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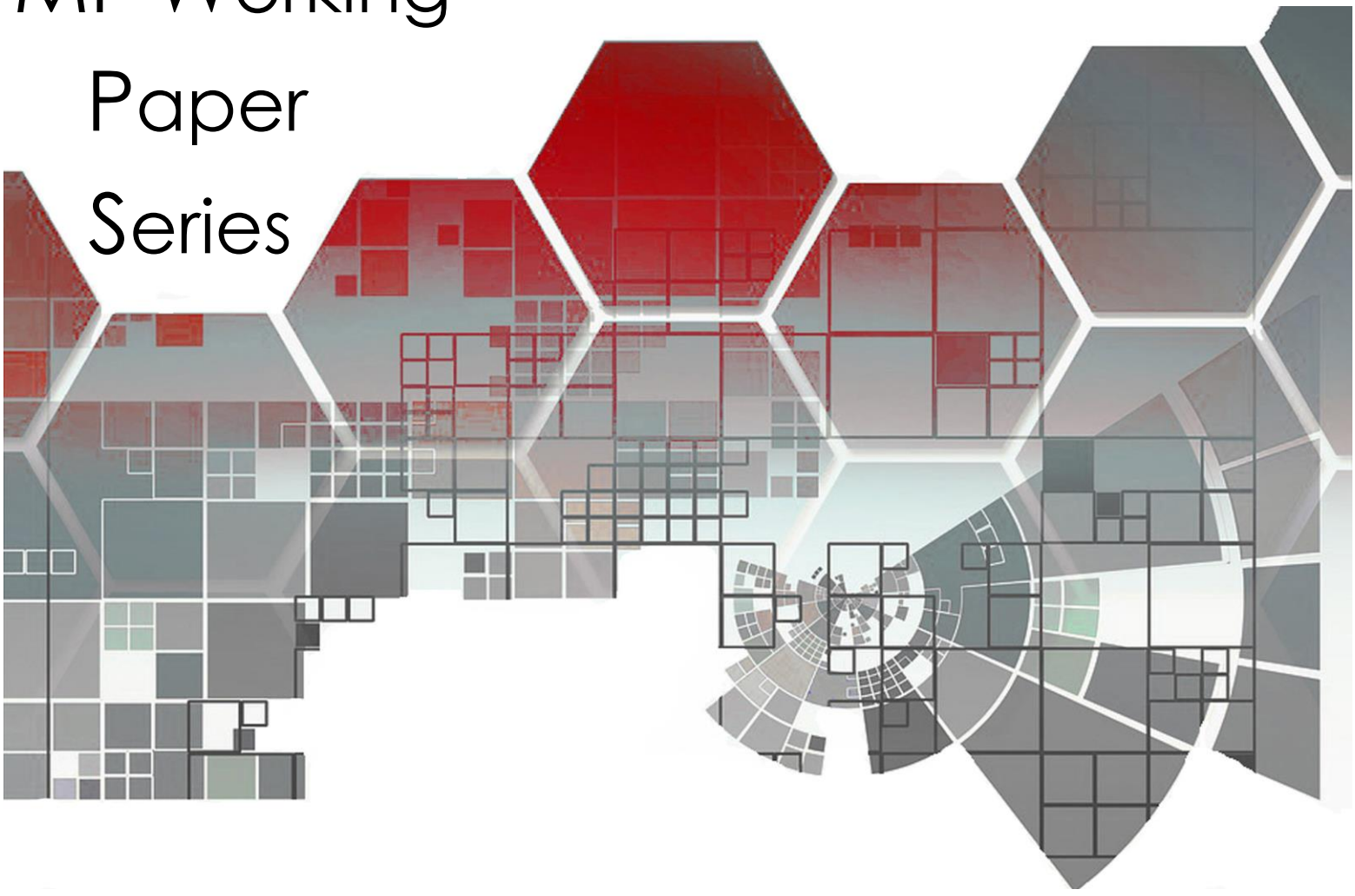

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Abstract

Most long-term GDP projections in developed countries expect a substantial decline in GDP growth rates over time. The main factor behind it is demographic changes, especially the decreasing working-age population. We argue that these projections do not consider improvements in the quality of the human capital, which may, at least to some extent, mitigate the effects of the negative demographic shock. We start with a simple observation – the skills of younger

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age cohorts are higher than of older cohorts. Assuming that the current level of skills will be obtained also by the generations which will enter the labor market in the future, the average level of skills among the working-age population will increase. Trying to catch this effect, we use the PIAAC standardized test results to create an aggregate human capital measure, the average skill level of the work force, for 18 EU countries and project it until 2040. We show that on average at least one sixth of the negative impact of the shrinking of the working-age population can be offset by the increase in the quality of human capital and that this number can increase to three quarters in a less conservative scenario.
Keywords: human capital, education, demography, GDP

