Evaluation of Current Environmental Kuznets Curve Model with New Indicators

Yuang Liu

University of California Irvine, Irvine, USA

Abstract. The Environmental Kuznets Curve was introduced by Grossman and Krueger in 1991, which implies a dynamic relationship between different indicators of environmental degradation and per capita income. In general, the curve suggests that a country's economic growth initially leads to environmental degradation. After per capita income of the country reaches certain stages, the relationship reverses （economic growth leads to progressions of environmental quality）. This curve has been a dominant modeling for economists investigating relationship between ambient pollution and social developments, and it seems guarantee future reduction in pollutant-emissions of developing countries. This study will focus on air pollution problems in developing countries and investigate whether the trend described by EKZ Curve holds constant with different environmental and social indicators like HDI, AQI and GDP.

Keywords: Environmental Kuznets Curve, Human development Index, Air quality Index

1. Introduction

According to the data from Global Change Data Lab more than 6.67 million people died from ambient pollution on this planet in 2019, and Global Burden of Disease study shows that 4506193 people died outdoor air pollution in the latest year (Hannah Ritchie and Max Roser, 2022). Developing countries face a much greater extent of pollution level than developed countries: in developed countries, more than 56% citizens live in polluted environments exceeds the WHO guidelines, while this number increased to 98% in developing countries. The huge pollution coverage seriously jeopardizes the health and life safety of local citizens.

Pollution also brings a latent economic burden to a country's economy, since polluted work space and diseases from unclear environments reduce returns of stock markets and productivity of employee. According to the data from Greenpeace, air pollution induces a cost of $2.9 trillion in 2018, which is 3.3 percent of the world GDP. For developing countries like China and India, outdoor and indoor air pollutions caused more than 5 percent GDP cost in 2018, which is a disaster (Niall McCarthy, 2020).

Pollution has caused such a huge loss of human life and property, which has led to growing calls for real actions for reducing pollutant emissions. As global economy progressing in a faster and faster pace, environmental quality is not developing with economic growth for most developing countries. The Environmental Kuznets Curve hasn't seemed to reach its peak yet, or the curve itself has some bind spots in evaluating economic stages of countries. Today economists have to re-examine applicability and comprehensiveness of the curve to ensure that government sectors which rely on this curve are not wasting their resources on a misleading theory.

A theory cannot achieve comprehensiveness and pertinence at the same time, but a systematical method especially focus on special social and economic features of countries is still in demand. Considering different indicators of countries help perfecting the theory as well as preventing the theory to be too general to be effective. In this paper, I evaluate different social indicators to see whether current economies still follow the path described by Environmental Kuznets Curve.

Background Information: an overview of current air pollution issues in developing countries.

The term air pollution can be further divided into two kinds of pollution: outdoor pollution and indoor pollution. Outdoor pollution mostly derives from activities like combustion, fuel-burning, and industries. Indoor pollution mostly derives from burning of inefficient solid fuels. For developing countries which are largely dependent on industries to energize local economy and have poor technologies to make clean fuels accessible, these two kinds of pollution are unavoidable difficulties on their path of economic development. Local industrialization created two main pollutants: Ozone (O3) and particular matter (PM 2.5), which are the main incentives of local environmental degradation and respiratory diseases. Outdoor and indoor pollution lower GDP by reducing labor efficiency, which means harmful

working environment leads to failure of concentration and absence of employee. Pollutions also damage social welfare by accelerating systematic organ failure for adults and hindering infants' cognitive functions like attention and memory.

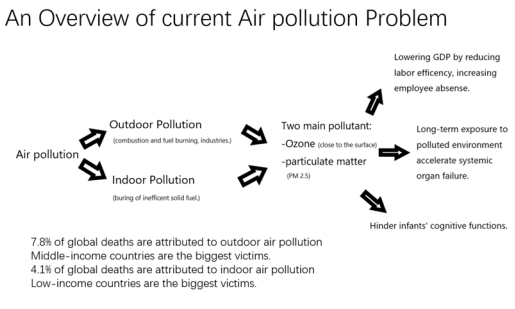


Fig.1 There is no doubt that investigating solutions to air pollution is pressing.

