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# Cognitive abilities and air pollution

***Raufhon Salahodjaev[1,2], Oybek Yuldashev[1,2], Bekhzod Omanbayev[2]***

[1]*Central Asia Research Group, Uzbekistan*
[2]*Westminster International University in Tashkent, Uzbekistan*

*corresponding e-mail: rsalaho1@binghamton.edu*
*address: 32 Shevchenko Str. 100060, Tashkent, Uzbekistan*

The link between intelligence and air pollution is subject to controversy. Some studies report that intelligence has insignificant effect in reducing the greenhouse gas emissions. By using carbon dioxide (CO2) emissions for a large set of countries we present further novel empirical evidence on the relation between level of intelligence and air pollution. Our findings suggest that the relation follows a U-shape pattern and resembles environmental Kuznets curve.

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## Introduction

Within the past decade academic literature documented a wealth of empirical evidence that intelligence is a predictor of economic development (see e.g. Lynn and Vanhanen, 2012). The intelligence was found to be positively related with GDP per capita, economic growth and financial development of a nation (Meisenberg and Lynn, 2012) and inversely related with lower corruption, crime and degree of informal economy (Potrafke, 2012; Salahodjaev, 2015a).

Research shows that cognitive able societies aim to achieve more efficiency, higher quality political regimes (Kanyama, 2014) and support policies that create prosperity (Jones, 2011)[1].

For example, higher IQ individuals were found to be more active during the elections, vote for democratic parties and for candidates with environmental agendas. At the same time, more intelligent bureaucrats were found to be more supportive of policies resulting in larger and prospective rewards rather than smaller but immediate ones.

Indeed, recent cross-national evidence provides further support to the idea that high-IQ societies are characterized by more rational and efficient use of natural resources that improve the quality of life (Salahodjaev, 2016b).

Considering that air pollution (resulting from increased carbon dioxide emissions) is currently one of the most challenging issues in sustainable development agenda, while problem solving abilities are heavily related to the level of intelligence (Burns et al., 2006);

[1] For example, Arvanitis and Ley (2013), using data for 2324 Swiss firms for the year 2008, show that in the absence of market failures the likelihood of adopting environment-friendly technologies increases.

it is interesting to investigate the relation between the level of intelligence and carbon dioxide emissions across countries.

To the best of our knowledge, so far only one study investigated the intelligence greenhouse gas emissions nexus (see Squalli, 2014) with the results being rather dismal and showing no meaningful relation. Still, generalization of the results of this study for the rest of the world can be spurious since, 1) the findings address only one country, namely the USA; and, 2) the USA did not ratify the Kyoto Protocol.

Therefore, this study explores further the effect of intelligence on air pollution on a sample of 155 countries and provides additional contribution to the literature. Departing from plethora studies, we measure the level of intelligence of a nation by mean nation's IQ score and anticipate that air pollution acts as a channel through which cognitive abilities impact wellbeing of nations.

Specifically, our findings suggest that high IQ societies are more responsible in reducing greenhouse gas emissions and, consequently, characterized by higher quality of life. As a measure of air pollution our study employs annual percentage change in $CO_2$ emissions metric tons per capita for the period, of 1997-2011. In contrast to previous studies, we find that intelligence has inverted U-shaped link with CO2 emissions, so called "intelligence Kuznets curve" similar to environmental Kuznets curve (EKC). This effect remains robust after we control for extant antecedents of air pollution.

This paper is structured as follows. The following section presents data and econometric model. Then we discuss the key results and make the conclusion of this study.

## Data and method

### *Sample*

We analyze a cross-sectional dataset consisting of 155 countries from 1997 to 2011.

### *Dependent variable*

As a proxy for commitment to reduce greenhouse gas emissions we take annual percentage change in CO2 emissions metric tons per capita for the period 1997-2011 as a measure of air pollution. CO2 usually stem from burning of fossil fuels and cement manufacturing. These include carbon dioxide produced during consumption of solid, liquid, gas fuels and gas flaring. The data is adapted from the World Bank (http://data.worldbank.org/indicator/EN.ATM.CO2E.PC).

In our sample the annual growth rates of CO2 emissions range from -10.29 in Singapore to 19.14 in Equatorial Guinea. We anticipate that countries committed to reduce greenhouse gas emissions have negative growth rates in CO2 emissions over the investigated period.

### *Key independent variable*

To test the effect of intelligence on air pollution we follow the framework of related studies and employ national IQs provided by celebrated studies of Lynn and Vanhanen (2002, 2012) in subsequent empirical analysis. Nation IQs have been successfully used in the empirical research (Salahodjaev, 2015b; Salahodjaev, 2015c; Kanyama, 2014).