JEL classification: I25, O15, O21

1 Introduction

According to the European Commission's (EC) forecast, the average annual GDP growth rate in the European Union (EU) between 2019 and 2070 will amount to 1.3 percent, in comparison to 1.6 percent in the two first decades of the 21st century. The slowdown of the GDP growth will to a large extent result from demographic changes — the decrease in number of inhabitants (negative contribution of total population: -0.1 pp.) and aging population structure (negative contribution of the share of working-age population: -0.2 pp.) (European Commission, 2021). Similar results are presented in the OECD long-term forecast, according to which the GDP per capita growth in OECD countries will decrease from 1.3 percent in 2007-20 to 1.1 percent in 2030-60, and the negative contribution of active population will amount to -0.2 pp. (Guillemette and Turner, 2021).

Long-term (potential) GDP estimates have started to have a direct impact on the economic policy. In line with the new EU fiscal rules, they will influence the country assessment based on the debt sustainability analysis and affect the required fiscal consolidation if projected debt or deficit to GDP ratios are above the 60 percent or 3 percent thresholds respectively.[1] Meanwhile, the quality of human capital is omitted from the methodology for estimating potential GDP used by the EC or other international institutions. This is especially harmful for countries that invest in the long-term economic growth by improving the quality of education.

Is this decline in growth rates inevitable? In this paper we argue that while the quantity of labor force will be lower, its quality (average skill level) will be higher. The age cohorts that enter the labor market are better educated than

[1] The European Council adopted the three pieces of legislation that will reform the EU's economic and fiscal governance framework on April 29, 2024. See details at the European Council's website, accessed on May 1, 2024.

the cohorts that leave the labor market. The interaction between these two factors – the demography and the human capital quality – will to a large extent determine the future path of development. While the impact of the former factor gains a lot of attention in the literature and public policy, the attention to the latter factor remains neglected. This is detrimental to countries that focus on investment in human capital and have largely improved the quality of education in recent decades.

To fill this gap, this article aims at estimating the impact of the expected increase in human capital quality in relation to the negative effects of population ageing in 18 European Union Member States (henceforth EU18). To achieve it we create an aggregate human capital measure, project it until 2040, and split the changes into demographic, economic activity and human capital quality factors. We use the standardized adult test results and European Commission's population and activity rates projections. The selection of the countries is determined by the availability of data (intersection between OECD and EU countries which participated in the first round of PIAAC tests).

We show that in the second decade of the 21st century (2011-2020) the positive impact of human capital accumulation on GDP (+1.2 pp) almost offset the negative contribution of working-age population decline (-1.5 pp). In the next two decades (2020-2040) the further increase in human capital quality will offset the negative contribution of the demography by at least 1/6 (+0.7 in comparison to -4.2). This result has been achieved with the assumption that the age cohorts entering the labor market will acquire skills at the maximum level of the cohorts currently in the working-age. Taking into account improvements in educational attainment and quality of education, the potential for the positive impact of the increase in human capital quality on the GDP growth is probably substantially higher. In the catching-up scenario, in which all countries achieve

the quality of education of the top-performing country (Finland), the increase in human capital would offset the negative contribution of the demography by almost 3/4. Our results are an important argument for including the quality of human capital in the long-term estimates of GDP growth.

The article is organised as follows. In the next section we review the literature on measuring human capital and incorporating it into macroeconomic estimates. The third section contains the description of the relation between skills and age. The purpose of this section is to document that the expected increase in the quality of human capital over time has a solid basis. In the fourth section we explain the method of calculating and projecting the aggregate human capital levels, while in the fifth section we present the results. The sixth section presents an alternative scenario of human capital development in the 18 EU countries studied and projections of its additional contribution to growth. We finalize with a conclusion section, in which we try to give a broader context to the results of our study.

2 Literature review

The literature on human capital and its macroeconomic impact is very extensive and goes back to the origins of economics as a separate discipline of science (Smith, 1776). In the context of this study, the literature review can be divided into two main parts – the types of human capital measures and the ways in which human capital could be taken into account in macroeconomic estimates.

There are at least three approaches to measure human capital:

1. the indicator approach which assesses the quality of human capital with some proxies, like mean years of schooling (Barro and Lee, 2013), illiteracy level, or using more complex indices which weigh a few independent components (Kraay, 2018);

2. the cost approach aggregating costs of investments in schooling, training, improving competences (Kendrick and others, 1976). Depending on the source, only formal or also informal expenses are included. Sometimes lost opportunity cost is also included – for example when young people devote their time to learning instead of working;

3. the (lifetime) income approach which measures the present value of the future expected income of the whole population of the country (Fraumeni and Christian, 2020).

