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The Existence of Environmental Kuznets Curve: Is it a Methodological Fact?

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Abstract

Environmental Kuznets curve is believed to exist for some environmental indicators but not for others. Carbon dioxide, as a global pollutant, is also believed to be one among those indicators for which the environmental Kuznets curve hypothesis cannot be verified. Quadratic and cubic parametric models have been commonly used in the environmental Kuznets curve estimation. The models tend to fix the relationship, while curve estimations need flexibilities that can only be met non-parametrically as it leaves room for data to speak for themselves. This paper applies the Epanechnikov kernel function for local polynomial smoothing of emission-income relationships. The overall (panel) emission-income relationship is an inverted U-shaped curve. Each country, except Norway, has reached its unique turning point. Developing countries must adopt stricter antipollution policies to slow down environmental damages.

Keywords: Environmental Kuznets curve, nonparametric estimations, local polynomial smoothing, Epanechnikov kernel.

1. Introduction

Environmental Kuznets curve (EKC) hypothesis suggests that environmental degradation follows an inverted U-shaped pattern in relation to economic growth (Heerink, Mulatu, & Bulte, 2001; Kander, 2005). The relationship is named after Kuznets, (1955) who hypothesised that income inequality rises and then falls with economic development. Studies concerning environmental Kuznets curve started early 1990s with Grossman & Krueger's (1991) pathbreak study on the environmental effect of the North American Free Trade Agreement (NAFTA). Grossman & Krueger (1991) suggest three separate mechanisms through which a change in trade and foreign investment policy can affect the level of pollution and the rate of depletion of scarce environmental resources. These effects are also discussed from growth angle in Bousquet & Favard, (2005).

The *scale effect* in which pollution increases with trade and investment liberalization, if liberalization results into expansion of economic activities without changing the nature of those activities. The *composition effect* where, with trade liberalization, countries specialize in products of their competitive advantage. If competitive advantage is a result of differences in environmental regulations, then composition effect of trade liberalization will be damaging the environment. And as Dasgupta, Laplante, Wang, and Wheeler (2002) assert, with stricter environmental regulations, more developed nations will experience capital outflow due to high environmental standards that producers are required to meet. Enterprises will tend to invest in developing nations where environmental regulations are more loser. To prevent capital outflow, developed nations will have to reduce their strictness which will altmately increase pollution in both developed and developing nations (Dasgupta, Laplante, Wang, & Wheeler, 2002). Thus, protecting the capacity of ecological systems to sustain welfare is of as much importance to poor countries as it is to those that are rich (Arrow, et al., 1996). The *technique effect* is where environmental amenities improve with liberalization. In this case, competitive advantage is a result of advancement in technology.

Grossman & Krueger, (1995) argue that as output increases, new technologies that facilitate efficiency in production emerge, which in turn results into scarce resources conservation. Antle & Heidebrink, (1995) found a negative income-environmental amenities relationship at lower levels of income and a positive relationship at higher levels, implying more demand for quality environment at higher income levels. However, they also observed that for some environmental amenities, such as water quality, the relation is positive even at lower levels of income.

Developed economies moved from agriculture to heavy industrial production, and finally, to light manufacturing of services (Stern, 2004), suggesting a movement from low to high to low pollution levels. As Bousquet & Favard, (2005), point out that, the large share of services in Gross Domestic Product (GDP) in the post industrial phase of development could have a positive impact on the environment.

The hypothesised level of turning point indicates that most developing countries will continue to suffer low environmental quality for a long time. However, low-income countries may realize a turning point even at a low income level if stricter environmental regulations will be enforced. If governments are slowly responding to environmental pressures, communities, and non-governmental organizations may force polluters to produce to the optimal level of pollution. They may decide not to buy pollution-intencive products and thus force producers to improve the quality of the environment (Dasgupta, Laplante, Wang, & Wheeler, 2002).

Other studies, for example, Heerink, Mulatu, & Bulte, (2001) have focused on the relationship between income inequality and environmental quality. When income inequality decreases with average income, it is not possible to determine the sign of the variation for pollution, (Bousquet & Favard, 2005).

The curvature of pollution-income relationship is said to be determined by the scale of abatement cost. For pollution-income relationship to be inverse-U-shaped, pollution abatement cost must have increasing returns to scale (Andreoni & Levinson, 2001). Shafik (1994) found an iverse-U-shaped pollution-income relationship for annual deforestation, total deforestation, suspended particulate matter, ambient sulfur dioxide, and fecal coliform in rivers. The same result as in Mather, Needle, & Fairbairn's (1999) study for deforestation and income. They, however, contend that the existence of EKC does not mean that economic growth is the sole determinant.

