Pollution as One of the Determinants of Income in Malaysia: Comparison Between Single and Simultaneous Equation Estimators of an EKC

Halimahton Binti Borhan
University Technology Mara, Malaysia

Elsadig Musa Ahmed
Multimedia University, Malaysia

Abstract: This study aims to examine the relationship between economic growth and different indicators of air and water pollution in Malaysia. Air pollution indicators were assessed on a number of measures: carbon monoxide, sulphur dioxide (SO_2), nitrogen dioxide, ozone and particulate matter (PM_{10}); while water pollution indicators were evaluating on a number of measures: biochemical oxygen demand, cadmium and arsenic. The income level per capita gross domestic product per capita were measured from the year 1996 to 2006 quarterly. Being different from the study by Hung and Shaw (2004) and Shen (2006), this study estimates population density as an endogenous variable. It formulates a four-equation simultaneous model for empirical research. Testes for exogeneity with the Hausman test and estimates the simultaneity model using the two-stages least squares method. The Environmental Kuznets Curve (EKC) hypothesis is supported in the cases of SO_2 and PM_{10}, and there are several differences found between single polynomial equation estimators commonly used in EKC literatures and simultaneous equation estimators.

Keywords: Pollutants, Economic Growth, Malaysia, Environmental Kuznets Curve, Simultaneity

1 Introduction

The seriousness and the long-term negative impact of pollution cannot be overemphasised. If left to persist, it can bring harmful effects to our health and economy that will result in increasing health and social costs being incurred. On the basis of the study by Zhang and Yang (2007), extraordinary levels of economic performance have been clearly demonstrated over the last century by many countries. Whether there is actually any contribution by environmental degradation negatively to economic growth and growth ceases eventually or whether it is achieved through the sacrifice of environmental quality. There are many recent studies of the Environmental Kuznets Curve (EKC) that have tried to answer this question. On the basis of the earlier papers such as Shafik and Sushenjit (1992), Panayoutou (1993) and Grossman and Krueger (1995) presented initial evidence that some pollutants followed an EKC pattern.

According to Department of Environment Quality Report (2004), air pollution occurs when air impurities in the form of gaseous or particles are emitted into the atmosphere. Air pollutant comes from a variety of natural and man-made sources. Man-made sources include emission from industrial activities, emissions from motor vehicles and burning of fossil fuels and biomass. The water pollution in Malaysia is originated from point sources and non-point sources. Point sources that have been identified include sewage treatment plants, manufacturing and agro-based industries and animal farms. Non-point sources are mainly diffused ones such as agricultural activities and surface runoffs. According to Malaysia Environment Quality Report 2004, the Department of Environment has recorded 17,991 water pollution point sources in 2004 comprising mainly sewage treatment plants (54%), manufacturing industries (38%), animal farms (5%) and agro-based industries (3%).

Tun Dr. Mahathir, former prime minister of Malaysia (1996), stated that one of the key issues that need to be seriously considered in the efforts to establish and preserve a clean global environment is air pollution. Air pollution is fast and it is becoming a major environmental concern of most governments, with the rapid deterioration of air quality especially in urban areas. Increasing transportation activities arising from rapid industrial growth and urbanisation are the main contributing factors to the persistently prevailing problem of air pollution in the world today. According to him, in Malaysia, for instance, the transportation sector consumed some 40% of the country's total commercial energy demand in 1995 and is anticipated to continue to grow at about 8.1% per annum. Keynote address presented by Raja Dato' Zaharaton Director General, Economic Planning Unit, Prime Minister's Department, Malaysia (2004) stated that rapid development has created gaps in the prevention of pollution and the highly dense population in urban centers has converted rivers into open sewers. Cities are well known for being polluters of aquatic environment with sewage and municipal wastewater, industrial effluent and polluted urban runoff. Similarly, the farming communities pollute the aquatic environment with irrigation returns that contain fertilisers and pesticides and animal wastes. River water quality is also degraded by sediments from land clearance and solid wastes. Water pollution disrupts water supply services, affects human health and destroys aquatic lives and habitat. They came out with an idea that economic growth is by nature the remedy to environmental problems. Opposite opinion found in the recent works by de Bruyn (2000) focussed on the effect of using different indicators, the use of a wider range of explanatory variables than income alone.

This study contributes to the available literature by modifying Hung and Shaw (2004) model in using EKC and extends it to include variables such as number of university graduates, foreign direct investment, fixed capital investment, the secondary industry share, number of motor vehicles and government pollution abatement expense. This study also adopts Shen (2006) model and analyses and interprets the independent variables for secondary industry share and government pollution abatement expense (direct and indirect impact) by modifying this model and extends it to include variables such as number of motor vehicles, number of university graduates, foreign direct investment and government spending. Moreover, the study by Shen (2006) formulates three simultaneous equations method but this study extended the model to include four simultaneous equations method by estimating the population density as one of the endogenous variable. In fact, population density is also endogenous to the system, being affected by pollution through impacts on health and people die through diseases such as lung cancer, and so forth. There is no empirical study in Malaysia that using the government pollution abatement expense and population density as endogenous variables on pollution to estimate EKC as compared to Vincent (1997).