Pros and cons of the three ways of measuring human capital are quite commonly known in the literature. Some recent publications examining the topic include Abraham and Mallatt (2022) and Liu and Fraumeni (2020).

The indicator approach is used for example in the World Bank Human Capital Index (Kraay, 2018). Many indicators reflect the quantity aspect of education (years of schooling, percentage of population which completed a certain level of education), although there have been also attempts to correct quantity measures for learning outcomes (Filmer et al., 2020). Demirgüç-Kunt and Torre (2022) combine this measure with the Human Capital Index.

The cost approach is mostly useful for research where public expenditure of various types is assessed. This measure assumes that the stock of human capital is equal to current the investments for instance in health and education, increased by old investments deflated by the depreciation rate (United Nations, 2016). Despite the limitations of this method, the cost approach is treated as a reliable tool for calculating human capital because it is based on actual investments and it may be incorporated into the system of national accounts (Angrist et al., 2021).

The methodology behind the lifetime income approach is described in details in the United Nations' Guide on Measuring Human Capital (United Nations,

2016) in Fraumeni and Christian (2020) and Liu and Fraumeni (2020). In this method the flow of expected income (given the age, gender, number of years of formal education) is calculated for every human being. Then, these flows are discounted to assess the net present value (NPV). Summed NPVs of the whole population represent the stock of human capital for a given country in a year. The income approach has been criticized because of the number of assumptions which need to be made in order to calculate the value of human capital for every country. Nonetheless, some reputable databases make use of this method, with World Bank's The Changing Wealth of Nations (CWON) 2021 among them.

To our best knowledge, none of the above mentioned measures have been projected for the purpose of evaluating their contribution to future GDP growth and/or the ability of human capital accumulation to compensate the negative observed or prospective demographic trends. One exception in this aspect is the aggregate human capital measure focusing on educational attainment developed by Lutz et al. (2017). However, this measure does not fully capture the quality aspect of human capital.

The second part of this literature review briefly summarizes the issue of how human capital could by included into macroeconomic estimates and especially its contribution to GDP growth. In the second half of the twentieth century economists realized that human capital is an important determinant of productivity, wages, economic growth or well-being and explained these mechanisms (among others Schultz, 1961; Becker, 1962; Romer, 1990; Lucas Jr, 1988; Barro, 2001). Economists have noted that increases in output have been large in comparison with the increases in physical capital or labor force. Investment in human capital is one of the most possible explanations for this difference. Expenditures on education, health, R&D have significant impact on economic development but are not fully included in the national accounts or potential

growth calculations.

Most empirical studies adopt a narrow perspective on the role of human capital by adjusting the workforce for changes in age, gender, and levels of educational attainment (Jorgenson and Fraumeni, 1989). One of the most comprehensive examples of that phenomenon is illustrated in the recent EU KLEMS & INTANProd growth accounts database[2] which incorporates such compositional changes in the labor input. According to the recent results of EU KLEMS, average annual contribution of labor force composition to labor productivity growth in the advanced economies of the European Union and the United States amounted to only 0.2 pp. after 2000 (Bontadini et al., 2023). Similar magnitudes for the traditional neoclassical model are reported in Jones (2014) and Jones (2019).

3 Relationship between skills and age

The literature on changes in human capital with age concludes that it rises in the first years of working life due to general education and learning-by-doing and maxes out at the age of about 30-40 years. Then it becomes stable until around 50, when it starts declining (Feyrer, 2007; Werding, 2008; Göbel and Zwick, 2009, 2012; Ruzik-Sierdzinska et al., 2013). An important aspect of the loss of productivity is not only the loss of ability to perform tasks, but also the changing nature of the tasks, which speeds up the deterioration of competences (Autor et al., 2003). Egert et al. (2022) estimations show that the human capital level of people aged 50-59 is 3 percent lower than maximum human capital, and for the final age group the depreciation increases to 5 percent.

[2]EU KLEMS is an industry level, growth and productivity research project funded by the Directorate General for Economic and Financial Affairs (DG-ECFIN) of the European Commission. EU KLEMS stands for EU level analysis of capital (K), labor (L), energy (E), materials (M) and service (S) inputs. Source: https://euklems-intanprod-llee.luiss.it/ (accessed on July 7, 2023).