Some environmental issues do not portray the environmental Kuznets curve. Mozumder, Berrens, & Bohara, (2006) found a positive relationship between income per capita and loss of biodiversity. Seppälä, Haukioja, & Kaivo-oja, (2001) rejected the EKC hypothesis for direct material flow and income per capita in industrialized countries. Even though, they still believe that, with large samples, the hypothesis may not been rejected.

Giannias, Liargovas, & Alexandrovich, (2003) study, identified countries in a four quadrant model. A group of countries that have attained high economic growth and high environmental quality is found in the first quadrant. The second quadrant consists of countries with low income but high environmental quality. Quadrant three is inhabited by countries which have low economic growth and low environmental quality. While quadrant four harbors countries whose economic growth is very high but the quality of the environment is low. They suggest that development and environmental policies should go hand in hand. However, their findings may have been influenced by model specification as Milliment, List, & Stengos, (2003), rejected the null hypothesis of EKC for parametric models in favor of the semiparametric models.

2. Methodology

2.1. Data

This study utilizes secondary data from ten countries for a period of thirty one years (that is, from 1980 to 2010), thus making a panel data. The countries involved in the analysis are, Austria, Chile, Colombia, Cuba, Denmark, Finland, Greece, Ireland, Norway, and Portugal. At first, two years (2009 and 2010) were omitted because Cuba lacked data in these observations. This aimed at making the panel a balanced one. But after ploting their GDP trends, three countries (Chile, Colombia, and Cuba) were removed in the final analysis. This aimed at running away from the outlier problem. After removing the three countries, two years (2009 and 2010) were reintroduced for the final analysis because the remaining countries had all the observations. Carbondioxide (CO2) emission is an environmental indicator which is used in this study. Both emission and income data have been extracted from the World Bank's, (2013) World Development Indicators.

2.2. Empirical Models

Most of the literatures reviewed in this study, have analyzed the environmental Kuznets curve for different environmental indicators using the parametric approach. Some have analyzed using quadratic functions (see Stern, 2003; Heerink, Mulatu, & Bulte, 2001) and others cubic functions (e.g. Shafik, 1994) who analyzed and tested the significance of the three models (linear, quadratic and cubic). In curve estimation, pure parametric thinking often does not meet the need for flexibility in data analysis (De Brabanter, De Brabanter, De Moor, & Gijbels, 2013). Using panel data, Milliment, List, & Stengos, (2003), analyzed the environmental Kuznets curve for sulfur dioxide and nitrogen oxide emissions basing on semiparametric approach. This study follows a nonparametric approach in analyzing the environmental Kuznets curve (EKC) for carbondioxide emission. Adopting the local polynomial smoothing model illustrated by Gutierrez, Linhart, & Pitblado, (2003), the current study's income and pollution variables have been considered as a set of scatter data $\{x_1, y_1, \ldots, x_n, y_n\}$ from the model

$$y_i = m(x_i) + \sigma(x_i)\varepsilon_i \qquad (1)$$

for some unknown mean and variance functions $m(\cdot)$ and $\sigma^2(\cdot)$, and symmetric errors ε_i with $E(\varepsilon_i) = 0$ and $Var(\varepsilon_i) = 1$. Without making any assumption about the functional form of $m(\cdot)$, we wish to estimate $m(x_0) = E\left[Y \mid X = x_0\right]$. For some x in the neighborhood of x_0, a Taylor expansion of $m(\cdot)$ gives

$$m(x) \approx \sum_{j=0}^{p} \frac{m^{(j)}(x_0)}{j!}(x - x_0)^j = \sum_{j=0}^{p} \beta_j (x - x_0)^j$$

That is, $m(x)$ can be approximated locally by a p^{th} order polynomial in $x - x_0$. Substituting the expression into equation (1), for x_i s local to x_0, $m(x_0)$ can be estimated as the constant term (intercept) of a regression of y_i on the polynomial terms $(x_i - x_0), (x_i - x_0)^2, \dots, (x_i - x_0)^p$.