2 Sources of Data

This study has gathered the external information from The Department of Environment (DOE), Department of Statistics in Malaysia, University library, British Council, National library and Memorial library. Besides, the sources such as books, newspapers, journals and Internet that are relevant to the research topic are used. To examine the relationship between air pollution and economic growth, the study estimates several equations that relate the level of pollution in a location to a flexible function of the current and GDP per capita in the country and to other covariates. Air pollution indicators were assessed on a number of measures: carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3) and particulate matter (PM_{10}). Water pollution indicators were assessed on a number of measures: biochemical oxygen demand (BOD), cadmium (CD) and arsenic (AS). The income levels gross domestic product (GDP) per capita were measured from year 1996 to 2006 quarterly. This study measures all the data variables from 1996 to 2006 quarterly in which quarterly data is taken into account as the closer look on the changes of income per capita in Malaysia. One decade is good enough for the study to be conducted in which 1996 to the year of 2006 is the actual time of the development in Malaysia. According to Elsadig (2008), the aggressive development in Malaysia is in the year of 1990s and pollution becomes the serious problem in 1997. This evidence indicates that this study shows the real impact of pollutions towards economic growth during this prime time.

Table 1 ***T*-test to check the statistical significance of the cubic terms of log (per capita GDP) in all the pollutants**

	SO_2	PM_{10}	CO	O	NO	CD	AS	BOD
Intercept	−3.7206	4.8690	0.6623	−2.2185	−3.6558	−6.4228	−6.1513	3.6534
(log (per capita GDP))^3	−7.1689	0.7707	0.1503	−0.6655	0.3676	9.4118	3.5058	0.0018
Adjusted R-square	0.2375	0.0054	−0.0236	0.0039	−0.0225	0.1356	0.0104	−0.0238

3 Methodology and Estimation Procedures

This study examines the interactions between air and water quality and per capita income using ambient concentrations of air and water quality data in Malaysia. The conceptual framework can be represented as follows:

$$\log P_t = \alpha_0 + \alpha_1 \log Y_t + \alpha_2 (\log Y_t)^2 + \alpha_3 \log \text{abate}_t + \alpha_4 \log \text{ind}_t + \alpha_5 \log \text{PD}_t + \alpha_6 \log \text{MV} + \alpha_7 T_2 + \alpha_8 T_3 + \alpha_9 T_4 + e_t \quad (1)$$

$$\log Y_t = \beta_0 + \beta_1 \log P_t + \beta_2 \log \text{LL}_t + \beta_3 \log \text{FL}_t + \beta_4 \log U_t + \beta_5 \log G_t + \beta_6 \log \text{FDI}_t + \beta_7 \log K_t + \beta_8 T_2 + \beta_9 T_3 + \beta_{10} T_4 + €_t \quad (2)$$

$$\log \text{abate}_t = \lambda_0 + \lambda_1 \log K_t + \lambda_2 \log \text{ind}_t + \lambda_3 \log P_t + \lambda_4 T_2 + \lambda_5 T_3 + \lambda_6 T_4 + \nu_t \quad (3)$$

$$\log \text{PD}_t = \prod_0 + \prod_1 \log P + \prod_2 T_2 + \prod_3 T_3 + \prod_4 T_4 + t \quad (4)$$

Being different from Shen (2006), this study excludes the weight of secondary industry share from GDP variable in Equation (1) as this will create a problem of double counting because the weight of secondary industry share is already included in Equation (1) as one of the independent variable. A study by Shen (2006) only regarded income per capita and government pollution abatement expenses as endogenous variables. In actual fact, population density is also endogenous to the system, being affected by pollution through impacts on health. According to Lopez (1994) and de Bruyn (2000), pollution may act as a negative externality, directly reducing output and productivity of man-made capital and labour. Examples are the loss of days worked due to health problems, the corrosion of industrial equipment due to polluted air or water and product avoided because of being polluted. Pollutants that are inhaled have serious impact on human health affecting the lungs and the respiratory system; they are also taken up by the blood and pumped all round the body. The magnitude of the London fog of 1952, which affected such a large number of people, was the first incident that made people aware of the damage done to the atmosphere due to industrialisation. The SPM levels increased manifold and resulted in more than 4000 deaths (www.edugreen.teri.res.in). Therefore, a three simultaneous equations method might produce bias and inconsistent estimates. This study formulates four simultaneous equations model that can be as Equations (1-4). A *t*-test has been employed by this study to check the statistical significance of the cubic terms of log (per capita GDP) in all the pollutants. This study found that generally all of them are not significantly different from zero even at 10% level as can be seen from Table 1 below except for SO_2 and CD. Because majority of the indicators of air and water pollutants are insignificant, therefore this study omit the cubic terms in Equation (1).

4 Results and Discussion

This study finds no evidence of multicollinearity in which none of the independent variables are correlated with each other. The robust estimates of heteroscedasticity are presented in Tables (2-11) as white.

There are some indicators of pollutants shows that heteroscedasticity found in which the error terms for some of the variables in the model do not have a constant variance. White test is significant at 5% level of significance for some of the pollutant indicators. Because of only minor indicators show significant

Table 2 Regression results: estimated results for air and water pollutants [Equation (1)] (*t*-statistics in parentheses)