Moreover, most measures of educational attainment show that younger age groups are now better educated. In Figure 1, we present the average scores of the PIAAC tests (see the next subsection for a broader discussion about PIAAC test methodology), which show that the highest scores are achieved by the age group 25-29 (on average). The share of people with tertiary education is the highest in the 25-34 age group (EU18 average), and tertiary education levels have increased significantly over the last decade (see Figure 2).

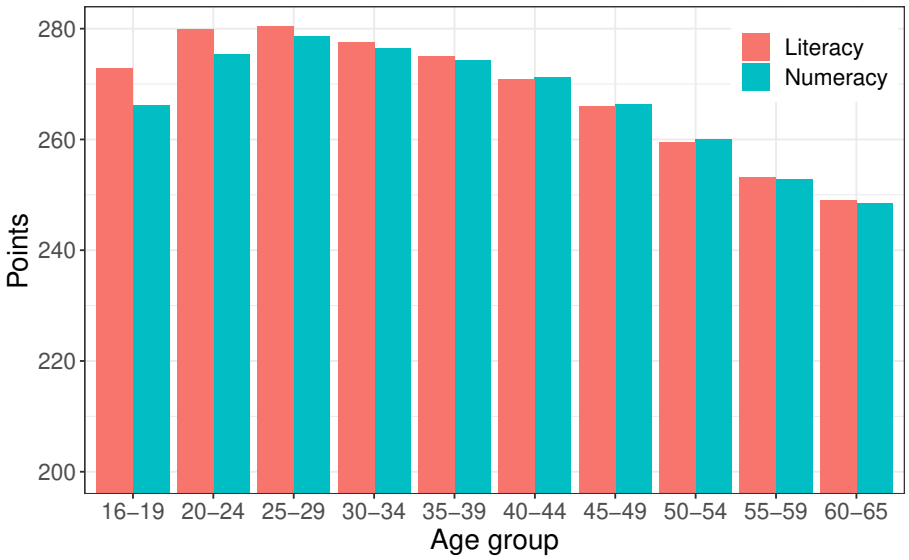


Figure 1: Average PIAAC results in EU (18 countries) by age.

Furthermore, Kudins (2022) shows that factors contributing to the increase in macroeconomic productivity are technological readiness and lifelong learning in the country. These factors can be seen as catalysts that ensure the economic usefulness of older workers in terms of productivity in the countries of the modern world.

All of these suggest that the aggregated "quality of human capital" is improving and in the next decades this trend should continue.

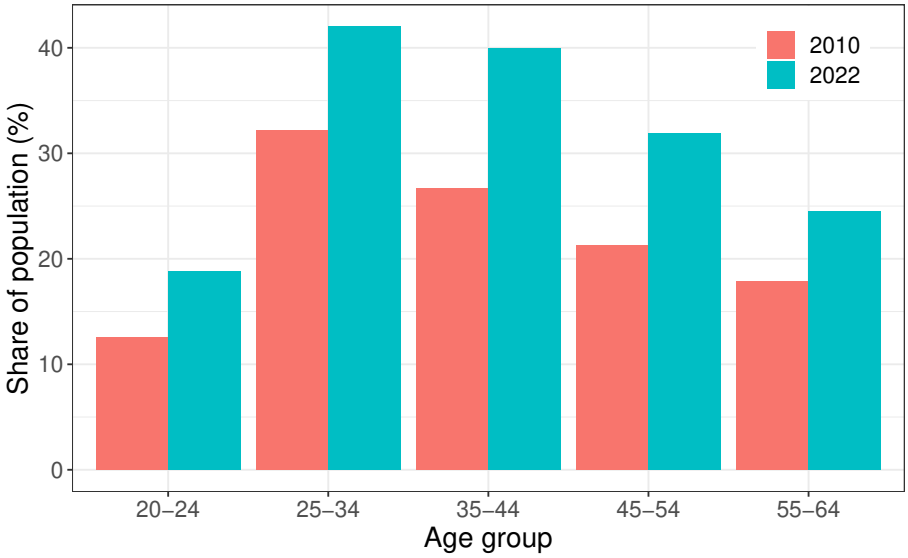


Figure 2: Average tertiary education attainment in EU by age.

4 Model and data

4.1 PIAAC data

A reliable measure of human capital, not in terms of input but in terms of effect, is useful in quantitative analysis. Comparable measures include standardized external tests, income-approach measures or complex indices. Differences in PIAAC test results by age cohorts can theoretically be considered a proxy for development and investment in human capital.

