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Why is the relationship between productivity and education & research so complicated?




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Abstract

Just recently, the OECD published results from a new PISA survey that indicated large, mainly negative, changes in educational achievement in many countries over the period 2003–2025. Similar results have been obtained with the mathematics TIMSS exams that have been carried out over the period 1995–2023. On the other hand, we have observed a marked decline - even a standstill - in productivity even though there has been no decline in R&D activity in most countries. Nor have we seen a decline in schooling expenditures; rather, there has been trend-line growth. We compare the co-movements of these variables in a panel setting and find that the relationships are far from linear, reflecting some tendencies of diminishing returns. Another important element that can explain the changing relationship is the change in the gaps between the local productivity level and the global productivity frontier. This factor is not constant either, but depends on the functioning of markets, which in turn shows up in the openness of the economy and the level of foreign trade.

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Introduction

In 1962, Edward Denison published a famous book on the sources of economic growth in the United States (Denison 1962). Denison's study showed that investment in education is of crucial importance from the point of view of economic growth. The same conclusion applied to "knowledge," which can be interpreted as the results of research and development activities. Denison's results made a profound effect on economic thinking and economic policies not to speak about educational and research financing. Since 1962, nobody has really challenged Denison's main results, even though estimates of the size of the respective contributions have changed many times. Here we do not challenge the basic logic of Denison's results but rather consider the efficiency issue: does investment in education and R&D have a constant rate of return irrespective of time, the stock of human capital and knowledge, and the country?

Table 1. Existing data on educational attainment

Measure	Population and concept	Timing	Role and limit in this study
PISA	15-year-old students; applied mathematics, reading and science skills.	School-age cohorts; successive test cycles.	Main skills measure. Does not measure the current workforce or identify a school-policy effect.
TIMSS	Primarily grades 4 and 8; curriculum-related mathematics and science.	Repeated every four years; earlier schooling.	Potential complementary check. Own validation incomplete; no own results included.
PIAAC	Adults aged 16–65; literacy, numeracy and adaptive problem solving; background information on skills use.	Adult skills at survey dates; changes require comparable waves.	Closer to working-age capabilities. Own analysis on hold; published literature only.
GDP per hour worked	Whole economy; real output divided by hours worked.	Annual; matched to the actual PISA test year plus the stated lag.	Productivity outcome. Also reflects capital, technology, organisation and the composition of production.

Sources: OECD (2023), OECD (2026a), OECD (2026b), OECD (2026c) and Von Davier et al (2024).

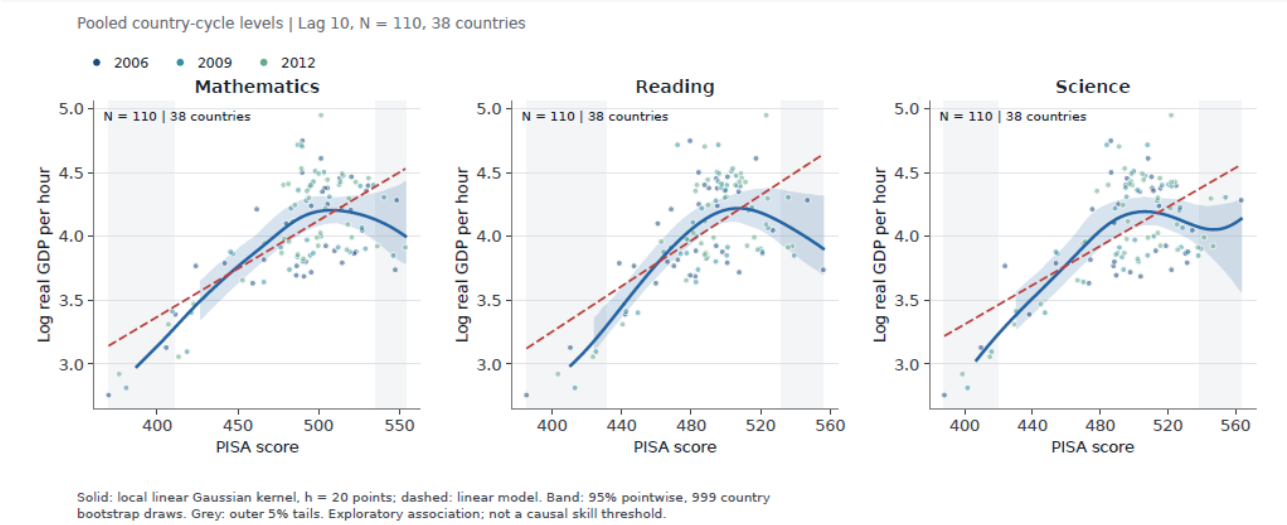
What makes us somewhat skeptical is the recent data on educational attainment. There are some alternative indicators of educational attainment (Table 1), but here we concentrate on the new PISA results and the relationship between PISA and labor productivity for practical data reasons (not because of different or "wrong results). In Figure 1 we show the basic scatter diagram for the values of all three PISA scores together with the corresponding aggregate productivity values. It seems that the relationship is not linear but rather concave, suggesting that there is some sort of diminishing-returns property in schooling. When the quality of basic education is already very high, further improvement may not show up in aggregate productivity. Estimation results are not, however, robust enough to exclude alternative explanations.