	Single polynomial equation		Simultaneous equations	
	SO_2	**PM_{10}**	**SO_2**	**PM_{10}**
Intercept	18.21882	15.57414	173.5490	236.0215
log(per capita GDP)	3.0681 (0.2204)	1.1648 (0.1651)	19.8546 (0.7046) White 0.7104	26.326 (1.3796) White −1.7191
(log(per capita GDP))^2	−3.7415 (−0.2536)	−0.7097 (−0.0949)	−27.159 (−0.6346) White −0.9870	−37.3356 (−1.2883) White 2.0665
log(abatement expense)	−0.1101 (−0.6007)	0.0203 (0.2191)	0.1265 (0.1650) White 0.6250	0.3384 (0.6516) White 0.8317
log(secondary industry share)	0.5700 (0.3204)	0.5655 (0.6273)	2.0301 (0.3798) White 1.1930	3.4048 (0.9406) White 1.0077
log(population density)	−5.6719 (−0.2948)	−2.1758 (−0.2232)	−34.403 (−0.4257) White 1.4629	−42.824 (−0.7824) White −0.7754
log(motor vehicles)	−0.3288 (−0.0307)	0.7002 (0.1289)	15.836 (0.3515) White −1.6756	23.742 (0.7782) White −0.0177
Time trend, *T2*	0.2618 (1.0621)	0.0815 (0.6522)	0.5336 (0.6369) White −0.7202	0.4703 (0.8289) White −0.4204
Time trend, *T3*	0.3725 (0.7423)	0.2015 (0.7925)	1.0351 (0.5218) White −0.6732	1.1900 (0.8859) White −0.1105
Time trend, *T4*	0.2334 (0.3268)	−0.1078 (−0.2978)	1.2237 (0.4210) White −0.5028	1.3680 (0.6950) White −0.0843
Adjusted *R*-square	0.7256	0.3187	0.6965	−0.3461
Hausman test for exogeneity (*F*-statistic)	–	–	10.5153	3.1926
Turning point	0.4100	0.8206	0.3655	0.3526
BG LM test	–	–	0.0197	0.2684
Ramsey reset test	–	–	0.1280	0.1053
Chow test	–	–	1.0617	0.7213

Table 3 Regression results: estimated results for air and water pollutants [Equation (1)] (*t*-statistics in parentheses)

	Single polynomial equation		Simultaneous equations	
	CO	**O**	**CO**	**O**
Intercept	229.2427	78.1112	89.1727	229.9870
log(per capita GDP)	−1.9372 (−0.1059)	−1.0508 (−0.1885)	−4.0498 (−0.1058) White −1.0391	10.2251 (0.7561) White −1.7851
$(\log(\text{per capita GDP}))^2$	−8.5496 (−0.4408)	−2.7080 (−0.4584)	−3.0078 (−0.0518) White 1.3102	−21.9872 (−1.0705) White 1.8557
log(abatement expense)	0.0833 (0.3458)	0.0540 (0.7364)	−0.3298 (−0.3167) White 4.7703	0.2718 (0.7384) White 0.5084
log(secondary industry share)	5.0573 (2.1622)	2.1743 (3.0515)	4.6453 (0.6400) White 0.1227	4.3354 (1.6901) White 1.0983
log(population density)	−41.5185 (−1.6416)	−14.7214 (−1.9107)	−15.8505 (−0.1444) White −2.4276	−42.4565 (−1.0946) White 3.0461
log(motor vehicles)	21.9925 (1.5601)	7.3372 (1.7085)	8.2269 (0.1345) White 2.0655	23.0138 (1.0644) White −2.1142
Time trend, *T*2	0.5122 (1.5805)	0.2066 (2.0926)	0.2454 (0.2156) White 3.2121	0.4819 (1.1985) White −0.9785
Time trend, *T*3	1.1714 (1.7755)	0.3539 (1.7608)	0.5979 (0.2219) White 3.4750	1.0480 (1.1009) White −0.4770
Time trend, *T*4	1.5047 (1.6026)	0.3730 (1.3042)	0.6695 (0.1696) White 3.6434	1.4002 (1.0037) White −0.3044
Adjusted *R*-square	0.2332	0.4590	0.0949	0.1406
Hausman Test for exogeneity (*F*-statistic)	–	–	8.1682	5.1838
Turning point	(0.1133)	(0.1940)	(0.6732)	0.2325
BG LM test	–	–	1.2479	0.2247
Ramsey reset test	–	–	0.2568	0.0907
Chow test	–	–	1.6422	0.2204

Table 4 Regression results: estimated results for air and water pollutants [Equation (1)] (*t*-statistics in parentheses)

	Single polynomial equation		Simultaneous equations	
	NO	**AS**	**NO**	**AS**
Intercept	32.8991	−235.8941	−386.6431	−108.3967
log(per capita GDP)	10.8362 (0.5999)	19.2564 (0.5744)	51.5974 (1.1944) White 1.1228	58.8377 (0.8744) White −0.3166
(log(per capita GDP))^2	−10.8957 (−0.5691)	4.0732 (0.1146)	−36.4016 (−0.5548) White −1.0011	−39.9935 (−0.3914) White 0.5081
log(abatement expense)	0.0003 (0.0013)	0.0899 (0.2036)	−0.8706 (−0.7406) White 0.6503	0.4445 (0.2427) White 3.7647
log(secondary industry share)	1.7649 (0.7644)	−6.7912 (−1.5846)	−3.1568 (−0.3853) White −0.6388	−6.8833 (−0.5393) White 0.6185
log(population density)	−7.9015 (−0.3165)	38.9377 (0.8402)	66.3549 (0.5355) White −2.8891	14.0882 (0.0730) White −1.9141
log(motor vehicles)	2.2815 (0.1640)	−24.5781 (−0.9515)	−38.0844 (−0.5514) White 1.9256	−10.7440 (−0.0999) White 1.4150
Time trend, *T2*	0.1368 (0.4278)	−0.5795 (−0.9759)	−0.7079 (−0.5511) White 1.0779	−0.3789 (−0.1894) White 0.7877
Time trend, *T3*	0.1930 (0.2964)	−1.5189 (−1.2565)	−1.7004 (−0.5592) White 0.9469	−1.0299 (−0.2174) White 0.6593
Time trend, *T4*	0.2792 (0.3012)	−2.1299 (−1.2381)	−2.4191 (−0.5429) White 1.1519	−1.3651 (−0.1967) White 0.7608
Adjusted *R*-square	0.0890	0.1292	−0.4065	0.0533
Hausman test for exogeneity (*F*-statistic)	–	–	2.6951	2.3141
Turning point	0.4972	(2.3638)	0.7087	0.7356
BG LM test	–	–	0.4665	
Ramsey reset test	–	–	0.6749	0.2159
Chow test	–	–	0.3545	2.9725