To preserve the locality, we introduce a kernel function $K(\cdot)$, which is a probability density function that is symmetric about zero and a bandwidth *h* to control the degree of locality. Defining $\beta_j = m^{(j)}(x_0)/j!$ we can then estimate $\beta_0 = m(x_0)$ by minimizing in β_j the weighted least squires expression

$$\sum_{i=1}^{n} \left\{ y_i - \sum_{j=0}^{p} \beta_j (x_i - x_0)^j \right\}^2 K_h(x_i - x_0)$$

for $K_h(a) = h^{-1} K(a/h)$.

Consider model (1) expressed in matrix notations

$$\mathbf{y} = m(\mathbf{x}) + \varepsilon$$

where $\mathbf{y}$ and $\mathbf{x}$ are the $n \times 1$ vectors of scatter plot values of pollution and income, ε is the $n \times 1$ vector of errors with zero mean and covariance matrix $\boldsymbol{\Sigma} = \operatorname{diag}\{\sigma(x_i)\}\mathbf{I}_n$, and $m(\cdot)$ and $\sigma(\cdot)$ are some unknown functions as previously noted. We define $m(x_0) = E\left[Y \mid X = x_0\right]$ and $\sigma^2(x_0) = \operatorname{Var}\left[Y \mid X = x_0\right]$ to be conditional mean and conditional variance of random variable Y (residual variance), respectively, for some realization x_0 of random variable X.

The method of local polynomial smoothing is based on the approximation of $m(x)$ locally by a p^{th} order polynomial in $(x - x_0)$ for some x in the neighborhood of x_0. For the scatter plot data $\{(x_1, y_1), \dots, (x_n, y_n)\}$, the p^{th} order local polynomial smooth $\hat{m}(x_0)$ is equal to $\hat{\beta}$, an estimate of the intercept of the weighted linear regression,

$$\hat{\beta} = (\mathbf{X}^T \mathbf{W} \mathbf{X})^{-1} \mathbf{X}^T \mathbf{W} \mathbf{y} \tag{2}$$

where $\hat{\beta} = (\beta_0, \hat{\beta}_1, \dots, \beta_p)^T$, is the vector of estimated regression coefficients (with $\left\{\hat{\beta}_j = (j!)^{-1} \hat{m}^{(j)}(x)\big|_{x=x_0}, j = 0, \dots, p\right\}$ also representing estimated coefficients from a corresponding Taylor expansion); $\mathbf{X} = \left\{(x_i - x_0)^j\right\}_{i,j=1,0}^{n,p}$ is a design matrix; and $\mathbf{W} = \operatorname{diag}\left\{K_h(x_i - x_0)\right\}_{n\times n}$ is a weighting matrix with weights $K_h(\cdot)$ defined as $K_h(x) = h^{-1}(x/h)$, with $K_h(\cdot)$ being a kernel function and h defining a bandwidth. Assuming constant residual variance $\sigma^2(x_0) = \sigma^2$ and odd degree *p*:

$$\hat{h} = C_{0,p}(K) \left[\frac{\hat{\sigma}^2 \int w_0(x)\,dx}{n \int \left\{\hat{m}^{(p+1)}(x)\right\}^2 w_0(x) f(x)\,dx} \right]^{1/(2p+3)} \tag{3}$$

where $C_{0,p}(K)$, is a constant that depends on the kernel function $K(\cdot)$ and the degree of a polynomial and w_0 is chosen to be an indicator function on the interval $[\min_X + 0.05 \mathrm{X} \operatorname{range}_X, \max_X - 0.05 \mathrm{X} \operatorname{range}_X]$ with $\min_X$, $\max_X$, and range_X being, respectively, the minimum, maximum, and range of X. To obtain the estimates of a constant residual variance $\hat{\sigma}^2$ and $(p+1)^{th}$ order derivative of $\hat{m}(x)$, denoted as $m^{(p+1)}(x)$, a polynomial in X of order $(p+3)$ is fit globally to y, and $\hat{\sigma}^2$, is estimated as a standardized residual sum of squares from this fit.

The expression for the asymptotically optimal constant bandwidth used in constructing the ROT bandwidth estimator is derived for the odd-order polynomial approximations. For even-order polynomial fits, the expression would depend not only on $m^{(p+1)}(x)$ but also on $m^{(p+2)}(x)$ and the design density and its derivative $f(x)$ and $f'(x)$. Therefore the ROT bandwidth estimator would require estimation of these additional quantities. Instead, for an even-degree p of the local polynomial, the command uses the value of the ROT estimator (3) computed using degree $p+1$. As such, for even degrees this is not a plug-in estimator of the asymptotically optimal constant bandwidth.

