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By Peter Voigt, Anna Thum-Thysen and Wouter Simons

Abstract

Education provides substantial long-term gains for individuals, the economy and society as a whole. Accordingly, investing in education and training is part of the solution to many of the challenges Europe is facing, including globalisation, shrinking of the workforce and the changing nature of regular work. Policy makers allocate an important share of taxpayers' money to achieve high quality education. However, spending may be subject to inefficiencies, i.e. potentially even more of an envisaged educational outcome (such as quantity, quality or inclusiveness of education) could be achieved if the money were spent according to best practice as defined by the performance across EU member states ("best practice across the EU"). To provide a measure of these gains we conduct a simple 'back-of-the-envelope' exercise, which relates PISA science score improvements from increasing efficiency in public spending on education to improvements in annual GDP per capita. Efficiency scores relating spending to PISA scores and semi-elasticities relating PISA scores to GDP per capita are taken from the existing literature. Results indicate that if we managed to eliminate any inefficiencies in spending with a view at achieving high PISA scores, annual growth of GDP per capita in the EU would be 0.8 percentage points higher in the long run; with variations across member states between 0.4 (as in Estonia) and 1.6 percentage points (as in Cyprus).

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The main message in a nutshell

Public entities spend taxpayers' money to provide public goods and achieve important societal outcomes, such as high-quality education. Regarding the use of these public resources, effectiveness (i.e. reaching high quality and equitable outcomes, or "doing the right thing") should go hand in hand with efficiency (i.e. using resources in the best possible way, or "doing things right").

In this Economic Brief, we concentrate on efficiency. Any spending may give rise to inefficiencies, i.e. even higher outcomes could be achieved if the money were to be spent more efficiently. To provide a measure of these potential gains as a contribution to a more general discussion on education and training policies, we conduct a simple 'back-of-the-envelope' exercise and we ask:

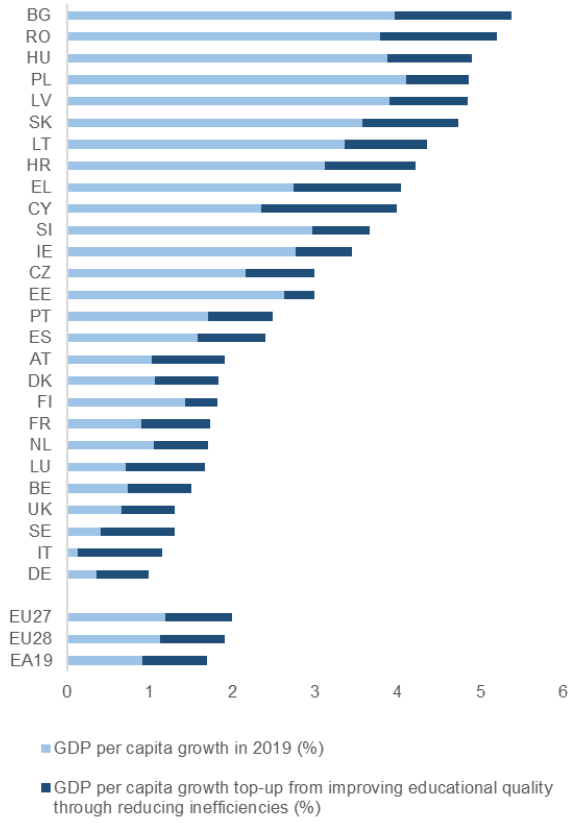
How much additional GDP growth could we achieve by improving the efficiency of public spending on education in the EU?

This question and the results from our corresponding calculations were also discussed at the first joint ECOFIN and EYCS (education) Council formation meeting on November 8th 2019. Ministers exchanged views on the role of education and training in contributing to long-term sustainable growth and shared best practices on policies promoting efficiency and effectiveness of investment in education and training.

We compute the economic benefits from setting up national education systems according to best practice as defined by the performance across EU Member States, which we refer to as "best practice across the EU" throughout this Brief.[1] Our estimates suggest that Member States could expect increases in annual GDP per capita growth rates between 0.4 p.p. (Estonia) and 1.6 p.p. (Cyprus). The average for both the EU28 and the EA would be approximately 0.8 p.p. (see Graph 1 for details).[2] The additional GDP per capita growth rate of around 0.8 p.p. would have translated into a potential increase in GDP for 2019 of up to EUR 115 billion in the EU28 and EUR 84 billion in the EA, respectively.