Table 5 Regression results: estimated results for air and water pollutants [Equation (1)] (*t*-statistics in parentheses)

	Single polynomial equation		Simultaneous equations	
	CD	**BOD**	**CD**	**BOD**
Intercept	−2.3819	−12.2719	448.3516	−37.8905
log(per capita GDP)	56.8715 (1.7646)	1.3886 (2.1332)	115.3773 (1.6287) White −0.0843	1.9976 (1.1883) White 1.0424
(log(per capita GDP))^2	−34.6931 (−1.0156)	−0.5949 (−0.8622)	−110.8392 (−1.0302) White −0.3464	−0.0974 (−0.0382) White −1.1890
log(abatement expense)	0.6352 (1.4971)	−0.0264 (−3.0847)	1.6025 (0.8312) White 2.9429	−0.0682 (−1.4914) White −0.3548
log(secondary industry share)	−4.6362 (−1.1254)	−0.2929 (−3.5196)	−1.6773 (−0.1248) White 1.4839	−0.6255 (−1.9617) White −0.8768
log(population density)	−5.8386 (−0.1311)	2.8061 (3.1185)	−89.9059 (−0.4425) White −2.1708	7.4004 (1.5348) White 0.9763
log(motor vehicles)	−1.6261 (−0.0655)	−1.5432 (−3.0769)	45.0976 (0.3982) White 0.8573	−4.0924 (−1.5226) White −0.6125
Time trend, *T2*	−0.3917 (−0.6862)	−0.0311 (−2.6952)	0.3999 (0.1898) White 0.4181	−0.0801 (−1.6034) White 1.1838
Time trend, *T3*	−1.0139 (−0.8725)	−0.0751 (−3.2009)	0.8763 (0.1757) White 0.3408	−0.1909 (−1.6129) White 1.1399
Time trend, *T4*	−1.2386 (−0.7490)	−0.1079 (−3.2292)	1.5932 (0.2180) White 0. 4425	−0.2757 (−1.6000) White 1.0580
Adjusted *R*-square	0.4794	0.1433	0.3212	−0.5419
Hausman test for exogeneity (*F*-statistic)	–	–	8.3368	6.7598
Turning point	0.8196	1.1671	0.5205	10.2546
BG LM test				
Ramsey reset test			0.0474	0.2058
Chow test			1.7521	1.8187

Table 6 Estimated results for income equation [Equation (2)] (*t*-statistics in parentheses)

	log (GDP)	log (GDP)	log (GDP)	log (GDP)	log (GDP)
log SO_2	0.1665 (0.4300) White 0.6091				
log PM_{10}		−0.0035 (−0.0522) White −0.4962			
log CO			0.1170 (1.6174) White 2.6735		
log O				0.0960 (2.5240) White 0.3745	
log NO					−0.0433 (2.2442) White 2.0715
Intercept	−8.7097	−1.0585	−13.7309	−2.6658	0.3399
log(local labour)	−3.7092 (−0.6067) White −0.4454	−1.1328 (−2.7995) White 1.0819	−3.0961 (−2.0512) White −0.6090	−1.3072 (−3.1965) White 1.2882	−0.9811 (−2.0327) White 0.0147
log (foreign labour)	−0.6705 (−0.3887) White −0.6109	0.0661 (0.4884) White 1.6267	−1.0830 (−1.4630) White 1.9912	−0.1456 (−1.1371) White −0.5927	0.2533 (1.7483) White −0.1329
log(physical capital)	0.1595 (1.8919) White −0.7498	0.14033 (3.2036) White −1.1533	0.0799 (1.2488) White −2.1872	0.1106 (4.2214) White −1.3241	0.1819 (5.3082) White −1.3375
log(govt. spending)	0.2078 (2.1629) White 2.8970	0.2164 (6.7489) White 0.0938	0.2577 (3.3672) White −0.2169	0.2248 (6.8695) White 0.7227	0.2302 (5.8810) White −0.5947
log(foreign direct investment)	0.0343 (0.7424) White 0.9480	0.0158 (2.5218) White 0.0196	−0.0159 (−0.6707) White −1.4242	0.0153 (2.5481) White 0.7039	0.0155 (2.1772) White −0.0829
log(university students)	0.3001 (0.5683) White −1.9221	0.0921 (0.9574) White −1.2672	−0.3586 (−1.1457) White 0.6487	0.0172 (0.2390) White −0.6157	0.1490 (1.7904) White−0.2676
Time trend, *T2*	−0.1056 (−0.7539) White −3.1259	−0.0468 (−3.8813) White −1.3045	−0.0905 (−2.4607) White −1.2830	−0.0588 (−4.8029) White −0.3583	−0.0440 (−3.2579) White −0.7385
Time trend, *T3*	−0.1326 (−0.6364) White −3.3239	−0.0442 (−2.0541) White −1.4353	−0.1230 (−2.0952) White −1.5365	−0.0565 (−3.5845) White −0.3332	−0.0381 (−2.0978) White −0.3189
Time trend, *T4*	−0.1259 (−0.7468) White −1.9922	−0.0587 (−2.7525) White −0.6012	−0.1639 (−2.0217) White −1.4887	−0.0632 (−2.8893) White −1.0929	−0.0467 (−1.7673) White −0.0512
Adjusted *R*-square	0.2372	0.9126	0.5481	0.9081	0.8704
BG LM test	0.1860	0.1046	0.4115	0.1424	0.0555
Ramsey reset test	1.1305	8.4243	0.5229	12.9410	4.7618
Chow test	4.9258	3.9532	2.0844	2.5135	2.8809