The estimates of the conditional variance of local polynomial estimators are obtained using

$$\hat{V}\mathrm{ar}\left\{\hat{m}(x_0)\,\middle|\,X = x_0\right\} = \sigma_m^2(x_0) = \left(\mathbf{X}^T\mathbf{W}\mathbf{X}\right)^{-1}\left(\mathbf{X}^T\mathbf{W}^2\mathbf{X}\right)\left(\mathbf{X}^T\mathbf{W}\mathbf{X}\right)^{-1}\hat{\sigma}^2(x_0) \tag{4}$$

where $\hat{\sigma}^2(x_0)$ is estimated by the normalized weighted residual sum of squares from the $(p+2)th$ order polynomial fit using pilot bandwidth h^*.

When the bias is negligible the normal-approximation method yields a $(1-\alpha)\times 100\%$ confidence interval for $m(x_0)$,

$$\left\{\hat{m}(x_0) - z_{(1-\alpha/2)}\sigma_m(x_0),\ \hat{m}(x_0) + z_{(1-\alpha/2)}\sigma_m(x_0)\right\}$$

where $z_{(1-\alpha/2)}$ is the $(1-\alpha/2)th$ quintile of the standard Gaussian distribution, and $\hat{m}(x_0)$ and $\hat{\sigma}(x_0)$ are as defined in (2) and (4), respectively.

3. Empirical Findings

3.1. Variable Characteristics

Before undertaking the local polynomial smoothing, the study explores the trend of income for each country in the sample. Three countries, Chile, Colombia, and Cuba labeled as 2, 3 and 4, in Figure 1 are not included in the main analysis because their per capita GDP growth is very low compared to the rest of the countries in the sample. Including them, could have led into spurious results. The data have been transformed using logarithm to avoid ending up with abnormally larger bandwidths when undertaking the local polynomial smoothing. As it can be shown in Figure 2, using lowess smoother, which does not specify the kernel function, the shape of emission-income relationship of raw data is different from that of transformed data.

3.2 . Estimation Results

Using the second-order Epanechnikov kernel, the local polynomial smoothing is performed. The panel estimation results are identified as overal while time series estimation results refer to each country separately. The nonparametric density curve estimations are as depicted in Figure 3. As it is shown in Figure 3, the first box represents the panel estimation and it is an inverted U-shaped curve. There exists an environmental Kuznets curve (EKC) for Carbon dioxide emission in the selected sample. The kernel curve estimations show that six out of seven countries investigated have attained the level of income where emissions have started decreasing. This level of income is what this study has referred to as the turning point in Table 1. Denmark has shown a remarkable emission reduction, which could mean stricter environmental regulations. Other countries have started reducing emissions, except Norway. But there is hope that Norway's emission trend will start decreasing because other countries in the region demand quality air.

In Table 1, each country has a unique turning point, standard deviation, and a bandwidth. However, they both have the same constant used in bandwidth calculation. This is due to the fact that the study applied the same kernel function throughout and the same degree of a polynomial which this constant depends on.

4. Conclusions

The findings have shown that environmental Kuznets curve for carbon dioxide does exist. However, the result could have not materialized if careful sample selection was not carried out. The sample used for the final analysis involves European countries which have higher per capita income which means that using another sample could mean nonexistence of the EKC. For example, the inclusion of excluded three countries with low per capita income could have turned the curve into an inverted N curve. This is because though they have low per capita income, their carbon dioxide emission is very high.

The nonparametric, through Epanechnikov kernel, approach in this study might have something to do with the shape of the pollution-income relationship. So it follows that, careful sample selection and the estimation technique used might have determined the shape of the pollution-income relationship in this study. It is, therefore, important for developing countries to adopt strict antipollution policies because right now, even though their per capita income is very low, they are already suffering from severe environmental degradation resulting from carbon dioxide emissions. Natural realization of a turning point may take decades or may not materialize at all, making the adoption of stricter environmental regulations, in developing countries, an inevitable action.

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Author’s Biography

F. Dominick became a Tutorial Assistant, a position held for three consecutive years, at St. Augustine University of Tanzania since September, 2009. He was promoted to the position of Assistant Lecture soon after his postgraduate studies in September, 2012. The author was born in Tarime District of Mara Region on 24th June, 1982.