It could arguably take many years before these full effects of reforms may materialise as upskilling of the population is a slow process. When gradually phasing in the reform effects, the gain in annual GDP growth rate would stand at 0.16 p.p. after 15 years, when the reform is assumed to be fully enacted. In the following years, the growth rates increase even further as the original workforce is progressively replaced, reaching its maximum of 0.8 p.p. after 55 years. With GDP continuing to grow at this additional 0.8 p.p. per year, we could expect it to be 50% above GDP in a no-reform-scenario after 80 years, the expected length of a life-time in developed countries.

Graph 1: **GDP per capita growth as in 2019 and top-up effect if public spending on education had been as efficient as best practice across the EU[3]**



Source: calculations by European Commission (based on OECD and AMECO data).

Note: The efficiency scores were calculated on the basis of a stochastic frontier analysis (SFA, see Annex 1). Based on the observations in the sample, SFA implies calculating a hypothetical (non-deterministic) frontier, which we interpret as reflecting best practice across the EU. Conceptually it is possible that no country is exactly on the frontier, i.e. all countries have leeway to improve the efficiency of their spending.

The figures give an idea of the economic gains from moving towards best practice in terms of spending on education. In practice, it may require fundamental educational reforms and member states may be facing inherent constraints that can make it very difficult to reach the frontier. *Entirely* removing inefficiencies in a complex framework is challenging if not impossible, in particular in a short period of time.

A variety of policies may help to achieve better educational outcomes (regarding both efficiency and effectiveness) are discussed in the literature and among policy makers and they were also discussed during the joint ECOFIN and EYCS (education) Council formation meeting mentioned above. These include measures to ensure quality and equal opportunities, but also e.g. adaptation of curricula to ensure skill formation stays in line with future labour market needs. Reconsidering financing models for education and training, also through better exploiting synergies with EU funds, is yet another promising way, such as fostering synergies with complementary structural policies.

Advancing people's competences is one of the best investments a society can make

Education provides substantial long-term gains for individuals, the economy and society as a whole.[4] Accordingly, investing in education and training is part of the solution to many of the challenges Europe is facing, including globalisation, shrinking of the workforce and the changing nature of regular work.

Education and training can improve productivity by equipping people with key competences to perform tasks effectively, e.g. by using sophisticated technologies or generating and adopting new ideas.[5] The availability of these skills is a precondition for fostering research and development and firm-based innovation of products and processes. In addition, a highly skilled workforce contributes to economic resilience[6] and lowers the incidence of (future) labour market mismatches,[7] which could be a drag on productivity.[8]

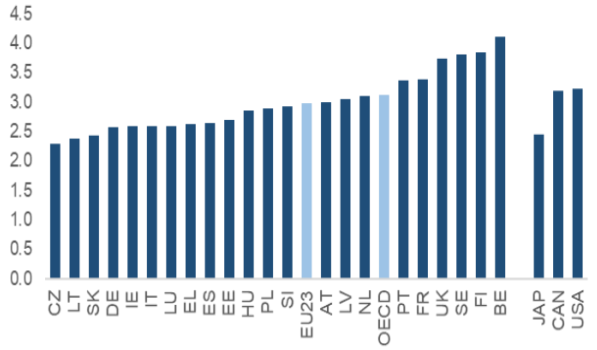
Moreover, education is also an effective remedy to fight poverty, unemployment, social exclusion and excessive income inequality. Many education policies therefore typically deliver a double-dividend for the society. [9]

The benefits of investing in education and training are typically high, while materialising over a long period. In the EU, a scenario of reducing the overall share of low-qualified people by half by 2025 is estimated to realise an annual economic net benefit of around EUR 200 billion.[10] Similarly, if the EU succeeded in reducing the proportion of low-achievers in basic skills to less than 15%, an ambition reflected in the strategic framework for European cooperation in Education and Training, the economy could plausibly gain some EUR 5,000 billion over an 80-year time horizon (i.e. average life expectancy of a person).[11]

Efficiency of spending on education

Europe's national education systems largely rely on public expenditures.[12] Currently, Member States spend more than EUR 700 billion or around 4.6% of GDP each year on education and training (Graph 2).