The Programme for the International Assessment of Adult Competencies (PIAAC) is a survey of adults aged 16-65 conducted by the OECD both in Member States and in countries cooperating with the organization. The first cycle of the assessment started in 2011 and the OECD intends to repeat them every 10 years. Data collection for the PIAAC 2nd Cycle[3] started in 2022 but

[3]PIAAC 2nd Cycle is the official name of the assessment. More details available on the OECD website (accessed on July 31, 2023).

the results will be published in 2024.

During the first cycle 37 countries were surveyed in 3 rounds. The rounds covered the following countries:

- Round 1 (2011-2012): Australia, Austria, Belgium (Flanders),[4] Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Italy, Japan, Korea, Netherlands, Norway, Poland, Russian Federation, Slovak Republic, Spain, Sweden, United Kingdom (England and Northern Ireland), United States of America,
- Round 2 (2014-2015): Chile, Greece, Indonesia, Israel, Lithuania, New Zealand, Singapore, Slovenia, Turkey,
- Round 3 (2017): Ecuador, Hungary, Kazakhstan, Mexico, Peru and once again USA.

The second cycle will also be conducted in rounds. 31 countries participated in the first round in 2022-2023 (30 OECD members and Russian Federation). Another round is planned in 2024-2029 but the list of participating countries has not been published yet. Literacy and numeracy are assessed again during the 2nd Cycle of PIAAC, apart from the new modules, including Adaptive Problem Solving. A representative sample of around 5000 individuals is/will be participating in each country (the same number as in 1st round).

The PIAAC test consists of three parts proceeded by a background questionnaire, requesting information about gender, age, wages, formal education, professional training, willingness to change job, among others. The three areas of the assessment are literacy, numeracy and problem solving. Every category is graded separately, and the results may range from 0 to 500 (though actual results circulates around 250-300).

[4] Given that only the region of Flanders participated in the study, we do not include Belgium in our sample.

Test results by cohort for EU18 countries show that human capital of the 20-24, 25-29 or 30-34 year-old adults is at the highest level (see Table 1). The same pattern repeats for most countries, although with some exceptions – especially Denmark and Slovakia, where persons aged 35-39 obtained the highest average test scores.

An example of the application of PIAAC test results in economic studies was by Hanushek et al. (2015) with the purpose of evaluating the returns to education. They estimate that a one-standard-deviation increase in numeracy skills is associated with an 18 percent wage increase among prime-age workers.

	16-19	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-65**	**Average**
Finland	282.5	298.1	304.3	**306.9**	300.7	290.3	287.7	275.0	264.0	256.4	286.6
Netherlands	284.6	294.4	295.4	**295.6**	293.3	288.5	279.9	274.1	262.1	260.8	282.9
Sweden	268.1	289.6	**292.7**	285.3	289.3	284.4	281.3	270.7	272.1	260.9	279.5
Denmark	268.0	281.0	285.9	283.0	**287.1**	284.3	274.2	267.8	263.5	255.6	275.0
Czechia	271.4	285.0	286.8	**288.0**	277.5	274.7	269.5	268.2	265.9	260.3	274.7
Slovakia	274.4	278.9	279.4	277.9	**283.0**	275.6	276.2	268.8	266.0	265.1	274.5
Estonia	276.8	**286.8**	285.6	284.0	277.5	275.3	270.6	267.2	261.4	258.8	274.4
Austria	271.8	283.6	**285.0**	276.7	281.2	275.4	272.6	268.0	255.0	252.4	272.2
Germany	272.6	281.2	**285.5**	277.5	275.0	278.4	269.5	262.0	262.1	247.5	271.1
Hungary	266.8	273.9	**277.9**	277.7	275.0	275.4	271.5	262.3	253.8	249.3	268.4
Lithuania	277.7	281.7	**282.0**	273.7	266.9	266.6	263.2	255.3	254.1	254.2	267.5
Poland	273.1	**276.4**	275.8	271.5	266.4	263.1	262.0	251.6	247.0	245.8	263.3
Ireland	260.0	268.4	268.6	**272.0**	267.0	264.5	254.5	254.4	245.6	243.2	259.8
France	264.7	273.7	**275.8**	271.6	269.7	259.8	250.3	249.4	238.6	237.4	259.1
Slovenia	269.3	**276.6**	274.1	268.3	266.5	263.7	255.9	243.3	231.2	236.4	258.5
Greece	254.4	256.7	252.7	**258.3**	254.6	252.7	256.4	251.2	247.2	245.2	252.9
Italy	260.9	249.9	**265.1**	258.2	252.6	251.1	247.0	245.4	236.9	227.7	249.5
Spain	255.2	**263.1**	259.4	260.6	260.2	254.3	248.7	241.6	226.6	220.4	249.0

Table 1: PIAAC test scores for selected EU countries (average of Numeracy and Literacy tests.)