The author pursued primary education from 1991 to1997, at Kines A primary school in Rorya District. He undertook secondary education from 1999 to 2002 at Nyegina Secondary School in Musoma Rural District. He was then selected to join advanced secondary education from 2003 to 2005, at Tarime Secondary School in Tarime District. He joined St. Augustine University of Tanzania, in Mwanza city, for undergraduate studies, majoring in economics, from 2006 to 2009. The author joined the University of Dar es Salaam, in the City of Dar es Salaam, for postgraduate studies majoring in economics from 2010 to 2012.

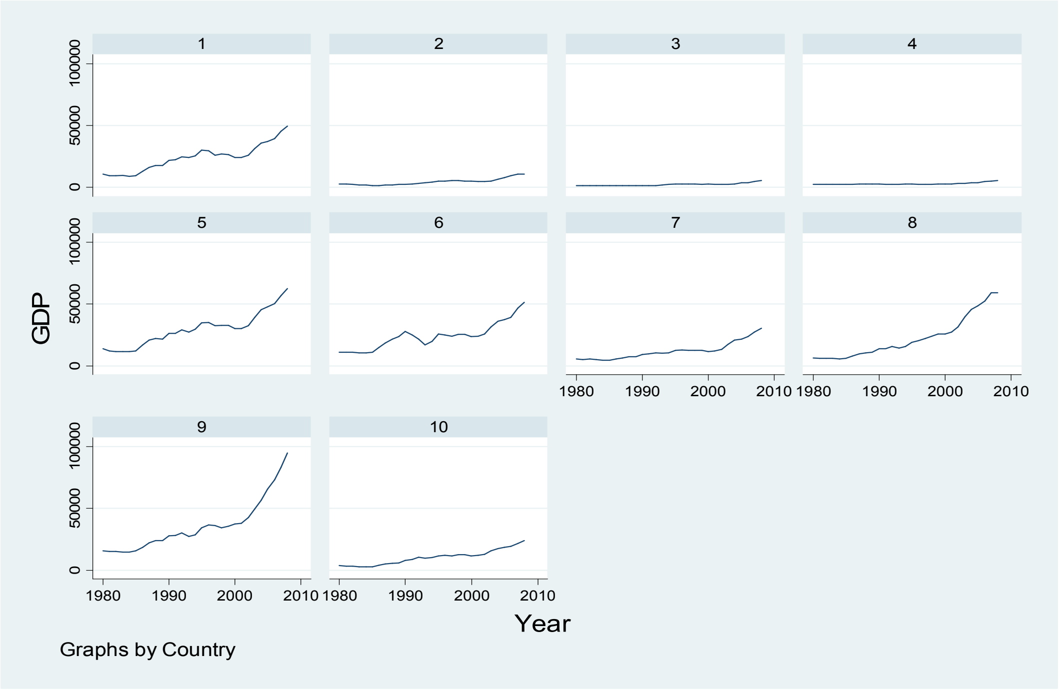


Figure 3. Per capita Income Trend by Country from 1980 to 2008
Where, 1=Austria, 2=Chile, 3=Colombia, 4=Cuba, 5=Denmark, 6=Finland, 7=Greece, 8=Ireland, 9=Norway and 10=Portugal