Graph 2: **Public expenditure on educational institutions from primary to tertiary level as a percentage of GDP, 2016**



Source: OECD, Education at a Glance, 2019 based on UIS/OECD/Eurostat data.

Note: data for non-OECD members unavailable; EU23 average covers the 22 EU Member states, which were also OECD members and Lithuania, which was not an OECD member in 2015 (note that data for Denmark is missing). UOE data is used here to make a comparison with non-EU Member States, while for the within EU comparison General Government Expenditure by function (COFOG) data was used.

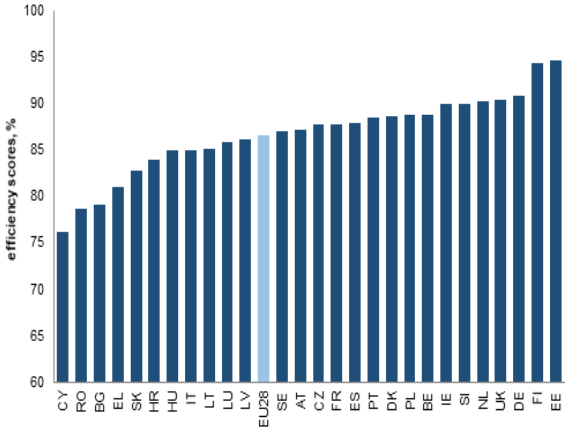
Given these substantial levels of public spending on education, it is important to understand how efficiently this money is spent. Canton *et al.* (2018)[13] estimate inefficiency of public spending on education in the EU over the period 2002-2015 along three main output dimensions: *quantity*, *quality* and *inclusiveness* of education; approximated by tertiary educational attainment, PISA scores (a measure of cognitive skills), and the share of the 25-29 year old not in employment, education or training (NEET-rates[14]), respectively. The authors control for factors affecting efficiency, such as parental education. In this paper, we use the inefficiency scores calculated on the *quality* dimension (see Graphs 3 and 4) to analyse the potential economic benefit that may arise from improving efficiency. The variables used to quantify these three dimensions are to our knowledge the best available international measures, but they could arguably be improved in future by further enhancing data collection in this regard.

The efficiency scores were calculated on the basis of a stochastic frontier analysis (SFA, see Annex 1). Based on the observations in the sample, SFA implies calculating a hypothetical (non-

deterministic) frontier, which we interpret as reflecting best practice across the EU. Conceptually it is possible that no country is exactly on the frontier, i.e. all countries have leeway to improve the efficiency of their spending.

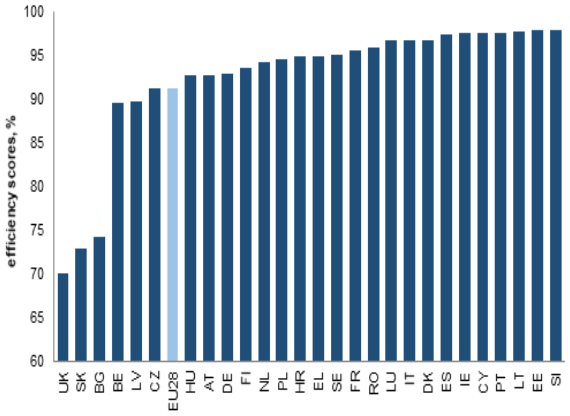
The scores were calculated with regard to two alternative scenarios, namely comparing EU countries among each other and comparing each countries' individual performance over time. Indeed, national education systems are quite specific and typically apply diversified approaches towards education that mirror to some extent national identities and distinct values. Controlling for time-invariant country specific characteristics such as e.g. institutional settings, the involvement of different government levels and cultural specificities (including relevant constraints) can therefore provide interesting insights. Conceptually, the common frontier and the country specific frontier(s) are both interesting cases, each providing us with useful information.[15]

Graph 3: **Efficiency scores, 2015, EU best performer**



Source: Canton *et al.* (2018), Section 6.1.

