could be used to predict future pollution paths depending on different scenarios. As a purpose of illustration, we randomly selected Mpape Site.

An illustration : Mpape site

Table 4
Data Summary

	SO2	NO2	Income	Pop. Density
	(ppm)	(ppm)	(mil/cap)	(10,000/km2)
1989			5.5116	2.2680
1990	0.0580	0.0230	6.0928	2.2807
1991	0.0620	0.0300	6.3672	2.2793
1992	0.0470	0.0320	6.7310	2.2528
1993	0.0300	0.0320	7.2292	2.2080
1994	0.0200	0.0210	7.6091	2.1211
1995	0.0180	0.0260	8.2687	1.9019
1996	0.0120	0.0330	8.6456	1.8821
1997	0.0090	0.0310	8.7916	1.8780
1998	0.0090	0.0310	8.0178	1.8985
Growth Rate			0.0416	-0.0198

Note: Income and density data are from Abuja and Lagos, respectively.

Mpape is located in the AMAC area of Abuja and is categorized asa semi-industrial site. Thedata for the Mpape Abuja Site are summarized in Table 4. During 1989-1998, personal income has increased by about 4 % per year. For the same period, density has decreased by about 2 % annually on average. However, since it has not changed much between 1995 and 1998, it seems that populationhas become stable since 1995. Over the 1990-1998 period, SO_2 concentration has decreased substantially from 0.058 ppm to 0.009ppm.Ontheotherhand,NO_2hasfluctuatedbetween0.021ppmand

0.033 ppm.

<Figure 1> shows theobserved SO_2 concentration (by points). It also shows the fitted SO_2 concentration (by a line) estimated by the <Figure 1> Observed and estimated SO_2 concentration of Kuro-dong Site 1990-1998 observed, 1989-2010 estimated equation (1) in Table 2.The fitting is extended up to 2010 for different economic growth scenarios. Three scenarios are assumed, in which income grows by

2%, 4%, and 6% respectively. Density isassumed to be constant. Although higher economic growth is expected to reduce SO_2 concentration, it will not change much the path because SO_2 has been already quitereduced.

<Figure 2> shows the observed and fitted NO_2 concentration. The fitting is estimated by the equation (3) in <Table 2>. Since NO_2 concentration has fluctuated during the observation period without any apparent tendency, one cannot tell it for sure from the observation alone how it will change in the future. However, we can provide <Figure 2> Observed and estimated NO2 concentration of Kuro-dong Site 1990-1998 observed, 1989-2010 estimated prediction of the NO_2 concentration path based on the estimation ofNO_2 concentration of 57 observation sites over 10 years. For any scenario of income growth, NO_2 of Kuro-dong Site is expected to decrease over time. The 6 % income growth will bring a discernible decrease in NO_2 compared to the 2 % income growth scenario since NO_2 concentration is just beginning to decrease.

Conclusion

We identified the inverted-U relationship between economic growth and air pollution in both SO_2 and NO_2. The turning point is estimate dabout 6 to 7 million won for SO_2, and 8 to 9 million won for NO_2.Our qualitative results are in favor of Kim and Chung(1998).

Our results contradict Lee and Lee (1996), which found U-relationships, instead of inverted-U, for SO_2 and NO_2 and predicted that the concentration of SO_2 and NO_2would increase as income grew. Since the air pollution data explored in Lee and Lee (1996) and this paper are from the same source, it needs to be explained why the two have such different results. Among 78 observation sites of 15 cities, Lee and Lee (1996) examined only 42 sites which had full observation during the period. For the 6 metropolitan cities this paper examined, they took only 27 sites out of 57 sites available. In their paper, they also said they had excluded several observations believed to be outliers. We suspect that these procedures might have introduced sampling bias, which seriously affected the outcome of the estimation. Turning points estimated in this paper are lower than those in Kim and Chung (1998). In particular, they estimated about 10 million won and 13 million won for SO_2 and NO_2, respectively. However, the air quality data investigated in Kim and Chung (1998) and this paper are qualitatively different. Many researchers in the field of urban air pollution report that the estimated turning points tend to be lower for the concentration data than for the emission data, which was used in Kim and Chung (1988). The differences in the turning point estimates between Kim and Chung (1998) and our results are consistent with these findings caveat must be noted. The inverted-U hypothesis should not be mechanically interpreted as if economic growth will bring about environmental improvement with time without conscious efforts. Since externalities are involved in pollution abatement, higher desire for clean environment at higher income cannot be realized until people address the problems by their collective action. Jo (1999) showed that environmental education and efficient environmental policies can explain a large portion of differences in conventional air pollution across countries, suggesting that they are as much important as income in predicting environmental qualities. It would be interesting to investigate such implications in Nigeria, and it will complement the study of the relationship between income and pollution as well.

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