Table 7 Estimated results for income equation [Equation (2)] (*t*-statistics in parentheses)

	log (GDP)	log (GDP)	log (GDP)
log CD	0.0360 (1.1702) White 0.5845		
log AS		0.0088 (0.4787) White 0.1315	
log BOD			–1.2260 (–3.0148) White –0.9078
Intercept	4.6668	–0.2576	5.8712
log(local labour)	–0.0809 (–0.0765) White –0.1186	–1.0587 (–2.5338) White 0.2980	–0.2495 (–0.4525) White 1.2110
log (foreign labour)	0.4727 (1.2519) White –0.1905	0.1382 (0.7378) White 0.0299	0.1590 (1.3370) White 0.8035
log(physical capital)	0.0527 (0.6550) White –0.4909	0.1352 (5.5978) White –0.1758	0.1263 (4.5170) White –0.1634
log(govt. spending)	0.0583 (0.4087) White –1.2190	0.1881 (2.7842) White –0.3185	0.3039 (6.3773) White 0.1672
log(foreign direct investment)	0.0364 (1.8717) White 0.2155	0.0199 (1.9362) White 0.4277	0.0086 (1.1705) White 0.3790
log (university students)	0.3335 (1.4562) White –0.1714	0.1441 (1.0822) White –1.0173	0.0548(0.7039) White –0.4068
Time trend, *T*2	0.0090 (0.1778) White 0.5188	–0.0387 (–1.8721) White –0.6986	–0.0623 (–4.4185) White –0.0844
Time trend, *T*3	0.0355 (0.4935) White 1.100	–0.0324 (–1.0753) White –0.6119	–0.0658 (–3.49016) White –0.4178
Time trend, *T*4	0.05781 (0.5558) White 1.2943	–0.0390 (–0.8462) White –0.1309	–0.0921 (–3.3283) White –0.2324
Adjusted *R*-square	0.8208	0.9128	0.8758
BG LM test	0.1954	0.1495	0.1870
Ramsey reset test	6.1133	7.6946	4.6451
Chow test	1.7053	10.1135	4.8259

at 5% level of significance, this study can proceeds without drop any of the variables. Breusch-Godfrey Serial Correlation LM test has been used by this study to test the error terms are not correlated with each other. Autocorrelation found in air pollutant equation for CO, NO_2, CD, AS and BOD, income equations for CO, NO_2, PM_{10}, CD, AS and BOD in abatement equation. Autocorrelation also found in population density equation. To check whether this model suffer with autocorrelation due to specification error, this study proceed with the Ramsey Reset test. The result in Tables (2-11) shows that all the indicators of pollutants in pollutant equation do not suffer with specification error, whereas O, NO_2, PM_{10}, CD, BOD and AS in income equation, AS in abatement equation and CO, O, PM_{10} and CD in population density equation suffers with specification error which means that this study omit certain relevant variables. Because this study takes eight measures of indicators of pollutants and 34.4% from the measures showing specification error, this study can conclude that this model is not suffering from specification error problems. Therefore, this study can continue without adding any other relevant variables. Then, to check parameter instability

Table 8 Estimated results for abatement equation [Equation (3)] (*t*-statistics in parentheses)

	log (Abatement)	log (Abatement)	log (Abatement)	log (Abatement)	log (Abatement)
log SO_2	−2.1672 (−4.3752) White 1.6054				
log PM_{10}		−5.6953 (−2.0520) White 2.8597			
log CO			−1.8312 (−5.1158) White 4.6606		
log O				−5.2975 (−4.5760) White 3.805269	
log NO					−1.9913 (2.8929) White 5.7020
Intercept	−13.2840	28.1693	0.1702	−12.9137	−8.0141
log(secondary industry share)	−4.4877 (−2.0410) White −1.5625	5.4729 (2.8292) White −0.0427	3.0997 (2.5090) White −0.5469	2.8605 (2.3037) White 1.7565	3.0445 (2.0240) White −0.8013
log(physical capital)	2.4428 (3.0088) White −3.0953	0.8640 (0.9209) White 0.7278	0.3845 (0.6372) White −1.5979	1.0052 (1.5703) White −0.9415	1.4035 (1.5936) White 0.8178
Time trend, *T2*	0.5274 (1.3207) White −1.6642	0.25144 (0.4477) White 0.3644	0.1282 (0.3357) White 0.2112	0.3201 (0.8155) White −0.9596	0.1031 (0.2207) White 0.6877
Time trend, *T3*	0.8428 (1.9055) White −2.1349	0.9177 (1.1932) White 0.1197	0.2468 (0.6325) White −0.1949	0.0462 (0.1205) White −1.0071	0.1816 (0.3774) White 0.4654
Time trend, *T4*	0.67423 (1.5891) White 0.2104	−0.8494 (−1.4257) White −0.8264	0.0252 (0.0659) White 0.0185	−0.6365 (−1.6465) White −0.7330	0.3464 (0.6872) White 0.2651
Adjusted *R*-square	0.1058	−0.8221	0.0476	0.0481	−0.3981
BG LM test	0.4139	1.4934	1.7655	0.4095	1.01840
Ramsey reset test	0.5831	1.1608	0.0474	1.5456	0.5521
Chow test	4.6841	0.2163	−1.3163	−0.2331	0.3579