These IQ scores were collected from intelligence tests in 192 countries with the population size exceeding 40,000.

### *Additional control variables*

To reduce potential omitted variable, bias our study incorporates a vector of additional independent variables, *X*. The complete list of vector of controls, X, is provided in the appendix.

Considering that the changes in the level of aggregate production are reflected on the levels of income per capita, we expect non-linear relation between GDP per capita and the level of air pollution. The intuition behind this conjecture is rather simple: at the dawn of economic development a society is mostly concerned with more rapid levels of production, higher incomes and larger air pollutions. On the other hand, as a nation approaches a level of income per capita that of developed economies, the society starts to appeal for more active reductions in greenhouse gas emissions to improve the wellbeing of its citizens.

Our study also considers the impact of trade on air pollution. Following previous studies (see e.g. Neumayer, 2000) we expect that the sensitivity of air pollution to changes in the volume of trade is ambiguous. On the one hand, the liberalization of trade, and consequent "race from the bottom" by the low-income countries, may lead to adoption of less rigid environmental standards and intensify existing levels of air pollution. On the other, globalization may lead to technological advances, enhanced environmental standards, the exercise of consumer power, and adoption of corporate codes of conduct (Frankel, 2009).

We also control for the changes in manufacturing sector as industrial activities are expected to increase the level of emissions (Cole, 2000). Hence, annual percentage growth in manufacturing value added is included into our empirical framework.

Finally, in line with similar environmental studies (Neumayer, 2002), we control for the population size and the level of political development. Table 1 provides the descriptive statistics along with descriptions of variables employed.

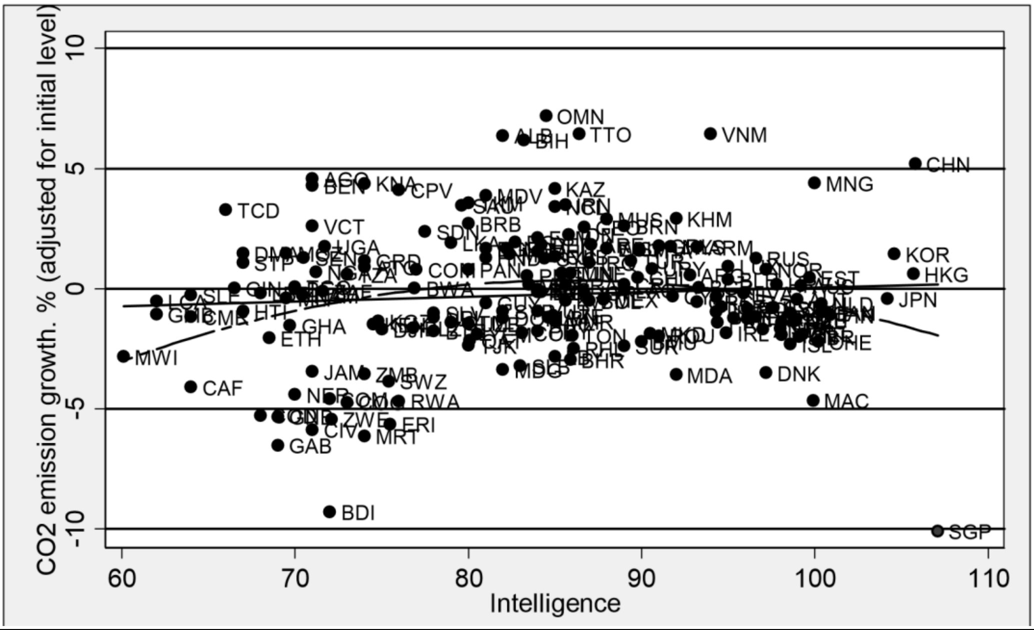
To get a preliminary understanding of the relation between intelligence and air pollution, Figure 1 plots change in greenhouse gas emissions for the years 1997-2012 against national IQ level. The preliminary investigation of Figure 1 suggests non-linear (inverted U-shape) relation between greenhouse gas emissions and IQ. The R-squared of non-linear model substantially exceeds the R-squared of the linear model.

Further regression analysis supports anticipated estimates: positive for IQ and negative for IQ squared.