Graph 4: **Efficiency scores, 2015, country-specific best performance**



Source: Canton *et al.* (2018), Section 6.2.

Potential economic gains from improving efficiency in public spending on education

To illustrate the magnitude of possible gains from reducing inefficiency, we run a thought experiment: What if all governments across the EU were able to move to best practice regarding the efficiency of public spending? We assume an endogenous growth model i.e. education has an innovation effect and thereby growth does not peter out A relatively simple numerical exercise can help translating efficiency estimates into economic growth figures (see Annex 2 for more details).

Substantial gains in terms of quality of education (proxied by cognitive skills) could be made in individual countries if inefficiencies in spending on education were to be reduced (as shown in Graphs 3 and 4). This additional educational quality can be linked to potential economic gains based on estimates of social returns to education as provided in the literature. We follow Balart *et al* (2018), based on Hanushek and Woessmann (2012)[16], to calculate the gains in per capita GDP growth rates per country. The authors suggest that an increase in quality of education by one standard deviation (or 100 points) of cognitive test scores is associated with 1.2 p.p. higher average annual growth rate in GDP over 40 years.

We calculate the corresponding gains both by using efficiency scores compared to the best practice across the EU (as shown in Graph 3) or the individual best practice per Member State observed over years; as shown in Graph 4), respectively.

Substantial policy changes are needed to move closer towards the frontier and *entirely* removing inefficiencies in a complex framework is challenging if not impossible, in particular in a short period of time. Indeed, it could take many years before the full effects of such reforms may materialise because upskilling of the population only takes place gradually. After calculating counter-factual effects (the effects if spending had been fully efficient), we therefore also calculate the effects from gradually phasing in the reform effects.

Results with the best practice across the EU as a benchmark (i.e. comparing EU countries among each other)

Comparing national education systems against best practice' defined by the performance across EU

member states opens an important dimension for improving efficiency, arising mainly from structural changes. Closing the gap to the top performing Member States' systems may mean reorganising the entire system.

Undergoing such a transformation and removing all inefficiencies (based on the efficiency scores depicted in Graph 3), implies important gains in terms of additional annual per capita GDP growth ranging from 0.4 p.p. (Estonia) to 1.6 p.p. (Cyprus), with an average of approximately 0.8 p.p. for both the EU28 and the EA. The additional GDP per capita growth rate of around 0.8 p.p. would have translated into GDP growth for 2019 of potentially around EUR 115 billion for EU28 and EUR 84 billion for EA, respectively.

Results with national systems as benchmarks (comparing countries' performance over time)

Changing a national education system might be non-trivial and takes time. Hence, it could be interesting to assess the possible gains from addressing inefficiencies in public spending on education with a view at reaching the national best practice level (defined by observing performance within a country over time).

We find additional per capita GDP growth per Member State in the range between 0.1 p.p. (Cyprus, Estonia, Lithuania, Portugal and Slovenia) and 2.6 p.p. (United Kingdom) per year above baseline scenario. The effect in the UK is comparably very large due to an unusual combination of good performance in levels and at the same time declining PISA scores and increasing levels of spending over time.[17]

On average our results imply GDP per capita effects approximately 0.7 p.p. for the EU28 and 0.3 p.p. for the EA, respectively. Calculated for 2019, the additional GDP per capita growth rates would have translated into a potential total increase in GDP of up to EUR 100 billion in the EU28 and EUR 37 billion in the EA, respectively.

Gradual phasing in of the reform effects

The estimates described above are counterfactuals and they are static. Arguably, moving to best practice across the EU in a complex framework is challenging, in particular in a short period. It could take many years before the full effects of such reforms may materialise because upskilling of the population only takes place gradually.

We take this dynamic dimension into account by presuming a gradual phasing in of the reform effects. Following Hanushek and Woessmann's (2019) recent work in this area, we assume that it takes 15 years (a proxy for the average time it takes to complete education) for all newly educated cohorts to have benefited from the full reform effect and an additional 40 years (the length of a working life) to replace the lower-skilled workers in all labour market cohorts by the better educated ones. In total, it takes 55 years for the whole workforce to have gone through the reformed education system and therefore for the education reform to unfold its full impact. Based on these assumptions, we phase in the effects of the reform efforts to reduce inefficiencies.