Air pollution problems in developing countries are not only substantial obstacles to the local economy but also hidden dangers to the health of citizens. There is no doubt that investigating solutions to air pollution is pressing.

2. Data

2.1 Human Development Index (HDI)

HDI is a new standard of economic development of a country, which measures three new dimensions of social welfare: life expectancy, education, and gross national income per capita (GNI per capita). HDI captures key issues of social development in a developing country, which makes it an important indicator to consider the stage of social development. We believe that an ideal indicator of social welfare should own these features and consider dimensions other than money.

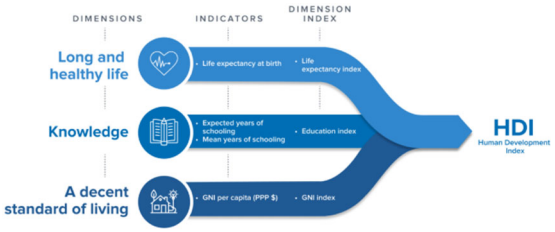


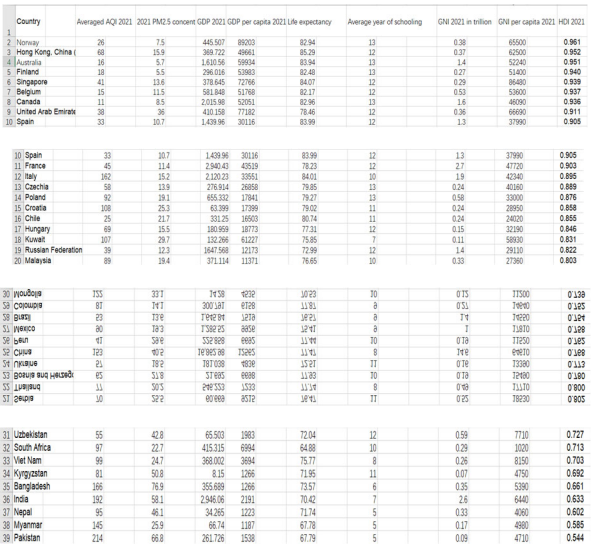
Fig.2 Human Development Index (Derived from https://hdr.undp.org/data-center/human-development-index#/indicies/HDI).

2.2 Air Quality Index (AQI)

Air quantity index (AQI) is developed by the U.S. Environmental Protection Agency (EPA) as a better standard, compared to air pollution index API), to monitoring air pollution. AQI contains SO2、NO2、PM10、PM2.5、O3、CO in the assessment, which considers six kinds of pollutants in total, while API contains SO2、NO2 and PM10 in it assessment, which considers only three kinds of pollutants. In conclusion, AQI adopts stricter standards, more pollutant indicators, and higher release frequency, and its evaluation results will be closer to the real feelings of the public.

2.3 Data collection

The dataset of 39 countries is collected for year 2021 from various international organizations and local government sectors. Including World Health Organization (WHO), United Nation's Economic, World Economic, International Monetary Fund (IMF), World Bank and Global Change Data Lab (GCDL). All monetary data in the study are calculated in current value of USA dollars.



