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**Cognitive abilities around the World** what can we learn from fifteen years of PISA tests

**Introduction and objectives**

One, if not, the most important factor to understand economic growth in the current era is the role of human capital and institutions: from the twentieth century the era of human capital began, first in North America later it spreads to the rest of the world1**,** several are the definitions of human capital but the idea that the weight of knowledge among people directly or indirectly shapes the world we are living in is neither new nor undeveloped.  
We can describe human capital as the sum of an individual innate abilities or acquired skills through time and experiences.  
  
Obviously to develop human capital investments are required and since the introduction of mass education schooling has been provided by many kinds of entities but mostly funded by public institutions, especially today the state plays a significant role in education: the reasons are surely multiple but with no doubt we can state that democracies around the world required educated citizenships and leaders2.

While some authors believe that IQ is not correlated to education, further evidence showed how IQ may be very malleable and adaptable and not genetically determined especially in early years by multiple factors3, schooling included; countries with higher IQ levels seem to be more productive: a gap in IQ levels directly correlate with economic development gap between nations, which is probably true that an improvement in national IQ of lower income countries may be one of the best approaches to reduce the gap in global inequality, but how can we achieve that? What are the determine factors when it comes to filling the gap between high IQ achieving countries and the rest of the world?

Literature suggests that we can divide the main elements of cognitive abilities development into two categories: direct and indirect factors which can affect children's IQ4; socioeconomic factors which have been proved to play a direct role in children's cognitive ability are:

* Child mortality
* Fertility rate
* Primary school enrollment

While other factors such as parent’s education level and Income per capita are still significant but secondary since they play a role in defining the main three factors listed above (i.e., Parents with high achieving educational degrees are most likely to have a lower fertility rate and access to better health care systems which affect two of the three factors listed above therefore indirectly boosting their kids IQ).

In the present study, I wanted to show, by examining in detail the Pisa scores of a wide variety of countries from 2000 to 2015, what we can observe in fifteen years of standardized cross-countries tests by answering four main questions using Pisa scores as a measure of IQ:

1. As economies thrive, can we observe a growth in educational achievements and therefore in IQ growth? If so, is the gap between low-income countries and high-income countries expanding or decreasing?
2. As already stated, Parents’ education can indirectly shape the cognitive abilities of their children, can we observe a difference between the effect on children’s IQ from male and female parents' educational levels?
3. Primary school enrollment is considered to be one of the most important factors when it comes to developing children's IQ. From the data in our possession, can we make an argument for which starting age is best for compulsory education?
4. Pisa scores have drawn a substantial increase in Italy’s performances, what correlations can we establish and what can we learn from?

What is PISA?

Pisa is an international student assessment measuring the proficiency of 15 years old students in mathematics, reading and science; conducted from the first time in 2000, Pisa takes place every three years offering a helpful overview to more than 70 countries participating.

What makes PISA effective? Other than focusing on notions PISA tests by design emphasize functional skills and problem-solving capacities that students have acquired throughout compulsory schooling, PISA is coordinated by OECD. Data collection for the most recent assessment was supposed to be completed in fall 2021 but it has been postponed by one year due to the recent pandemic; the data used in this paper goes from the first assessment in 2000 to 2015.

**The Dataset and main challenges**

The Education Statistics dataset is a comprehensive summary of indexes and general information around the topic of education around all countries of the world published by the World Bank Open Data; the dataset consists of almost a million rows and seventy columns; the actual csv file used for this paper comes from Kaggle.com where it is listed as open-source database.

More specifically the dataset consists of 886929 rows containing values of almost 4000 indexes and indicators for each country, the data is showed over time starting from 1970 to 2050 (predictions); the columns representing the years are populated with float data types (percentages and numbers) while the first four columns ‘Country Name, Country Code, Indicator Name, Indicator Code” contain string data types helpful for describing the indicator and correlating values to the actual Country.

While every Indicator is listed for all nations, only some are populated since not every statistical survey or indicator applies to every single country, for example the “Africa Dataset” Indicator will not contain values for Countries located in Europe; some years may be emptier than others, not all indexes appear every year; overall most of the data reported is between 1990 and 2014.

The actual indexes being used are as follows (as listed under ‘Indicator Name’):

* GNI per capita, Atlas method (current US$)
* Population, ages 10-15, total
* Official entrance age to compulsory education (years)
* PISA: Mean performance on the mathematics scale
* PISA: Mean performance on the reading scale
* PISA: Mean performance on the science scale
* Percentage of students in lower secondary general education who are female (%)
* Percentage of teachers in lower secondary education who are female (%)
* Annual statutory teacher salaries in public institutions in USD. Primary. Starting salary
* Annual statutory teacher salaries in public institutions in USD. Upper Secondary. Starting salary
* Expenditure on education as % of total government expenditure (%)
* Government expenditure on education as % of GDP (%)
* GDP per capita, PPP (current international $)

Although the EdStatsData dataset is very comprehensive one of the biggest challenges I had to face was the lack of data for the specific indicators I was interested in: a lot of work has been done regarding data preparation through subsetting in order to compare values from different countries.  
Another big factor that has negatively contributed to the scope of this paper was the lack of entries in the Pisa data: unfortunately only a fraction of countries take part in the cross-country assessment therefore after the due operations (mostly subsetting) I sometimes ended up with smaller datasets than expected.