To provide more robust and precise evidence on the impact of intelligence on air pollution, we further implement and estimate the following multivariate regression:

$$CO2 + a_0 + a_1 IQ_i + a_2 IQ_i^2 + \lambda X_i + \varepsilon_i$$

FIGURE 1.SCATTER PLOT OF INTELLIGENCE AND DEFORESTATION




Notes: adj R2 (linear) = 0.01; adj R2 (quadratic)

TABLE 1. SUMMARY STATISTICS

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Annual percentage change in CO2 emissions metric tons per capita | 1.0812 | 2.7932 | -10.2881 | 8.4785 |
| Nation's IQ | 84.2346 | 10.9177 | 60.1 | 107.1 |
| GDP per capita (log) | 8.7784 | 1.2510 | 5.6658 | 11.6121 |
| Trade as % of GDP (log) | 4.3554 | .4619 | 3.1855 | 5.9293 |
| Annual percentage growth in manufacturing value | 3.6526 | 3.3551 | -4.2387 | 17.5786 |
| Population size (log) | 15.5634 | 2.0111 | 9.8049 | 20.9303 |
| Democracy index | 3.4778 | 1.9338 | 1 | 7 |
| Annual percentage growth in GDP | 4.0177 | 2.1796 | -1.9864 | 14.3739 |
| Per capita logged CO2 emission in 1997 | 0.4844 | 1.6045 | -3.0490 | 3.4833 |

## Findings

The main results are reported in Table 2. Column (1) reflects the results for both linear and non-linear regressions (intelligence as right hand side variables) presented on Figure 1. The estimates are statistically significant at 1% level. The turning point in this figure coincides with the level of intelligence (approximately 81 points) slightly below global average IQ level (see Lynn and Vanhanen, 2012) and confirms the presence of EKC relationship for intelligence and air pollution. The adjusted R-squared is 7%, indicating that the level of intelligence alone is able to explain more than 7% of cross-national differences in CO2 emissions.

Column (2) shows the results from the multivariate regression which includes control variables discussed above and used to investigate the stability of the inverted U-shaped relation between intelligence and air pollution.

Turning to control variables we find that trade openness reduces CO2 emissions at 5% level of significance, while the initial level of economic development is not associated with CO2 emissions for 1997-2012.

We also find that economic growth tends to increase air pollution, with a one percentage point increase in GDP growth leading to 0.44 percentage points increase in per capita CO2 emissions. On the other hand, we fail to find evidence that democracy and population size have statistically significant associations with air pollution.

TABLE 2. MAIN RESULTS

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| IQ | 0.8863*** | 0.7842*** | | 0.8098*** |
| | (0.2900) | (0.2701) | | (0.2678) |
| IQ-squared | -0.0055*** | -0.0048*** | | -0.0049*** |
| | (0.0017) | (0.0016) | | (0.0016) |
| GDP per capita (log) | | -0.0274 | -0.1147 | 0.7249 |
| | | (0.2532) | (0.2044) | (0.4536) |
| Trade as % of GDP (log) | | -1.4238** | -1.6738*** | -1.1092* |
| | | (0.5575) | (0.5595) | (0.5741) |
| Industrial activity (%) | | 0.1470* | 0.1337* | 0.1439* |
| | | (0.0755) | (0.0765) | (0.0747) |
| Population size (log) | | -0.1706 | -0.3248** | -0.1272 |
| | | (0.1402) | (0.1268) | (0.1405) |
| Democracy | | -0.1745 | -0.0872 | -0.1839 |
| | | (0.1300) | (0.1251) | (0.1288) |
| GDP growth rate (%) | | 0.4370*** | 0.4387*** | 0.4783*** |
| | | (0.1277) | (0.1297) | (0.1281) |
| CO2 emissions (initial) | | | | -0.7032** |
| | | | | (0.3533) |
| Constant | -33.7750*** | -22.7449* | 12.4814*** | -32.8057** |
| | (12.0528) | (11.8694) | (3.7843) | (12.7921) |
| N | 155 | 155 | 157 | 155 |
| adj.$R^2$ | 0.0739 | 0.2328 | 0.1842 | 0.2480 |

Notes: Standard errors in parentheses; * p <0.1, **p<0.05, ***p<0.01

Column (3) reports the results from the assessment of the IQ effect over and above the control variables. Thus, we exclude intelligence and regress annual percentage change in CO2 emissions only on the vector of control variables. Compared to multivariate regression results reported in column (2) the adjusted R-squared for this specification declines by 5%. This reduction in goodness of fit captures the proportion of variance that is uniquely related to intelligence once we take into consideration potential antecedents of air pollution.