Table 9 Estimated results for abatement equation [Equation (3)] (*t*-statistics in parentheses)

	log (Abatement)	log (Abatement)	log (Abatement)
log CD	0.7562 (3.5055) White 2.8888		
log AS		1.0049 (3.2497) White 4.3402	
log BOD			17.9747 (1.5004) White 1.1135
Intercept	1.6821	4.2064	−66.44684
log(secondary industry share)	1.1158 (0.7996) White −3.0163	2.7080 (1.9179) White −0.3665	3.7532 (2.8545) White −0.8482
log(physical capital)	−1.7848 (−2.3305) White 0.0105	−1.3337 (−1.7097) White 0.5842	−0.2510 (−0.3861) White 1.5357
Time trend, *T*2	0.1126 (0.2980) White −0.7440	−0.0071 (−0.0167) White −0.2469	−0.1615 (−0.4020) White 1.0843
Time trend, *T*3	0.0289 (0.0766) White −0.7513	−0.1013 (−0.2367) White −0.2463	−0.2358 (−0.5854) White 0.8721
Time trend, *T*4	−0.1247 (−0.3357) White −0.9162	−0.2255 (−0.5301) White −0.4055	−0.2777 (−0.6902) White 0.3059
Adjusted *R*-square	0.0907	−0.205329	−0.0782
BG LM test	3.4720	3.0323	4.3021
Ramsey reset test	1.1838	5.2245	1.8920
Chow test	1.6789	1.0228	1.1730

of the model, this study use Chow test to determine the existence of structural break. Tables (2-11) shows that only CD in pollution equation, SO_2, O, NO, PM_{10}, BOD and AS in income equation, and SO_2 in abatement equation and CO, O, PM_{10}, BOD in population density equation suffers with structural break. This indicates that the estimated parameters are not stable during the sample period of 1996 quarter one to 2002 quarter one. Parameter instability may happen when there is a structural change in the relationship between dependent and independent variables. This structural change may be due to external forces such as oil crisis and financial crisis or due to policy changes such as fixed exchange rate to flexible exchange rate. Malaysia suffers with financial crisis in the year 1996 and 1997. Because only minor indicators of air and water pollutants suffer with this problem, this study does not break the data into pre and post.

This study will also discuss the issue concerns the exogeneity of the log form of per capita GDP, its quadratic term and per capita pollution abatement expense. It has been shown in Tables (2-5) results of the Hausman test for exogeneity shows that the null hypothesis of exogeneity of these variables is statistically rejected in all cases. This study is referring to the *F*-test as more than one endogenous regressor is involved (Gujarati, 1995). Necessitating the two-stage least square method for estimating the simultaneous equations model in this study suggests that the simultaneous relationship between per capita income and per capita pollutant emission does exist in the dataset of Malaysia. By applying the two stages least square method, the coefficient of motor vehicles turns to be higher in PM_{10}. It shows that when 1% increases in number of motor vehicles used per capita emission will increase by 23.742%. In the case of per capita emission of SO_2, it shows that when 1% increases in number of motor vehicles used per capita emission of

Table 10 Estimated results for population density equation [Equation (4)] (*t*-statistics in parentheses)

	log (pop. density)	log (pop. density)	log (pop. density)	log (pop. density)	log (pop. density)
log SO_2	–0.1395 (–11.3588) White 2.1207				
log PM_{10}		0.0391 (0.2569) White 1.6401			
log CO			–0.0766 (–2.3331) White –1.8140		
log O				–0.3516 (–3.6414) White 2.6231	
log NO					–0.1395 (–3.0737) White 6.3473
Intercept	3.6181	4.0784	4.3106	3.4577	3.7401
Time trend, *T*2	0.0410 (2.1851) White –0.3802	0.0013 (0.0331) White 0.1732	0.0188 (0.5413) White –0.2981	0.0426 (1.2270) White –0.8311	0.0327 (0.8827) White 0.6251
Time trend, *T*3	0.0571 (3.0121) White –0.6713	0.0017 (0.0331) White –0.4577	0.0310 (0.8780) White –0.0850	0.0310 (0.9225) White –0.8783	0.0442 (1.1749) White 0.4021
Time trend, *T*4	0.0383 (2.0587) White 1.097117	0.0197 (0.5276) White 0.1649	0.0267 (0.7749) White –0.3847	–0.0129 (–0.3790) White –1.6045	0.0547 (1.4352) White –0.4341
Adjusted *R*-square	0.6939	–0.0977	–0.0460	0.0189	–0.1575
BG LM test	0.0984	85.207	18.1045	4.0038	3.3283
Ramsey reset test	2.2359	7.9721	12.4543	8.9559	1.0074
Chow test	1.0947	18.4351	19.5461	13.9604	12.8074

Table 11 Estimated results for population density equation [Equation (4)] (*t*-statistics in parentheses)

	log (pop. density)	log (pop. density)	log (pop. density)
log CD	0.0170 (1.1738) White –0.8956		
log AS		0.0071 (0.3196) White –5.0984	
log BOD			–0.0428 (–0.0410) White 0.3961
Intercept	4.3619	4.3106	4.4259
Time trend, *T*2	0.0054 (0.1558) White –0.0284	0.0054 (0.1544) White –0.0393	0.0054 (0.1546) White –0.0308
Time trend, *T*3	0.0109 (0.3134) White –0.0516	0.0109 (0.3107) White –0.0709	0.0109 (0.3110) White –0.0555
Time trend, *T*4	0.0164 (0.4724) White –0.0714	0.0164 (0.4682) White –0.0969	0.0164 (0.4687) White –0.0759
Adjusted *R*-square	–0.0784	–0.0976	–0.0954
BG LM test	48.8607	70.3940	75.0113
Ramsey reset test	7.4573	–	–
Chow test	22.3804	19.7870	20.8669