The overall approach can be divided in the following phases: search and identification of the indicators needed for the research (both in Excel and Python), extraction of the usable data, creation of smaller datasets and lastly using the data to achieve information insights and visualizations.

Paragraph I  
are kids around the world getting smarter?

I we take a look at the mean Pisa performances (mathematics, reading and science scores all together) between 2000 and 2015 we can see how after 15 years the world performances seem to have a smaller tail but a similar mean.

Chart

Description automatically generated

The average score in the year 2000 has been 471.1, while in 2015 that number grew to 475.5, to find out if the difference is statistically relevant we performed a one-tail T-test with a 0.05 level of significance getting a p-value of 0.97 (the test has been performed between paired values, countries which do not have values for both years have been dropped) with such a high p value we are fairly confident to say that apparently there’s been a growth in Pisa scores among the same countries that took the test in 2000 and the 15 years later.  
  
It won’t be a surprise to discover that as the GDP per capita increases the better is in term of cognitive abilities; the following visualizations show Pisa performances as function of two economic indexes: GDP and GNI (GNI index is defined as the sum of the value added produced by all resident of one country, where in order to smooth fluctuations in prices a special method of conversion called Atlas is applied to convert national currency values into current US dollars).

Chart, scatter chart

Description automatically generated

Chart, scatter chart, bubble chart

Description automatically generated

In order to define if the gap between low and high-income level countries is shrinking or not we divided the countries in three bands following the GNI index rates defined by the World Bank5: lower middle-income: between $1,026 and $4,035; upper middle-income $4,036 - $12,475; high-income economies > 12,476.  
The lowest values for GNI among Pisa countries was 1,990$ so we divided the countries in two groups one with a GNI smaller than 12,476 (middle income) and one greater (high income).

After performing a series of T-tests for both groups we can say with relative confidence that while middle income countries have increased their scores (one-side test p-value = 0.97) the same cannot be said for high income countries (two-sided test p-value = 0.90).

Chart, funnel chart

Description automatically generated

Paragraph II  
The return in cognitive abilities of Mom and Dad’s degrees in high income countries

As already mentioned parent’s educational background is one of the indirect factors which can modify the children cognitive capabilities, in order to establish if there’s any difference between the educational achievement and their impact on the child capacities of one sex versus the other: we can drew two regression lines using the percentages of female and male population over 25 years old with at least one tertiary degree as a proxy for the educational achievements of the parents versus the average Pisa scores of the same year (argument can be made since the population of people with 25 years or more may be too wide to be taken as a proxy for the parents, unfortunately to my knowledge this was the closest data present in the dataset).

Chart, scatter chart

Description automatically generated

The data in the current dataset seem to point in a clear direction: the male slope has a significant higher slope that the female one (1.76 against 0.21) while the intercepts seem to be inverted for the two.  
Probably the data in this dataset are not enough to draw a conclusion but if further research may came to the same conclusions I suggest the reason why the “return” of females’ percentage seems to be flatter is probably to be found in the gender pay gap.

Paragraph III  
Primary school enrollment age, the sooner the better?

Levels of schooling around the world may vary with countries having different enrolment ages and durations, although there seems to be a “considerable uniformity probably relating to the biology of child development”6, assuming this statement true; can we define if there’s a significance difference between the scores of the countries based on their entrance age to compulsory education? Is having more years of school beneficial to the cognitive abilities of 15 years old students?

Chart, box and whisker chart

Description automatically generated

We divided once again the countries in two income groups following the same method listed above (GNI index), then we divided the countries by age of primary school enrollment age: unfortunately, we ended up with somewhat small samples; after performing two ANOVA tests (level of significance = 0.05) for high and middle income countries we can safely say that the means between the sample can be considered equal so, as for the data present in this dataset, lowering the age of primary enrollment does not seem to be beneficial both in high and middle income countries.

Paragraph IV  
Italy, a closer look: correlations and trends

In 2015 Italy seems to suffer a bit with an average score of 485 compared to high income countries with an average of 496. Although the results are not impressive the country’s performances seem to be going in the correct direction: “Between 2003 and 2012, Italy, Poland and Portugal increased their shares of top performers and simultaneously reduced their shares of low performers in mathematics”7.

Chart, line chart

Description automatically generated

As we can see there’s been impressive leap, especially in the mathematics performances, throughout these 15 years.  
Using the dataset in our possession I have created a correlation matrix with some economics factors to see if we could establish what good practices may have causes the improvement we saw.  
Although correlation does not mean causation I don’t see why an increase in teacher’s salary should have not played a role in latest better performances while a decreasing expenditure in education (fluctuation between 2000 and 2015 are around +-1% ) luckily did not impact negatively on student’s performances.

Table

Description automatically generated with medium confidence

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