	Country	Averaged AQI 2021	2021 PM2.5 concent	GDP 2021	GDP per capita 2021	Life expectancy	Average year of schooling	GNI 2021 in trillion	GNI per capita 2021	HDI 2021
1										
2	Norway	26	7.5	445.507	89202	82.94	13	0.38	65500	0.961
3	Hong Kong, China (	68	15.9	369.722	49661	85.29	12	0.37	62500	0.952
4	Australia	16	5.7	1,610.56	59934	83.94	13	1.4	52240	0.951
5	Finland	18	5.5	296.016	53863	82.48	13	0.27	51400	0.940
6	Singapore	41	13.6	378.645	72766	84.07	12	0.29	86480	0.939
7	Belgium	15	11.5	581.848	51768	82.17	12	0.53	53600	0.937
8	Canada	11	8.5	2,015.98	52051	82.96	13	1.6	46090	0.936
9	United Arab Emirate	38	36	410.158	71182	78.46	12	0.36	66690	0.911
10	Spain	33	10.7	1,439.96	30116	83.99	12	1.3	37990	0.905
10	Spain	33	10.7	1,439.96	30116	83.99	12	1.3	37990	0.905
11	France	45	11.4	2,940.43	43519	78.23	12	2.7	47720	0.903
12	Italy	162	15.2	2,120.23	35551	84.01	10	1.9	42340	0.895
13	Czechia	58	13.9	276.914	26858	79.85	13	0.24	40160	0.889
14	Poland	92	19.1	655.332	17841	79.27	13	0.58	33000	0.876
15	Croatia	108	25.3	63.399	17399	79.02	11	0.24	28950	0.858
16	Chile	25	21.7	331.25	16503	80.74	11	0.24	24020	0.855
17	Hungary	69	15.5	180.959	18773	77.31	12	0.15	32190	0.846
18	Kuwait	107	29.7	132.266	61227	75.85	7	0.11	58930	0.831
19	Russian Federation	39	12.3	1647.588	12173	72.99	12	1.4	29110	0.822
20	Malaysia	89	19.4	371.114	11371	76.65	10	0.33	27360	0.803
30	Mongolia	153	33.1	14.58	4232	70.23	10	0.15	11500	0.739
31	Colombia	81	14.1	300.187	6126	73.91	8	0.51	11490	0.725
32	Brazil	23	13.6	1,481.84	6970	72.21	8	0.14	11220	0.724
33	Mexico	80	18.3	1,382.25	8050	72.47	8	1	11810	0.728
34	Iran	47	58.6	332.828	6935	77.44	10	0.19	11250	0.783
35	China	124	40.2	19,985.89	13965	77.93	8	0.14	9980	0.768
36	Malaysia	21	18.2	387.038	9598	75.91	11	0.16	13360	0.803
37	Romania	65	21.8	57.895	9888	73.93	10	0.19	12490	0.821
38	Thailand	11	20.5	548.553	8533	77.14	8	0.49	11170	0.800
39	Pakistan	10	52.2	60.868	8532	67.41	11	0.25	18230	0.805
31	Uzbekistan	55	42.8	65.503	1983	72.04	12	0.59	7710	0.727
32	South Africa	97	22.7	415.315	6994	64.88	10	0.29	1020	0.713
33	Viet Nam	99	24.7	368.002	3694	75.77	8	0.26	8150	0.703
34	Kyrgyzstan	81	50.8	8.15	1266	71.95	11	0.07	4750	0.692
35	Bangladesh	166	76.9	355.689	1266	73.57	6	0.35	5390	0.661
36	India	192	58.1	2,946.06	2191	70.42	7	2.6	6440	0.633
37	Nepal	95	46.1	34.265	1223	71.74	5	0.33	4060	0.602
38	Myanmar	145	25.9	66.74	1187	67.78	5	0.17	4980	0.585
39	Pakistan	214	66.8	261.726	1538	67.79	5	0.09	4710	0.544

Fig.3 All monetary data in the study are calculated in current value of USA dollars.

3. Method

3.1 GDP and per capita income: what are they and why we need other indicators.

GDP, or Gross Domestic Product, calculates monetary value of all economic goods and services produced by a nation in its boundary during a period of time. The formula of calculating GDP is shown as:

GDP=C+G+I+NX

Where "C" stands for consumption by private consumers in the economy; "G" stands for government expenditure; "I" stands for the sum of investment spending; "NX" stands for net export.

and per capita income is calculated by dividing a country's total national income by its total population.

Per Capita Income = Total Income of the country/ Total Population

These two dominant financial measurements of a country's economy activities, however, share some latent blind spots when we use them evaluating other social problems:

1. Both indicator measures products and services, citizens' capitals and abilities to achieve a higher living standard. These "tools", however, do not always lead to the wanting social result. For instance, if a big portion of domestic products of a nation is for exports only, then these products may

not be influential on developing living standard of domestic citizens.

2. Both indicators measure values and amounts, but they lack in considerations of the diversity of domestic products and services. Limited product and service categories not only reduce vigor of domestic markets but also directly strain material and mental needs of local citizens. If a country's economy bears similar problems, we cannot detect these signals from national GDP and per capita income.
3. Both indicators are not efficient indicators for allocation of domestic economy value. For countries like China, more than half of the total property of a country is holding by top 3% richest citizens in the nation, which makes China's "second highest GDP in 2021" an almost meaningless ranking. A sum value or a value got by simply dividing is not enough to measure the developing stage of a country or the status of social developments.