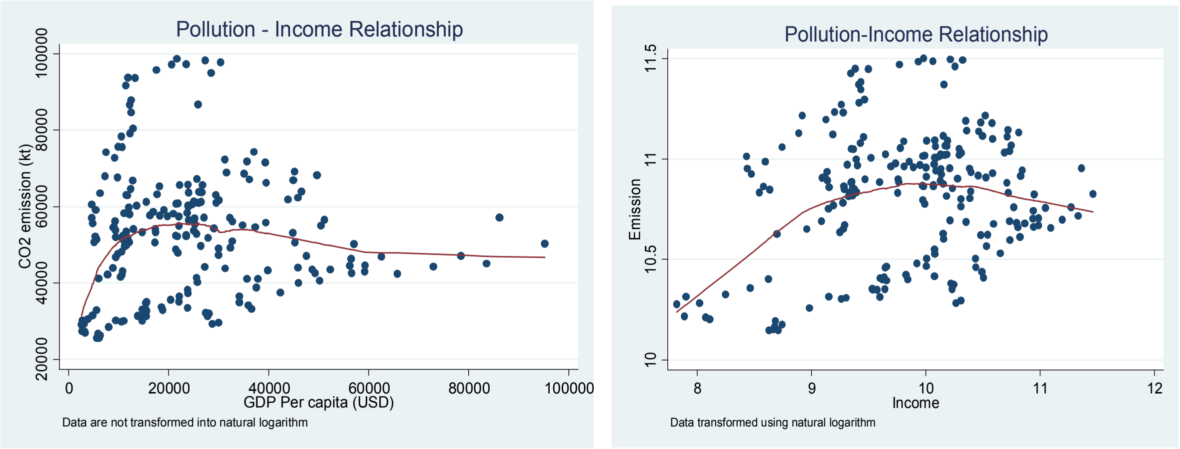


Figure 4. Lowess smoother for Raw and Transformed Data

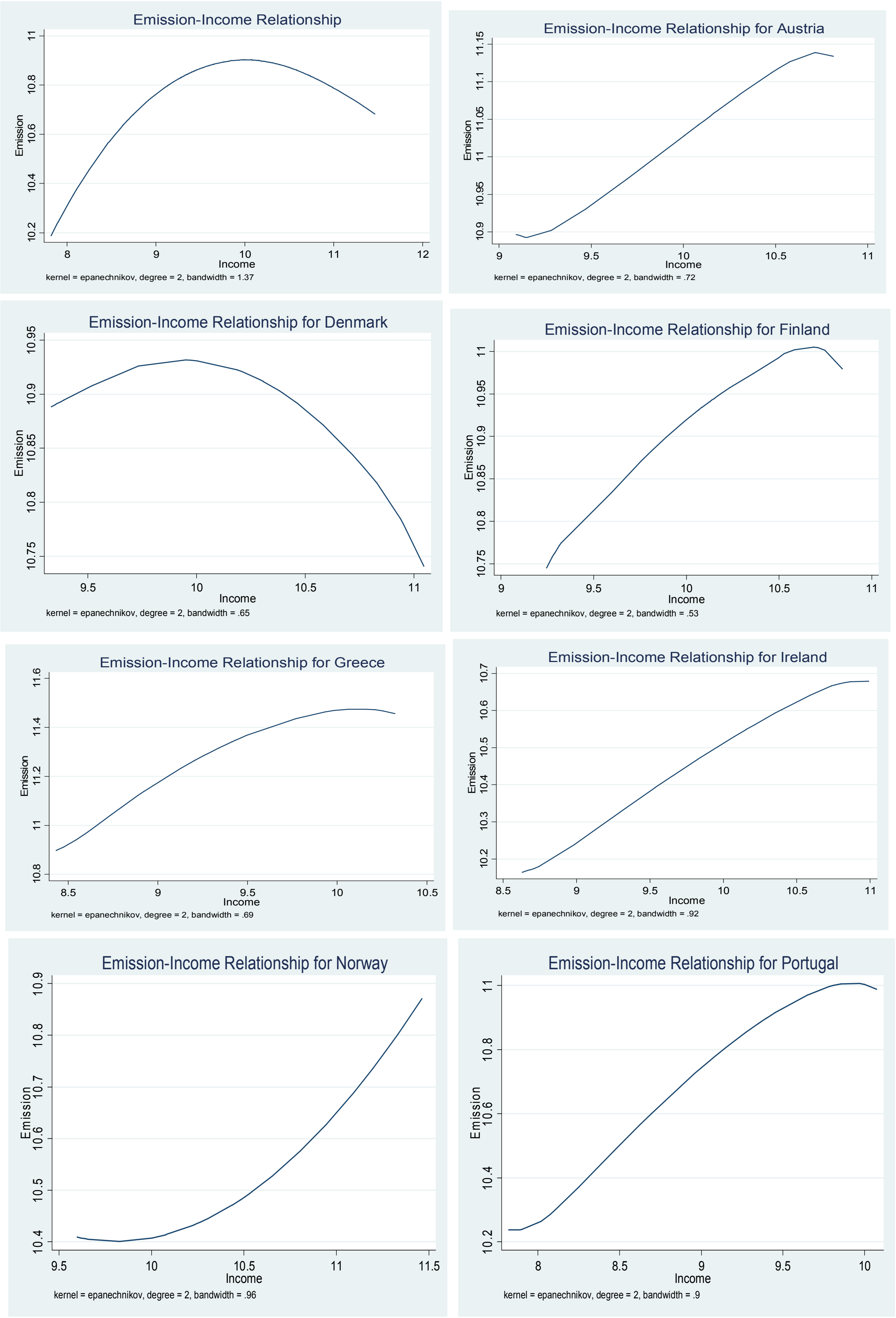


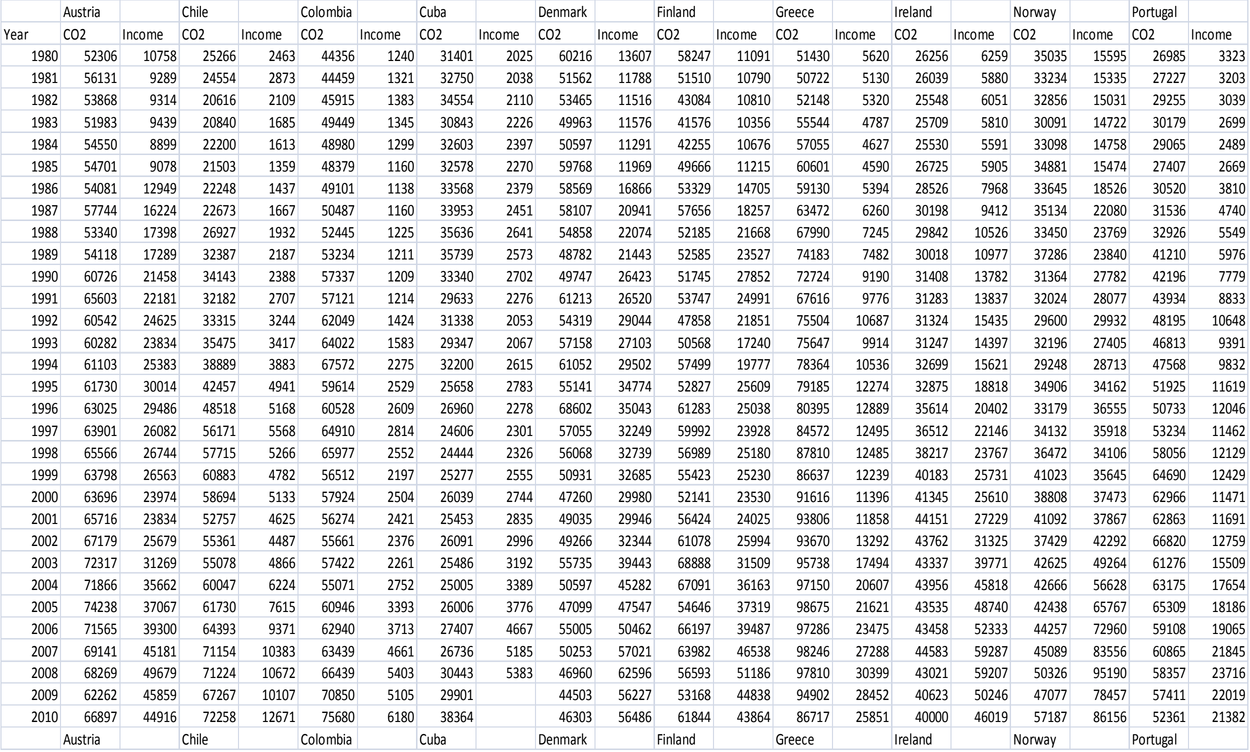
Figure 5. Non parametric Density curve Estimations (Environmental Kuznets Curves)

Table 7. Epanechnikov Kernel Estimation Results

Country	Bandwith	Constant	Standard Deviation	Turning Point (US$)
Overall	1.37	1.95	2.07	22,026
Austria	0.72	1.95	1.09	46,630
Denmark	0.65	1.95	0.98	22,026
Finland	0.53	1.95	0.80	44,356
Greece	0.69	1.95	1.05	24,343
Ireland	0.92	1.95	1.39	54,176
Norway	0.96	1.95	1.46	_____
Portugal	0.90	1.95	1.36	19,930