SO_2 will increase by 15.836%. This indicates that other main sources of pollution in Malaysia come from transportation. For population density, it shows that as one percent increase in population density, per capita pollution emission for SO_2 will decrease by 34.403%, per capita pollution emission for PM_{10} will decrease by 42.824%, per capita pollution emission for O will decrease by 42.4565% and per capita pollution emission for CD will decrease by 89.9059%. Using the simultaneous equation, the coefficient of population density turns to be higher and it shows that as population density increases pollution emissions reduces more compare to single polynomial equation. This indicates that people are very aware of pollution.

On the basis of the aforementioned discussions, before directly regressing environmental Kuznets curve in future studies, it is necessary to consider the simultaneity between income and pollution. This study finds that the differences between the single polynomial equation model and the simultaneous equations model do exist.

On the basis of the estimated results of income and abatement equations in Tables (6-11), most of the estimated coefficients are significant and consistent with the expected signs. In the income equation, physical capital and foreign labour majority contribute positively to the GDP. In the other hand, local labour majority contribute negatively to the GDP in the equation. This indicates that foreign labour is one of the determinants of economic growth in Malaysia compare to local labour. This is true as prior to the Asian financial crisis; the economy in Malaysia continues to be in a full employment situation. The tight labour market spread to the manufacturing and services sectors. This attracted the influx of both legal as well as illegal foreign workers. Total foreign workers rose from 4% of total employment in 1990 to about 10.7% in 1997 and 9% in 2001. As on July 2004, there are about 1.3 million registered foreign workers, constituting 12% of total employment in the country. As an immediate solution to the problem, foreign workers are allowed to be employed in the plantation, construction and selected services sectors as well as the manufacturing sector. This is to avoid disruption to the economic growth process (Economic Report 2004/2005, Ministry of Finance Malaysia).

The contribution of human capital in production is not significant in the model although labour is an important factor in production. This indicates that the economic development in Malaysia relies primarily on capital-intensive industries. The evidence can be seen in income equation, in which there is a positive significant relationship between physical capitals per capita with economic growth. This is true as Malaysian economic growth was stimulated by investment, with capital accumulation contributing more than 50% to productivity growth (Wahab, 2002). The three indicators of pollutant emissions, PM_{10}, NO_2 and BOD are negatively related to the GDP and the two measures, NO_2 and BOD showing significant on income. This is consistent with the theory that as pollution level increases income decreases. Thus, this study can conclude that there is small significant feedback of air and water pollutants on income in Malaysia as NO_2 and BOD are the indicators that show significant feedback. It could be due to NO_2 and BOD is the main contributors of air pollutants that reduce income in Malaysia which mainly comes from industrial activities.

Besides these, the coefficients of government expenditure are positive and all are highly significant. This indicates that government spending contributes as one the main determinants of economic growth in Malaysia. However, according to Sinha (1998), there seems to be some evidence that government expenditure did not lead to the growth of GDP. The policy implication is that the present structure of government expenditure is not very conducive to economic growth. However, it is quite possible that a different structure of government expenditure can contribute more effectively to economic growth. Foreign direct investment also has a positive significant effect on income. Again it shows that foreign direct investment is one of the determinants that increase the economic growth in Malaysia. According to Tsen (2006), Foreign Direct Investment has contributed to high percentages of gross fixed capital formation in Malaysia. The contribution of FDI in gross fixed capital formation was 15.1% in the year 1997, 13.9% in the year 1998 and 20.1% in the year 1999. The stock of FDI in Malaysia has also increased over time. The amount increased to US dollar 10.3 billions in the year 1990 and US dollar 54.3 billions in the year 2000. Moreover, FDI has contributed to a high portion of GDP in Malaysia. The stock of FDI as a percentage of GDP in the year 1985 was 23.7%. The stock of FDI over GDP raised from 24.1% in the year 1990 to 65.3% in the year 1999. Generally, FDI plays an important role in the Malaysian economy. Meanwhile, most of the coefficient of university graduates positively and significantly contributes to economic growth in Malaysia. According to Zin (2005), rapid economic growth increased demands for educated labor resulting massive expansion in school enrolment, which leads to an increase in competitiveness of educated worker in the labour market resulting higher income and higher economic growth.

Secondary industry share and the physical capital are another two critical determinants of the pollution abatement expense. According to Shen (2006), the heavier the weight of the secondary industry is the more pollution abatement expense would be needed. More physical capital leads to more pollution abatement expenses available. The result from this study shows that it follows the theory that there is a positive significant relationship between secondary industry share and pollution abatement expense. It can be seen that most of the coefficients of physical capital having a positive relationship with pollution abatement expense. This indicates that the higher the physical capital is the higher the pollution abatement expenses are. Because of this, to keep sustainable growth in the long run for the Malaysian economy, more pollution abatement investments are required even though pollution is not the main contributor that reduces income in Malaysia. Turning to the fourth equation that is population density equation, most of the coefficients of air pollution indicators show significantly on population and all of it having a negative relationship except for PM_{10}. This indicates that as pollution emission increases, population density reduces in Malaysia. Pollution can affect our health in many ways with both short-term and long-term effects. Examples of short-term effects include irritation to the eyes, nose and throat and upper respiratory infections such as bronchitis and pneumonia. Long-term health effects can include chronic respiratory disease, lung cancer, heart disease and even damage to the brain, nerves, liver or kidneys (www.lbl.gov/Education/ELSI/Frames/pollution-health-effects-f.html).