Our results suggest that reducing inefficiencies according to the best practice across the EU[18], in the short run, would cause only moderate changes in terms of GDP growth rates (<0.01 p.p. in the first three years). However, as the workforce will be gradually upskilled thanks to the reform, the gain in annual GDP growth rate increases to 0.16 p.p. after 15 years, when the reform is fully enacted. The additional growth rates increase even further every year as the original workforce is gradually replaced over the following decades, reaching its maximum of 0.78 p.p. after 55 years. With GDP continuing to grow at this 0.78 p.p. per year over baseline in 80 years (the expected length of a life-time in developed countries), we could expect it to be 50% higher compared to a no-reform scenario.

Policy considerations: how could efficiency and effectiveness of public spending on education be improved?

The exercise described in this Economic Brief gives an idea of the economic gains from moving towards best practice in terms of spending on education. In practice, it may require fundamental educational reforms and member states may be facing inherent constraints that can make it very difficult to reach the frontier. *Entirely* removing inefficiencies in a complex framework is challenging if not impossible, in particular in a short period of time.

A variety of policies may help achieving better educational outcomes (regarding both efficiency and effectiveness) are discussed in the literature and among policy makers and they were also discussed during the first joint ECOFIN and EYCS (education) Council formation meeting on November 8th 2019

mentioned above. These include measures to ensure quality and equal opportunities, but also adaptation of curricula to ensure skill formation stays in line with future labour market needs. Reconsidering financing models for education and training, also through better exploiting synergies with EU funds, is yet another promising way, such as fostering synergies with complementary structural policies.

(i) Education and training systems need to deliver excellence in an inclusive manner. Policies could be designed to enhance both equity and quality. In terms of scope, they could cover the full range from high quality and inclusive early childhood education and care up to vocational education and training and higher education, enhance teacher quality and school infrastructure, foster school autonomy coupled with accountability and facilitate adult learning.[19]

(ii) The importance of accelerating digitalisation in all parts of our societies, including in education and training, is highlighted e.g. by the lockdown due to SARS-CoV-2. In fact, investing in digital infrastructure for education and training and also developing new learning concepts, including distance-learning, remote-training tools, etc., is one of the preliminary lessons to be drawn from the Covid-19-crisis.

(iii) Moreover, a wider set of "ICT-complementary" and "transversal" skills can help to face the challenges and reap the benefits of digitalisation. combining specific digital skills with media literacy, socio-behavioural and other transversal competences, including critical thinking, team-work, resilience, communication, self-expression and being creative, seems to be a promising strategy.[20] Skills governance informed by pan-European skills intelligence and graduate tracking systems can help to identify future skill needs. High quality vocational education and training can play an important role in equipping students with the right skills. Focus also needs to be on putting in place systematic and coherent upskilling and reskilling for low-skilled adults.

(iv) Leveraging investment in education and training calls for a smart mix of public and private financing. Comprehensive spending reviews can enhance public sector effectiveness (i.e. 'doing the right things') and corresponding spending efficiency (i.e. 'doing it in the right way'). Since private financing is also important, particularly as regards training, tax or financial incentives or public-private partnerships incentivising to invest more in upskilling and reskilling of adults appear to be useful approaches. As the benefits of investing in people go beyond national borders, EU-level action and funds can complement national policies.

(v) Complementary structural policies can make investments in education and training more powerful in achieving their objectives. For example, reforms to promote business-friendly regulation could foster the demand for skills (e.g. by removing barriers to firm entry, exit and growth or by enabling skill-intensive sectors).[21] EU-level policy coordination, for instance through the European Semester, could be useful in identifying and promoting such synergies. The Budgetary Instrument for Competitiveness and Convergence could speed up the implementation of structural reforms.

(vi) Finally, in order to analyse the economic effects of education and training, good quality statistical data is needed on the inputs (e.g. education expenditure), the outputs (skills; qualifications) and the outcomes (i.e. social and labour market outcomes) of such investment.[22] However, currently the data on several of these aspects is fragmented, partial or sometimes lacking altogether.[23] The recording of such investment could be enhanced and connected to non-monetary education indicators in a comparable and systemic way. For that purpose, the development of a satellite account for education and training in line with UNECE recommendations[24] could pave the way for a comprehensive future European Satellite Account for Human Capital which would eventually provide for an integrated and coherent framework to record public and private expenditure and returns to human capital and link it with non-monetary indicators.