For those reasons, economic indicators like GDP and per capita income are not convincing indicators for social development of countries. That's why we need a study to evaluate developing stage of countries by new indicators.

3.2 AQI

AQI was developed by the U.S. Environmental protection agency to measure daily air conditions. The formula for calculating AQI on a certain pollutant is shown below:

$$I_p = \frac{I_{Hi} - I_{Lo}}{BP_{HI} - BP_{Lo}}(C_p - BP_{Lo}) + I_{Lo}.$$

AQI is divided into 6 different level of health concern, local environmental quality can be represented by these levels according to local AQI value. The higher the value of the index, the more harmful local environment will be for citizens to live. EPA also allocate specific colors to different level of pollution so that citizens can quickly determine whether local environment is harmful or not:

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Fig.4 Table of Different AQI Level (Derived from https://www.airnow.gov/aqi/aqi-basics/)

EPA invented AQI for 5 major pollutants: SO2、NO2、particle pollution、O3、CO, where particle pollution contains both PM 2.5 and PM 10.

3.3 HDI

HDI is calculated by equally-weighted geometric mean of three indexes from three different 0dimensions: education, life expectancy and Gross National Income (GNI). The formula is shown as

$$HDI = (I_{Health} * I_{Education} * I_{Income})^{1/3}$$

Fig.5 Formula of HDI (Derived from Max Roser 2019)

Where Indexes of different dimensions are calculated by

$$Dimension\ index = \frac{actual\ value - minimum\ value}{maximum\ value - minimum\ value}$$

Fig.6 Formula for Dimension Indexes (Derived from Max Roser 2019)

4. Result

4.1 GDP per Capita vs Averaged AQI

We made a GDP per capita against Averaged AQI diagram 2021 in a global scope, which contains GDP per capita 2021 on x-axis, Averaged AQI on y-axis. There Averaged AQI measures the environmental degradation `level for each country, and GDP per capita is a traditional measurement of economic development stages. Our goal is using this diagram, which is very similar to traditional diagram for evaluating trend of EKZ curve, to see do countries still follow the theory of EKZ curve today:

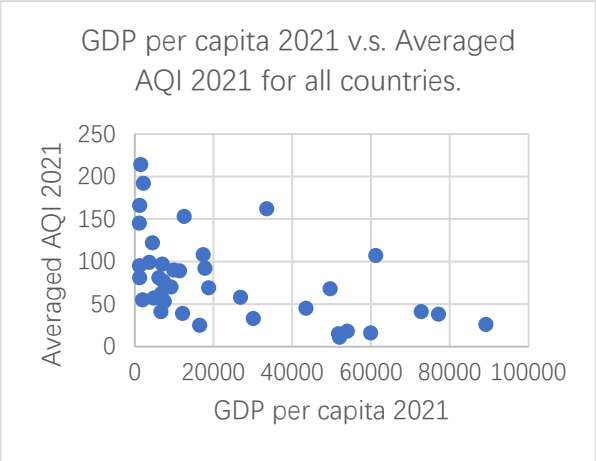


Fig.7 We made a GDP per capita against Averaged AQI diagram 2021 in a global scope, which contains GDP per capita 2021 on x-axis, Averaged AQI on y-axis

As shown in the graph, there is a rough negative relationship between GDP per capita of the year and AQI value (as the value of GDP per capita increases, the value of averaged AQI keeps increasing). These countries with higher level of GDP per capital are theoretic developed countries, and the lower the AQI value, the healthier the environment of a country is. What the graph shown us proves the theory of the environmental Kuznets Curve, which believes that the progression of economy will finally divert public concerns from increasing productions to sustainable developments, expect that the conclusion has several defects.

Firstly the distribution of data on the graph proves nothing more than there are countries with high GDP per capita with low averaged AQI and countries with low GDP per capita with high averaged AQI. We are not sure about

whether a developing country today would finally achieve similar economic and pollution level in the future, since geological and political differences make developing countries cannot 100% reference developing trajectories of developed countries. In that case, current distribution of GDP and AQI levels from global countries cannot prove the theory of Environmental Kuznets Curve, since it doesn't investigate the developing process of each developing country respectively.