4.2 Aggregate human capital calculation

The projections of country-level human capital are based on three main data sources. We use the PIAAC numeracy and literacy test results (a simple average) as a proxy for human capital per age group (16-19, 20-24, 25-29, ..., 60-65). The test results are mostly from 2011-2012 (in some countries 2015 or 2017) and we assume that they describe human capital in 2011 (our base

year) or 2015 for countries where the tests were conducted later.[5] To obtain the country-level human capital we calculate weighted averages of age-group test results. We use the latest population projection from Eurostat (EUROPOP2023)[6] and projections of participation rates from the Ageing Report 2024 (European Commission, 2023) to forecast the labor force for each age group. To match the PIAAC results data we restrict our sample to the population aged 16-65 divided in 5-year age groups. Historical data by age group (for the years 2011, 2015 and 2020) comes from Eurostat demographic data and LFS activity rates. Country-level human capital is the weighted average of the test results by age group, where we use the predicted/historical share of each age group in labor force in a given country in a given year. We apply the following formula:

$$HC_{c,year} = \Sigma_{age5} \frac{LF_{\{age5,c,year\}}}{LF_{\{c,year\}}} HC_{\{age5,c,year\}} \tag{1}$$

where

$age5 \in \{16-19, 20-24, 29-34, \ldots, 60-65\}$,

$year \in \{2011, 2015, 2020, 2025, 2030, 2035, 2040\}$,

$c \in \{AT, CZ, DK, EE, FI, FR, DE, EL, HU, IE, IT, NL, PL, SK, SE, ES, LT\}$

This measure has an intuitive interpretation – it is the expected PIAAC test result in a given country at a given time, which means that it reflects the average *quality* of the labor force.

Due to data restrictions (PIAAC test results are only available by 5-year age groups), we limit our attention to human capital projections at 5-year intervals. It would be possible to estimate the share of labor force switching groups each year, but we do not see additional advantages of this approach, given that we do not have human capital estimates for each age.

First, we calculate human capital for each age group for the years 2011, 2015

[5] Greece and Lithuania in 2014-2015, Hungary 2017.

[6] See Eurostat dataset PROJ_23NP (accessed on September 12, 2023).

and 2020, then we project it for the following years: 2025, 2030, 2035, 2040. We assume that the youngest people in the work force maintain the same level of human capital as the current generation (so people aged 16-19 will have the same level of human capital in all years in the projections). For each country we identify the age group for which the test results were the highest and call this level the maximum human capital of the country. All future generations obtain this level at the same age. Additionally, we assume that the future generations also keep the same level of human capital until they enter the age group 50-54. This relies on the assumption that the observed gains from education and experience are maintained in the society and all future generations can benefit from the current maximum stock of knowledge in a given country. However, we do not apply this assumption to people aged 50-54 in 2015, because this cohort did not have the maximum human capital level in 2011. All the cohorts that do not reach the maximum human capital level continue with the same test results as their peers in 2011. Following Egert et al. (2022) we assume that human capital level of people aged 50-59 is 3 percent lower than maximum human capital, and for the final age group the depreciation increases to 5 percent.

One caveat (which can actually also be seen as an advantage) of our approach is that we consider the entire labor force and not only the working population in our calculation of the aggregate human capital. This differs from the calculation of the value of labor as a factor of production in GDP estimates. In order to make our estimates consistent with GDP calculations we need to assume that average human capital level is the same for the employed and the unemployed. We believe that this is not a strong assumption, since we consider the aggregate human capital to reflect the long-run potential of the country in a similar manner to the treatment of the capital stock in EUCAM production function approach to the potential GDP calculation.[7]

[7]European Union's Commonly Agreed Methodology for output gap estimation using the

Another caveat of our approach is that we assume that after reaching the maximum level of human capital at the age 20-39 (depending on the country) it remains stable before it starts depreciating when the person reaches the age of 50 years. In the literature, there is a consensus that human capital increases with work experience and takes an inverted U-shaped form (Feyrer, 2007; Castelló-Climent, 2019). However, the size of the increase in the quality of human capital or productivity resulting from work experience is highly specific to the period and country analyzed. Therefore, we remain with our assumption and the presented results should be treated as a minimum, or a conservative scenario. We try to overcome this caveat in Section 6 where we present an alternative scenario in which we release this assumption.