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Annex 1: Estimating efficiency of public spending on education

The methodological approach and empirical findings briefly summarised below are comprehensively discussed in Canton *et al.* (2018). The thus obtained estimates of (in-)efficiencies in terms of public spending on education rely on a Stochastic Frontier Analyses (SFA).[25]

The corresponding stochastic frontier problem for country i in year t can be written as follows:

$$y_{it} = f(x_{it-1}, \beta)\varepsilon_{it}(z_{it})\exp(\omega_{it})$$

where y_{it} denotes an educational output, x_{it-1} public spending on education with a lagged effect[26], and $f(.,.)$ an (education) production function for country i in time t. β represents a the relationship between spending on education and educational output (proxying an input factor elasticity) while ε_{it} represents the level of efficiency which depends on the environmental factors z_{it}. $exp(\omega_{it})$ denotes a set of random shocks.

If $\varepsilon_{it} = 1$, country i in time t achieves the optimal output given the production technology $f(.,.)$. If $\varepsilon_{it} < 1$, country i in time t is not using its inputs optimally given the production technology. Technical efficiency ε_{it} is assumed to be positive with the boundaries $0 < \varepsilon_{it} \leq 1$.

Taking natural logarithms of the equation above yields:

$$\ln(y_{it}) = \ln\{f(x_{it-1}, \beta)\} + \ln\big(\varepsilon_{it}(z_{it})\big) + \omega_{it}$$

Assuming that the production function is log-linear and defining $u_{it}(z_{it}) = -ln(\varepsilon_{it}(z_{it}))$, we can write:

$$\ln(y_{it}) = \beta_0 + \beta_j \ln(x_{it-1}) - u_{it}(z_{it}) + \omega_{it}$$

with $u_{it} \geq 0$ as $0 < \varepsilon_{it} \leq 1$.[27]

This econometric model is estimated on the basis of a panel dataset as the inclusion of time-variation allows relaxing the assumption of time-invariant inefficiencies. Assuming a truncated normal distribution for the inefficiencies, technical inefficiencies in terms of public spending on education are estimated based on the model by Battese and Coelli (1995) for a pooled regression model and respectively on Greene (2005) when including fixed effects in the production function.

Canton *et al.* (2018) suggest estimating efficiency scores by following two different approaches: (1) across countries over time ('common EU frontier', i.e. no country specificities taken into account) and (2) within countries over time (i.e. controlling for the specificities of each country's education system by means of fixed effects). These different frontiers can be seen as two extreme cases: A common EU frontier allows evaluating efficiency assuming that education systems are transferable across countries while a country-specific frontier allows relaxing this assumption by considering national education systems as country-specific i.e. not easily changeable, especially not in a short period.

To reflect the dimensions of educational outputs considered as most important, three input-output pairs are looked at: (1) total public spending on all education levels (pre-primary up to tertiary) and tertiary educational attainment (measure of 'quantity'), (2) public spending on compulsory schooling (pre-primary up to secondary) and PISA science scores (proxy for 'quality') and (3) total public spending on all education levels and the rate of the 25-29 year old not in employment, education or training (NEETs)[28] (as a measure of 'inclusion'). In this brief we concentrate on dimension (2).

Annex 2: Calculating the economic effect potentially arising from improving the efficiency of public spending in Europe

In a first step we calculate the level of an educational output that can be achieved by maximising efficiency of public spending on education (i.e. reducing inefficiencies to zero) E^*. For this calculation we use the efficiency scores and the framework by Canton *et al*. (2018) described above. In a second step, we calculate the gain in GDP per capita growth potentially arising from increasing the educational output to its efficiency maximising level.