A similar outcome emerges when we focus on schooling expenditures (Figure 2), which are often used as an indicator of educational quality. As we see from Figure 2, however, there are many individual-country differences between the variables. The relationship between the PISA scores and expenditures is quite weak and sensitive to the sample. Thus, the positive slope is only due to relatively low income countries. Country differences show up more clearly when we look at the time series from individual countries, where we almost always see an upward-sloping trend in (real) expenditures but a decline in PISA results (thus pairwise correlations are typically negative). Even though the results seem quite robust, a warning is warranted. We do not have detailed expenditure data all the way down to the subject level, but only more aggregate expenditure numbers, and the development of real expenditures and the expenditures/GDP ratio is sometimes quite different.

A somewhat similar nonlinearity result appears again when we focus on investment in R&D (Figure 3). This figure looks quite similar to the PISA–productivity graph, even though the distribution of R&D expenditures is so skewed that it is difficult to draw firm conclusions about the nature of the curvatures beyond GDP shares of 3 percent. Even so, here

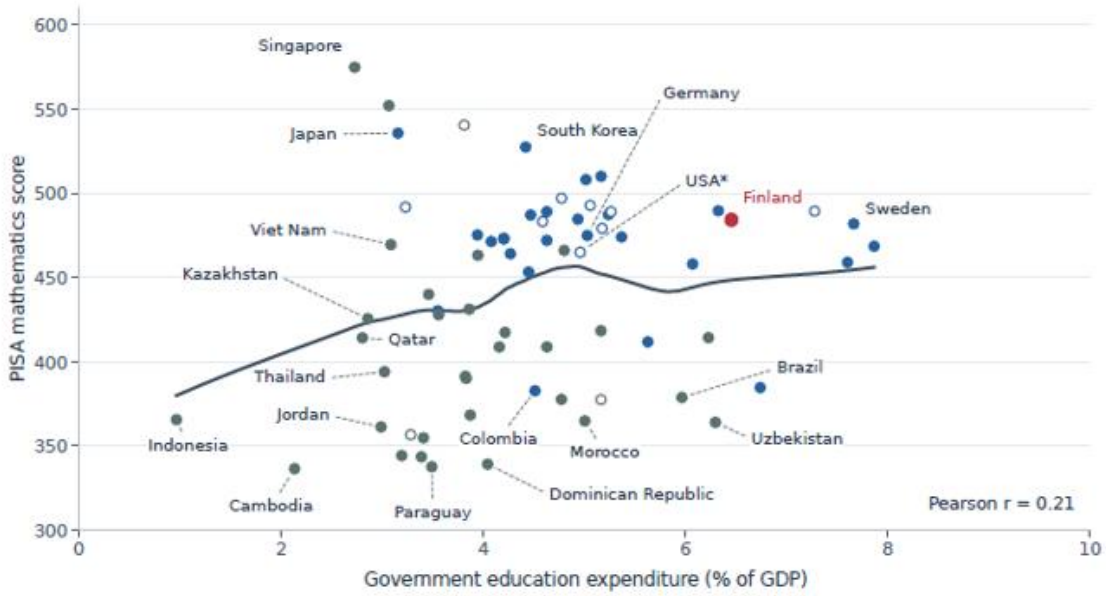
too, we find signs of diminishing returns that are consistent with the literature and the idea that it is more difficult and costly to make new innovations (cf. Bloom et al. 2020 and Goldin et al. 2024).

Figure 1. The relationship between PISA scores and productivity



Solid: local linear Gaussian kernel, h = 20 points; dashed: linear model. Band: 95% pointwise, 999 country bootstrap draws. Grey: outer 5% tails. Exploratory association; not a causal skill threshold.