Source: Author's computation

Table 2. Data used for the analysis



	Austria		Chile		Colombia		Cuba		Denmark		Finland		Greece		Ireland		Norway		Portugal	
Year	CO2	Income	CO2	Income	CO2	Income	CO2	Income	CO2	Income	CO2	Income	CO2	Income	CO2	Income	CO2	Income	CO2	Income
1980	52306	10758	25266	2463	44356	1240	31401	2025	60216	13607	58247	11091	51430	5620	26256	6259	35035	15595	26985	3323
1981	56131	9289	24554	2873	44459	1321	32750	2038	51562	11788	51510	10790	50722	5130	26039	5880	33234	15335	27227	3203
1982	53868	9314	20616	2109	45915	1383	34554	2110	53465	11516	43084	10810	52148	5320	25548	6051	32856	15031	29255	3039
1983	51983	9439	20840	1685	49449	1345	30843	2226	49963	11576	41576	10356	55544	4787	25709	5810	30091	14722	30179	2699
1984	54550	8899	22200	1613	48980	1299	32603	2397	50597	11291	42255	10676	57055	4627	25530	5591	33098	14758	29065	2489
1985	54701	9078	21503	1359	48379	1160	32578	2270	59768	11969	49666	11215	60601	4590	26725	5905	34881	15474	27407	2669
1986	54081	12949	22248	1437	49101	1138	33568	2379	58569	16866	53329	14705	59130	5394	28526	7968	33645	18526	30520	3810
1987	57744	16224	22673	1667	50487	1160	33953	2451	58107	20941	57656	18257	63472	6260	30198	9412	35134	22080	31536	4740
1988	53340	17398	26927	1932	52445	1225	35636	2641	54858	22074	52185	21668	67990	7245	29842	10526	33450	23769	32926	5549
1989	54118	17289	32387	2187	53234	1211	35739	2573	48782	21443	52585	23527	74183	7482	30018	10977	37286	23840	41210	5976
1990	60726	21458	34143	2388	57337	1209	33340	2702	49747	26423	51745	27852	72724	9190	31408	13782	31364	27782	42196	7779
1991	65603	22181	32182	2707	57121	1214	29633	2276	61213	26520	53747	24991	67616	9776	31283	13837	32024	28077	43934	8833
1992	60542	24625	33315	3244	62049	1424	31338	2053	54319	29044	47858	21851	75504	10687	31324	15435	29600	29932	48195	10648
1993	60282	23834	35475	3417	64022	1583	29347	2067	57158	27103	50568	17240	75647	9914	31247	14397	32196	27405	46813	9391
1994	61103	25383	38889	3883	67572	2275	32200	2615	61052	29502	57499	19777	78364	10536	32699	15621	29248	28713	47568	9832
1995	61730	30014	42457	4941	59614	2529	25658	2783	55141	34774	52827	25609	79185	12274	32875	18818	34906	34162	51925	11619
1996	63025	29486	48518	5168	60528	2609	26960	2278	68602	35043	61283	25038	80395	12889	35614	20402	33179	36555	50733	12046
1997	63901	26082	56171	5568	64910	2814	24606	2301	57055	32249	59992	23928	84572	12495	36512	22146	34132	35918	53234	11462
1998	65566	26744	57715	5266	65977	2552	24444	2326	56068	32739	56989	25180	87810	12485	38217	23767	36472	34106	58056	12129
1999	63798	26563	60883	4782	56512	2197	25277	2555	50931	32685	55423	25230	86637	12239	40183	25731	41023	35645	64690	12429
2000	63696	23974	58694	5133	57924	2504	26039	2744	47260	29980	52141	23530	91616	11396	41345	25610	38808	37473	62966	11471
2001	65716	23834	52757	4625	56274	2421	25453	2835	49035	29946	56424	24025	93806	11858	44151	27229	41092	37867	62863	11691
2002	67179	25679	55361	4487	55661	2376	26091	2996	49266	32344	61078	25994	93670	13292	43762	31325	37429	42292	66820	12759
2003	72317	31269	55078	4866	57422	2261	25486	3192	55735	39443	68888	31509	95738	17494	43337	39771	42625	49264	61276	15509
2004	71866	35662	60047	6224	55071	2752	25005	3389	50597	45282	67091	36163	97150	20607	43956	45818	42666	56628	63175	17654
2005	74238	37067	61730	7615	60946	3393	26006	3776	47099	47547	54646	37319	98675	21621	43535	48740	42438	65767	65309	18186
2006	71565	39300	64393	9371	62940	3713	27407	4667	55005	50462	66197	39487	97286	23475	43458	52333	44257	72960	59108	19065
2007	69141	45181	71154	10383	63439	4661	26736	5185	50253	57021	63982	46538	98246	27288	44583	59287	45089	83556	60865	21845
2008	68269	49679	71224	10672	66439	5403	30443	5383	46960	62596	56593	51186	97810	30399	43021	59207	50326	95190	58357	23716
2009	62262	45859	67267	10107	70850	5105	29901		44503	56227	53168	44838	94902	28452	40623	50246	47077	78457	57411	22019
2010	66897	44916	72258	12671	75680	6180	38364		46303	56486	61844	43864	86717	25851	40000	46019	57187	86156	52361	21382
	Austria		Chile		Colombia		Cuba		Denmark		Finland		Greece		Ireland		Norway		Portugal	

Source: World Bank (2013) World Development Indicators

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