The next issue is the fact that our projections depend only on one iteration of the adult test results could be considered a caveat, however relying on different iterations also proves to be challenging. Campbell and Üngör (2020) show that looking at the average test results in different periods of time can be very misleading. In their example country – Ghana – the test score dropped from 480 in 1980 to 345 in 2007, which could indicate a substantial deterioration of the human capital level. However, Campbell and Üngör (2020) notice that the drop might be due to broader schooling availability, suggesting that the test results in 1980 could be affected by a kind of selection bias (only the richest and/or smartest fraction of the population had access to schooling at that time and was able to participate in the evaluation). Our measure of human capital is not subject to this constraint.

4.3 Growth accounting – HC contribution

Based on our measure of human capital we are able to calculate the contribution of human capital to economic growth in a standard growth accounting exercise.

production function approach. For more details see Havik et al. (2014).

The aggregate production function can be reformulated in the following way:

$$Y_{c,year} = A_{c,year} \times K_{c,year}^{1-\alpha} \times (HC_{c,year} \times L_{c,year})^{\alpha} \tag{2}$$

where $\alpha = 0.65$ (in line with EUCAM) is the labor share in income,[8] $Y_{c,year}$ – GDP in country c in a given year, K is the aggregate capital stock, L – total labor supply (which can be expressed in terms of the number of workers or total hours worked per year) and HC is our measure of aggregate human capital (which can be interpreted as the labor force-weighted average PIAAC result in the areas of Literacy and Numeracy).

This approach was used by the World Bank in an altered version of the Oxford Global Economic Model (World Bank (2022), Annex 2). The difference to the standard approach is that we explicitly account for the level of human capital, rather than leaving it in the unexplained TFP part.

With this approach we are able to calculate the projected contribution of human capital to economic growth until 2040 and verify to what extent improvements in the aggregate human capital level are able to compensate the predicted negative demographic changes.

Given our data, the contribution of human capital to the cumulative 5-year

[8]We evaluate the robustness of the main result to an alternative scenario in which we assume gradual decline in the labor share from 0.65 in 2010 to 0.4 in 2040 and conclude that the conclusions related to the ability of human capital to compensate for negative demographic trends is of the same level of magnitude on average (around 1/6). While in almost all the countries in our sample human capital growth is expected to slow down over time, population drops are expected to be larger and larger. This means that a lower future labor share affects stronger the contribution of demography to growth (mitigating the negative effect). Declining labor shares have been described for example in Karabarbounis and Neiman (2014). According to PWT 10.1 data (Feenstra et al., 2015), they have been decreasing in most EU18 countries, at least until 2015. To our knowledge, there are no projections of labor share in the time horizon considered and it goes beyond the scope of this paper to forecast it. For this reason, we provide a linear convergence scenario, simulating a substantial drop of 0.25 in the labor share in 25 years. Results of this analysis are available from the authors upon request.

growth in country c is given by:

$$HCcontr_{c,year} = \alpha \times \left(\frac{HC_{c,year}}{HC_{c,year-5}} - 1 \right) \times 100 \tag{3}$$

The contribution of working-age (16-65 years old) population change is:

$$POPcontr_{c,year} = \alpha \times \left(\frac{POP_{c,year}}{POP_{c,year-5}} - 1 \right) \times 100 \tag{4}$$

and, finally, the contribution of changes in activity:

$$ACTcontr_{c,year} = \alpha \times \left(\frac{ACT\_RATE_{c,year}}{ACT\_RATE_{c,year-5}} - 1 \right) \times 100 \tag{5}$$

where the average activity rate is $ACT\_RATE_{c,year} = \frac{LF_{c,year}}{POP_{c,year}}$.

It is important to point out that we do not provide new forecasts of GDP growth – we decrease the contribution of the Solow residual ("the measure of our ignorance") by taking out from it one part which we are able to measure (and which can be affected by public policy), namely the human capital stock.

5 Results

In this section we first discuss the projections of human capital per cohort and the aggregate country results. In the second part we provide historical and projected growth decomposition in order to evaluate the contribution of human capital to economic growth and its potential to mitigate the negative effects of declining and ageing populations.

5.1 Human capital projections

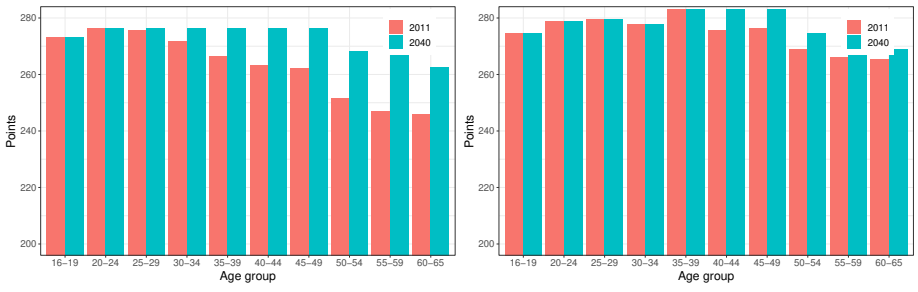
We start with presenting the human capital projections by age cohort. These projected test results are then weighted by projected cohort labor force shares

to obtain forecasts of the aggregate human capital level in each country until 2040.