Figure 2. The relationship between educational expenditures and the PISA math scores



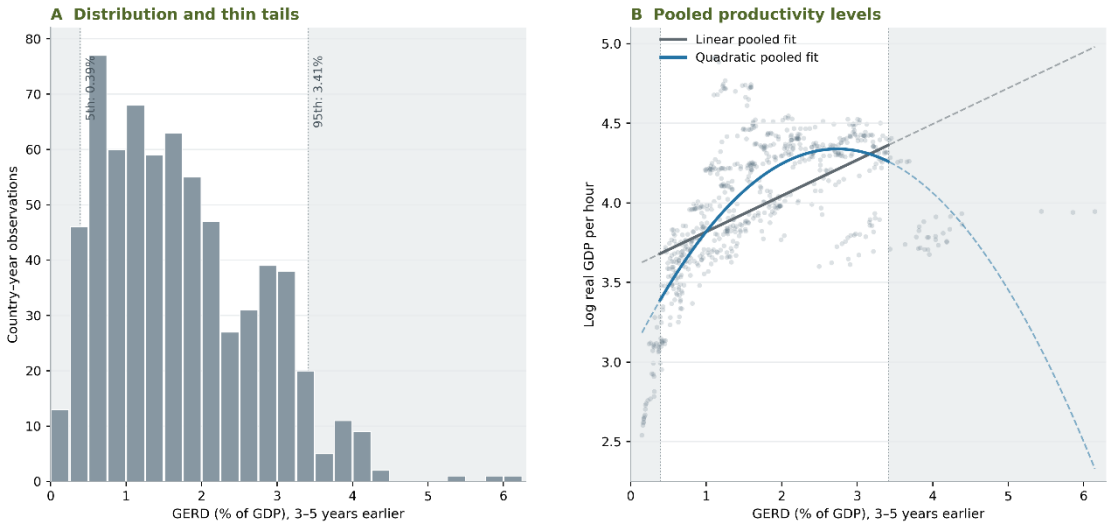
PISA mathematics 2022 · Education expenditure 2019 · 69 countries/economies

Note: Open circles indicate an OECD caution concerning the representativeness of PISA 2022 results because sampling requirements were not fully met. An asterisk identifies this caution for a labelled country. In the United States, school participation was 63% after replacement schools were included, below the 85% target. Student exclusions were approximately 6%, exceeding the 5% limit. These departures may introduce bias into the reported score; neither the presence nor the direction of such bias can be established from the available evidence.

Blue: study OECD countries; grey-green: other countries/economies; red: Finland. Line: descriptive smoother.

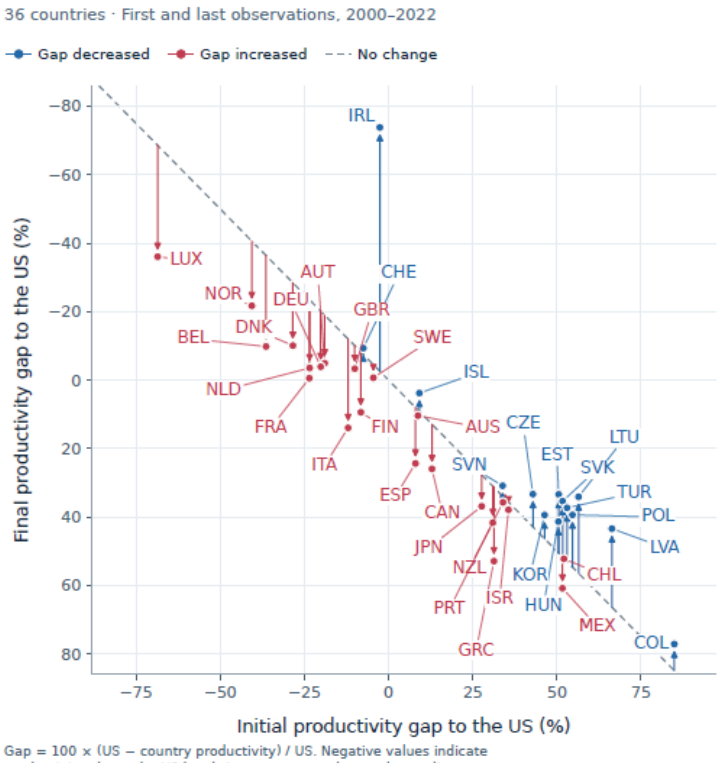
Sources: OECD PISA 2022, Table I.B1.5.4 and US country note; UNESCO UIS / World Bank WDI.