To obtain the gain in GDP per capita growth we use a measure of social returns to education (i.e. an estimate of the relationship between educational output and economic performance) from the literature. Per country, we calculate:

$$\Delta Y = \beta \Delta E^*$$

where ΔY is the change in economic outcome (we choose GDP per capita growth) that can be achieved by reducing inefficiencies in public spending on education to zero. β is a measure taken from the literature on 'social returns to education' (i.e. the expected economic impact from a change in educational output). The estimates of β taken from the literature (Balart *et al.* 2018, based on Hanushek and Woessmann 2012) imply that an increase in PISA scores of 100 points is associated with a 1.2 percentage point increase in annual GDP per capita growth. An increase of around 100 points on the PISA science test score scale corresponds to the difference between the average Peruvian student and the rest of the OECD in 2015. In our sample, the increases in PISA science scores stemming from efficiency improvements range from 31 in Estonia to 136 in Cyprus.

The β coefficient taken from the literature could suffer from an endogeneity bias. Hanushek and Woessmann (2012) and later also Balart *et al.* (2018) conduct a series of robustness checks in this regard, such as for example by controlling for possible omitted variables (geographical location, political stability, capital stock, population growth and school inputs), which do not significantly affect the estimated impact of cognitive skills.

Adding a dynamic dimension

To take into account the fact that it takes time for the full effects of education reforms to materialise, we follow Hanushek and Woessmann's (2019) approach for phasing in the reform, assuming a time horizon of 80 years (e.g. from 2019 to 2099). There are in total four phases:

1) 2019–2034 (15 years): It takes 15 years (average time of education) to have all newly educated cohorts having benefited from the full reform effect, which is assumed to be implemented ad hoc. The path of increased achievement is assumed as linear.
2) 2035 –2059 (25 years): After the assumed length of work life of 40 years, the original workforce is fully replaced, i.e. there is no cohort which has not (at least partly) benefited from the reform;
3) 2060–2074 (15 years): The first 15 cohorts, which had not fully benefitted from the reform, are replaced;
4) 2075–2099 (25 years): The whole workforce has gone through the reformed education system.

The increase in the annual growth rate differs across the different phases as described in Hanushek and Woessmann (2010), Annex C. Assuming a 25 PISA point increase and a growth coefficient of PISA scores of 1.98, Hanushek and Woessmann (2019) obtain a difference in GDP of 30%. The net present value can be obtained by summing the yearly discounted differences in GDP between the reform scenario and the non-reform scenario. Hanushek and Woessmann (2019) obtain additional GDP of EUR 71 trillion distributed over 80 years for a reform that increases student achievement by 25 PISA points. In this paper, we compare GDP in 2099 under the reform scenario with GDP under the non-reform scenario. The reform scenario corresponds to an increase in 65 PISA points.

The approach taken is based on the assumption of an underlying endogenous growth model, in which it is presumed that education has an effect on innovation – and thereby has a permanent effect on economic growth.

This assumption is contested by the literature on semi-endogenous growth models, in particular Jones (1995), who proposes a "stepping-on-toes" parameter that incorporates the idea that too many researchers can curb the additional growth effects after some time. Hanushek and Woessman (2011) have tested their results from an endogenous growth model against a neo-classical growth model, namely the most conservative model where spending on education is pure factor accumulation and has no innovation effect, so that growth peters out again. They found that the quantitative difference between the endogenous and neoclassical model framework matters less than academic discussions suggest. In fact, it apparently takes very long for the two models to diverge substantially.

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[1] The best practice does not refer to education policies but only to the efficiency of public spending on education.

[2] They result from improvements in learning outcomes (PISA science scores) of 65 points on average in the EU (ranging from 31 to 165 points across member states). This figure corresponds to the difference between the average Turkish student and the average OECD student in 2015.

[3] The presented calculations are merely hypothetical since, for various reasons, it will likely be impossible to eliminate all inefficiencies arising from public spending. However, the simple numerical exercise presented in this note outlines the order of magnitude of potential gains, which could be made by addressing inefficiencies in the education systems and what that would mean for individual Member States and Europe at large. For more details on the empirical evidence see Annex 1 and Annex 2 and Canton, Thum-Thysen and Voigt (2018).

[4] See for example European Commission (2014).

[5] Woessmann (2017).

[6] Woessmann (2017).

[7] European Commission (2014).

[8] Vandeplas and Thum-Thysen (2019).

[9] Cedefop (2017).

[10] Cedefop (2017).

[11] Hanushek and Woessmann (2019).