Secondly GDP per capita level can be the fundament for recovery of natural environment, but natural recovery is not an inevitable result of high GDP per capita level. When analyzing Environmental Kuznets Curve, economists usually assume that natural degradation during early stages of developing societies derives from strategical sacrifices of ambient environment for growing production level, and when production level reached certain level (GDP per capita level reaches certain stage), public concern drifts from enlarging production to recovery of natural resources, which leads reduction of environmental degradation level of the country. It's common for a developed country to reallocate economic resources from environmental protection to other fields, like national defense, for specific international situations at the time. Environment and production are not two only field that a country concerns, and that's why high GDP per capita will not always lead to increasing efforts in environmental protection.

Finally, no one knows when will that turning point arrive due to big differences between social features. If economists want to find the peak of Environmental Kuznets Curve, they had to define how large the development's scope is. If economists observe a clear trend of reducing ambient pollution in China during recent years, they still could not assert that the pollution level of the country will keep reducing in following years, since they don't know is that reduction a stable trend for upcoming years or only a fluctuation of pollution level in a macroscopic view. The fluctuation can also derive from factors other than economic reasons. For instance, China's epidemic prevention policies leads to reduction in operation time of factories as well as emission-reduction acts like curfew. These policies are not features of certain developing stages, but they can lower environmental degradation level of a country.

4.2 HDI Against AQI

The graph below shows relationship between global HDI and averaged AQI in 2021. The trend line roughly implies a negative relationship between two variables. The greater the HDI value of a country is, the lower this country's averaged AQI should be.

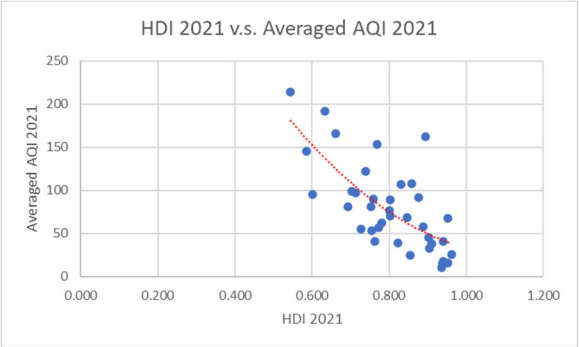


Fig. 8 The graph below shows relationship between global HDI and averaged AQI in 2021

We believe that the graph explains a lot about trends of environmental degradation for a country, which claims that as HDI of a country reach certain stage, the environmental degradation level will reduce. The reason why HDI is a better indicator of social development than GDP is that HDI is more a result of social development than basic resources for social development. Knowing the great influence from ambient pollution on local economy and social welfare, economists can conclude that environmental recovery is one of the preconditions of high HDI levels. In that case, HDI could be a better indicator than GDP for measuring theorical trend of Environmental Kuznets Curve.

5. Conclusion

HDI can be a better than GDP per capita for considering a country's current location on the Environmental Kuznets Curve, since it directly implies the stage of social development rather than giving fundamental resources. HDI, however, also has its own defects. The Environmental Kuznets curve needs more insights into its practicality for individual societies.

References

1. Max Roser (2014) - "Human Development Index (HDI)". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/human-development-index' [Online Resource]
2. Nations, U. (2022, October 13). Human development index. Human Development Reports. Retrieved October 31, 2022, from https://hdr.undp.org/data-center/human-development-index
3. Life expectancy of the World Population. Worldometer. (n.d.). Retrieved October 31, 2022, from https://www.worldometers.info/demographics/life-expectancy/
4. Average years of schooling. Our World in Data. (n.d.). Retrieved October 31, 2022, from https://ourworldindata.org/grapher/mean-years-of-schooling-long-run

5. AirNow.gov, U.S. EPA. (n.d.). Aqi Basics. AQI Basics | AirNow.gov. Retrieved October 31, 2022, from https://www.airnow.gov/aqi/aqi-basics/
6. World Economic Outlook Database, October 2021. IMF. (n.d.). Retrieved October 31, 2022, from https://www.imf.org/en/Publications/WEO/weo-database/2021/October