Figure 3. Investment in research & development and productivity



But why would there be such a nonlinearity in the schooling-attainment–productivity relationship? There is no shortage of suitable candidates, but in our view the most obvious explanation is the different country dynamics in terms of the global productivity frontier (cf., e.g. Andrews et al. 2025 and Egert et al. 2023). Following the seminal paper of Lucas (2009), we can argue that when a country is far from the frontier, technology adaptation is easy and cheap, while the opposite applies when it starts closing the gap. Then the return from domestic investment to human capital and knowledge will inevitably decrease. In Figure 4 we illustrate the dynamics with OECD countries. Clearly there is a difference between countries that start from a low level and those that have been closer to the U.S. level.

Figure 4. Changes in the productivity gap vis-à-vis USA

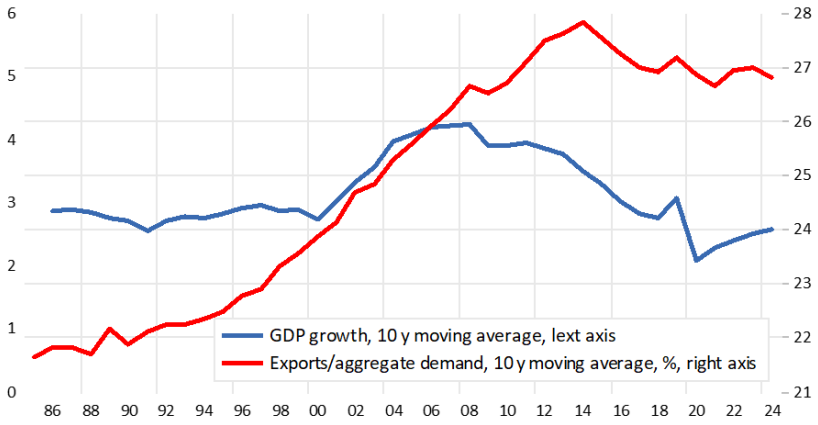


Gap = 100 × (US − country productivity) / US. Negative values indicate productivity above the US level. Arrows start on the no-change line; the vertical axis is reversed. A decrease means a smaller signed gap. Observation years vary: 610 country-years in the combined R&D and PISA samples. AUS has 2 observations; CHE, CHL and NZL each have 3.
Source: OECD, PPP GDP per hour worked (2020 price base).

Lucas's model says that the growth rate of output or productivity in country (i) is related to the frontier country in the following way: gi = g*(GDP*/GDPi)θ, where (g) denotes the growth rate of GDP and GDP itself is per-capita GDP at constant prices. Starred values indicate the productivity-frontier country (here, simply the USA). θ is the key parameter that reflects the strength of the catch-up effect. We estimated the parameter using the BCLD (2026) cross-country productivity comparison data with 1650 data points for the period 1950-2022 and obtained a value of 0.72 when the growth rates were computed over 10 years. When the lag length was increased to 50 years, the parameter value was 0.66, which both are very close to 0.70 that Lucas himself used in simulations.

But what is behind the parameter θ? Lucas calls it "openness," but not just the size of foreign trade; rather, openness in the sense of "openness to the functioning of free markets" (see Gräbner 2018 for the numerous different measures of openness that are far from equal both in terms of levels and change rates). Even though this is the case, we estimated a panel equation in which GDP growth was explained by the export share of aggregate demand (the most often used measure) and lagged GDP growth (plus fixed effects) for 27 EU countries for 1960–2025 and obtained an elasticity estimate for the trade share equal to 0.12 (R2=0.60). This clearly indicates that "closed economies" will ultimately fail to achieve high growth rates. This may also (partly) explain the slowdown of growth after the financial crisis: economic opening has not continued to increase in the same way as during the pre-2015 period but has rather started to decline.

Figure 5. The relationship between openness and growth



Source: The graph is based on WDI data from 185 countries for 1985-2024.

Concluding remarks

We are used to hearing recommendations of the type: just increase educational and research finance to avoid a productivity-growth slowdown. But our analyses suggest that the outcome is not so simple as proposed. The proposed remedies may work well with less-developed countries, but when countries are close to the productivity frontier a more sophisticated investment strategy is required that acknowledges the simple fact that not all schooling and not all research is equally productive. And the functioning of the whole society—i.e., the product and labor markets—deserves more than just lip service.

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