Finally, we consider the effects of the dynamics of air pollution on initial levels of per capita CO2 emissions, the so called "convergence effect" (Strazicich and List, 2003). This consideration is not accidental, since we expect that certain nations possessing low levels of air pollution may be catching up with the nations with higher levels of emissions. Therefore, we add logged initial level of per capita CO2 emissions into the model. The results are reported in column (4) and show that the coefficient for initial level of air pollution is negative and statistically significant at 5% level. Hence, we find the support that cross-national CO2 emission rates are converging, with the inverted U-shaped relation between intelligence and air pollution remaining significant at 1% level. In contrast to findings above, the turning point for CO2 emissions is found at approximately 83 points.

## Robustness tests

To ensure the validity of the obtained results we implement robustness check presented in Table 3. We first test whether insignificance of political institutions and population size are driven by the choice of variables. Therefore, we replace democracy index with economic freedom index from Heritage Foundation. Moreover, we add economic freedom to assess non-linear effect of institutions on air pollution (see e.g. Buitenzorgy and Mol, 2011).

Similarly, we replace logged population size with population of ages 0-14 (% of total). The data is adapted from the World Bank.

TABLE 3. ROBUSTNESS TESTS

| | (1) | (2) |
|---|---|---|
| IQ | 0.7461** | 0.9299*** |
| | (0.2962) | (0.3283) |
| IQ-squared | -0.0043** | -0.0053*** |
| | (0.0018) | (0.0020) |
| GDP per capita (residual) | -0.2862 | -0.2705 |
| | (0.3549) | (0.3450) |
| Trade as % of GDP (log) | -0.9447** | -0.8389* |
| | (0.4606) | (0.4349) |
| Industrial activity (%) | 0.0412 | 0.0424 |
| | (0.0803) | (0.0759) |
| Population ages 0 -14 (%) | 0.0282 | 0.0489 |
| | (0.0466) | (0.0436) |
| Economic freedom | 0.2594* | 0.2282* |
| | (0.1317) | (0.1236) |
| Economic freedom squared | -0.0021* | -0.0018 |
| | (0.0012) | (0.0011) |
| GDP growth rate (%) | 0.5950*** | 0.5361*** |
| | (0.1584) | (0.1557) |
| Constant | -37.9072*** | -46.3446*** |
| | (12.6172) | (14.2552) |
| N | 132 | 132 |
| adj.R2 | 0.2893 | 0.2965 |

Note: Standard errors in parentheses; * p <0.1, **p<0.05, ***p<0.01.

Considering past evidence that suggests high correlation between GDP per capita and national IQ, and consequently leading to erroneous estimates, we test our regression results by another sensitivity test. That is, we regress logged GDP per capita on IQ and use the residuals as a measure of economic development independent of level of intelligence. The results are reported in column (1) and indicate that only economic freedom is marginally statistically significant. Notice that controlling for an alternative set of independent variables does not change the inferences with respect to intelligence. In fact the turning point is now approximately 87 points.

We estimated the model using weighted least squares regression (WLS). For example, variance of the error term (ε) may be correlated with the level of economic development such as national intelligence or GDP per capita. Therefore, ignoring non-constant variance may produce inefficient estimates for IQ and its squared term. To increase reliability of the effect of intelligence on air pollution, column (2) reports the results from WLS where residuals are weighted by IQ. The coefficients show that intelligence induced effects are statistically significant at 1% level.

## Concluding remarks

This study employs cross-national data and provides fresh empirical evidence on a relation between cognitive abilities and CO2 emissions. In line with related literature on the Environmental Kuznets Curve, we document similar relationship (inverted U-shape) for intelligence and air pollution. We also show that the non-linear relation between IQ and CO2 emissions remains intact when we control for a large set of air pollution antecedents.

Although our findings suggest that CO2 emissions decline when national IQs exceed 81 points, this should not be considered as an immediate evidence support the view that more intelligent societies are necessarily more active in reducing greenhouse gas emissions. We rather conjecture that our results extend the findings of similar studies suggesting that if a government implements policies targeting reduction in market failures, intelligence may offer a reasonable measure of the level of their acceptance (Salahodjaev, 2015a).

By analogy, national IQ may be a reasonable measure reflecting the level of a nation's commitment to reduce greenhouse gas emissions as more intelligent citizens are expected to be more heavily engaged in collective efforts of sustaining healthy environment (Salahodjaev, 2016a).

Finally, intelligence may serve as a proxy for human capital stock (Meisenberg and Lynn, 2011), with educated voters apprehending the long-term costs of air pollution, higher social trust and political awareness (Kemmelmeier, 2008; Rinderman et al. 2012) which endorse rational policies (Caplan and Miller, 2010) and improve the effectiveness of political system overall.

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