5 Conclusions

It is clear from the previous literature survey that for the existing empirical EKC studies is that, as mentioned by Shen (2006) pollution is viewed only as the outcome of economic growth although in many theoretical models pollution is assumed as both an input and a by-product of production. There is no feedback effect from pollution to economic growth as these studies are based on a single polynomial equation in which there is no simultaneous relationship between these two variables. However, through the loss of workdays due to health problem or restriction of environmental input's supply caused by pollution, pollutant emission may reduce production. Therefore, it might probably produce biased and inconsistent estimates by estimating the relationship only by a single polynomial equation as the economic growth and the environmental quality are jointly determined. On the basis of this view, to use a simultaneous equations model for the estimation of this study is therefore more appropriate. By taking into consideration government pollution abatement expenses and population density as an endogenous variables on pollution, there are no empirical studies on Malaysia that estimate the EKC using simultaneous equation method with the inclusion of these endogenous variable. In conclusion, a formulation of a simultaneous equations model between per capita GDP and per capita pollutant emission will be constructed by this study. To estimate the relationship between per capita income and various environmental indicators, as can be reviewed most of the previous EKC studies focus on using the cross country panel data. However, it is a new trend for EKC researchers moving from a cross-country study to an individual country's cross-region study. This is due to the latter one can allow more being learned from an examination in an individual country and also will eliminate the problems associated with cross-country data. Therefore, a formulation of a simultaneous equations model between per capita GDP and per capita pollutant emission will be done by this study based on individual country time series data by extending the model to include variables such as number of motor vehicles, number of university graduates, excluded secondary industry share from income per capita, foreign direct investment, government spending and separated between foreign labour and local labour as compared to previous literature by Vincent (1997). This study also adding population density as an endogenous variables and formulate four simultaneous equations as compared to Shen (2006).

This study put a recommendation for a future studies to include variables such as solid waste treatment, hazardous waste and noise in the city. These variables are all important to residents as the environment exerts an all-round influence apart from air pollution and water quality. Therefore, in any of these directions a further extension could be made.

References

Ab, W.M. (2002). 'Total Factor Productivity Growth: Survey Report', e-Books on Industry and Services, APO.

de Bruyn, S.M. (2000). 'Economic Growth and the Environment: An Empirical Analysis', Kluwer Academic Publishers, 2000, Dordrecht, Netherlands.

Economic Report 2004/2005. Ministry of Finance Malaysia. http://www2.treasury.gov.my/pdf/economy/er/0405/chapter1.pdf (accessed on 21 May 2008).

Elsadig, M.A. (2008). 'Green Productivity: Applications in Malaysia's Manufacturing Sector', Universiti Putra Malaysia Press, 21.

Grossman, G.M. & Krueger, A.B. (1995). 'Economic growth and the environment', *Quarterly Journal of Economics* Vol. 112, pp. 353-378.

Gujarati, D.N. (1995). 'Basic Econometrics', 3rd ed., McGraw-Hill International Editions, Singapore.

Hung, M. & Shaw, D. (2004). 'Economic Growth and the Environmental Kuznets Curve in Taiwan: A Simultaneity Model Analysis' http://www.sinica.edu.tw/econ/dshaw/download/ekc.pdf (accessed on 19 January 2007).

Lopez, R. (1994). 'The environment as a factor of production: the effects of economic growth and trade liberalization', *Journal of Environmental Economics and Management* Vol. 27, pp. 163-184.

Panayotou, T. (1993). 'Empirical tests and policy analysis of environmental degradation at different stages of economic development', World Employment Programme Research, Working Paper 238.

Raja Dato' Zaharaton binti Raja Zainal Abidin. (2004). 'IWRM implementation realities in Malaysia', http://www.epu.jpm.my/New%20Folder/speech/kpspeech/IWRM%20Implementation%20Realities%20in%20Malaysia%20Slides.pdf (accessed on 19th September 2007).

Shafik, N. & Sushenjit, B. (1992). 'Economic growth and environmental quality: time series and cross section evidence', World Bank working paper.

Shen, J. (2006). 'A simultaneous estimation of environmental Kuznets curve: evidence from China', *China Economic Review* Vol. 17, pp. 383–394.

Sinha, D. (1998). 'Government expenditure and economic growth in Malaysia', *Journal of Economic Development* Vol. 23, No. 2. pp. 71-80.

Tsen, W.H. (2006). 'Foreign direct investment in manufacturing industry in Malaysia: an empirical study', Unitar E-Journal Vol. 2, No. 2.

Tun Dr. Mahathir bin Mohamad. (1996). 'The Fifth Biennial International Association for Natural Gas and Vehicles Conference (NGV '96)' (accessed 12 September 2007).

Vincent, J. (1997). 'Testing for environmental Kuznets curves within a developing country', *Environment and Development Economics* Vol. 2, pp. 417-431.

Zhang, J. & Yang, Y. (2007). 'Economic Development and Environmental Protection in China'. http://www.anzsee.org/anzsee 2007papers/Abstracts/Zhang.Juyong.pdf (accessed on 4th January 2009).

Zin, R.H.M. (2005). 'Income distribution in east asian developing countries: recent trends', *Asian-Pacific Economic Literature* Vol. 19, No. 2, pp. 36-54.