[12] Public funding is the key source of spending on education in Europe, in particular at the primary and secondary level. At the tertiary stage, co-financing is more common and in terms of training, private financing is the key source.

[13] See Canton, Thum-Thysen and Voigt (2018).

[14] The interpretation of the NEET indicator requires caution. It touches upon several areas such as unemployment, early school leaving or labour market discouragement. See Elder (2015) for a discussion on its interpretation.

[15] Considering a common cross-country frontier (i.e. not controlling for country fixed effects) is relevant under the assumption that the technology of the education production function is perfectly transferable across countries, i.e. country-specificities do not matter. While this may be true to some extent (in the sense that smart education policies are certainly at least partly exportable and countries can learn from good practices implemented elsewhere), it is arguably a fairly strong assumption. Including fixed effects allows relaxing this assumption and evaluating the efficiency of Member States controlling for time-invariant country-specific institutional settings. Results for either specification (analysing efficiency across countries and time as well as controlling for fixed effects and analysing efficiency within countries) are both presented in Canton et al (2018) in order to provide a picture of two specific cases with the actual space for efficiency improvements situated somewhere in between. The same holds equivalently for the calculated gains in terms of GDP/capita relying on the efficiency estimates.

[16] Balart, Oosterveen and Webbink (2018).

[17] While seen across countries, the UK is doing well in terms of spending levels and PISA levels, seen over time the UK is at the high end of the spectrum in terms of increasing spending over time and at the low end of the spectrum in terms of decreasing PISA scores over time. In other words, the UK's intertemporal performance is at the low end. The combination of good performance in levels and comparably not so good inter-temporal performance, put the UK in a position that the hypothetical frontier value is very high compared to its actual values. In the fixed-effects model, which is used in the

"national frontier", the frontier for the UK is composed of (1) a high level of PISA scores (given its good performance on PISA levels, the UK's fixed effect is high) and of (2) returns to spending that are as high as the average country's inter-temporal returns. In other words, at the hypothetical frontier, the UK needs to combine high levels with high returns, which is a difficult task given diminishing returns to spending.

[18] We skip presenting trajectories of how addressing inefficiencies merely benchmarked at national level would affect GDP growth (i.e. removing the inefficiencies measured according to the country-specific frontiers). In fact, given the long-term horizon of such a dynamic perspective, addressing only inefficiencies according to national benchmarks without looking beyond at best practice across the EU appears to be an implausible scenario.

[19] Woessman (2008).

[20] The OECD (2016b) finds for instance that intensive use of ICT skills is associated with more frequent problem solving and greater interaction with others. Media literacy refers to the ability to access media, understand and critically evaluate them and create communications in a variety of contexts. It is strongly related to active forms of citizenship as well as ability to identify disinformation (McDougall, Zezulkova, van Driel, Sternadel 2018).

[21] Vandeplas and Thum-Thysen (2019).

[22] European Commission (2015): An in-depth analysis of adult learning policies and their effectiveness in Europe, Luxembourg: Publications Office of the European Union.

[23] Eurostat (2016): Statistical approaches to the measurement of skills, Luxembourg: Publications Office of the European Union.

[24] UNECE (2016): Guide on measuring human capital.

[25] The parametric stochastic frontier technique has been chosen (over e.g. Data Envelopment Analysis (DEA)) since the former allows testing for statistical hypotheses, taking account of statistical noise, providing parameter estimates of production factors, elasticities and controlling for relevant country-specific effects.

[26] When empirically assessing the returns to spending on education one should be aware that significant time lags occur between the actual spending and obtaining measurable results, such as e.g. achieving a degree, i.e. the latter is subject to accumulated spending over a longer time span and/or building upon earlier education and skill levels. This lag structure is proxied by one year-lag to still keep the number of observations large enough.

[27] A key question is how to identify the inefficiency term $(-u_{it})$ through distributional assumptions on u_{it} and ω_{it} (such as assuming a truncated normal distribution for the inefficiencies and a normal distribution for the error terms). See Kumbhakar and Lovell (2000) for more details on how to identify these two error components.

[28] The interpretation of the NEET indicator requires caution. It touches upon several areas such as unemployment, early school leaving or labour market discouragement. See Elder (2015) for a discussion on its interpretation.

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