Figure 3 shows changes in the projected average PIAAC test results by cohort from 2011 to 2040. We present two countries with different distributions of skills by cohort – Poland and Slovakia. Poland is characterised by high inter-generational differences in the level of education (younger cohorts with much higher average educational attainment than older cohorts) and significant improvements in the quality of education in recent decades, as shown by the PISA[9] tests results since 2000 (see Appendix D). Contrary to that, in Slovakia one may observe lower differences in age-related educational attainment and a decline in PISA test scores over time. As a result, the inter-generational differences in the skills level, as indicated by the PIAAC, are much greater in Poland than in Slovakia. This substantially affects our projections of human capital changes over time – it implies that countries like Poland can benefit more from human capital accumulation.

Figure 3: Human capital projections by cohort – 2011 vs. 2040.

(a) Poland (b) Slovakia



Tables 2 nad 3 show projected average test results by age cohort over time for those two chosen example countries (Poland and Slovakia, respectively). We assume that all future young cohorts will obtain the same level of human capital

[9]Programme for International Student Assessment

as did their peers in the 2011 PIAAC tests. Once a given individual enters the cohort with highest human capital level, the individual maintains this score until entering the 50-54 age group. After this point, the depreciation begins:

$$HC_{\{age5\in\{50-54,55-59\},c,year\}} = 0.97 \times HC_{\{age5=age^*,c,year\}} \tag{6}$$

and for the oldest cohort:

$$HC_{\{age5\in\{60-65\},c,year\}} = 0.95 \times HC_{\{age5=age^*,c,year\}} \tag{7}$$

where age^* denotes the age cohort which reaches the maximum level of human capital in a given country.

The lower the age at which the maximum test result is scored, the longer it takes for the cohort profile to stabilize. For example, in Poland the age group 20-24 obtained the highest PIAAC results and the final distribution of human capital will be reached only in 2035, while in Slovakia 40-44 and stabilization of cohort human capital already happened in 2020, meaning that future changes in the aggregate human capital levels in this country are due to demography and changes in economic activity. The older the cohort with the highest test scores, the shorter the time horizon for the projected improvements in human capital. There are four countries which can benefit from improvements in skills for the longest amount of time: Estonia, Poland, Slovenia and Spain. Denmark and Slovakia are at the other extreme, with no further gains from human capital expected.[10]

Figure 4 shows the results of aggregation of human capital by cohort in each country. Improvements are expected in all countries, though of different magnitude. The expected aggregate human capital stabilizes over time, which

[10]This is a rather conservative scenario, in which we assume that no further improvements in test results after 2011 are possible.

year	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	273.08	276.39	275.76	271.54	266.45	263.13	261.96	251.64	246.99	245.80
2015	273.08	276.39	276.39	275.76	271.54	266.45	263.13	261.96	251.64	246.99
2020	273.08	276.39	276.39	276.39	275.76	271.54	266.45	263.13	261.96	251.64
2025	273.08	276.39	276.39	276.39	276.39	275.76	271.54	266.45	263.13	261.96
2030	273.08	276.39	276.39	276.39	276.39	276.39	275.76	268.10	266.45	262.57
2035	273.08	276.39	276.39	276.39	276.39	276.39	276.39	268.10	268.10	262.57
2040	273.08	276.39	276.39	276.39	276.39	276.39	276.39	268.10	268.10	262.57

Table 2: Poland – Projected PIAAC tests results by age cohort.

year	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	274.36	278.93	279.36	277.86	283.02	275.55	276.20	268.82	266.04	265.15
2015	274.36	278.93	279.36	277.86	283.02	283.02	275.55	274.53	268.82	266.04
2020	274.36	278.93	279.36	277.86	283.02	283.02	283.02	274.53	274.53	268.82
2025	274.36	278.93	279.36	277.86	283.02	283.02	283.02	274.53	274.53	268.87
2030	274.36	278.93	279.36	277.86	283.02	283.02	283.02	274.53	274.53	268.87
2035	274.36	278.93	279.36	277.86	283.02	283.02	283.02	274.53	274.53	268.87
2040	274.36	278.93	279.36	277.86	283.02	283.02	283.02	274.53	274.53	268.87

Table 3: Slovakia – Projected PIAAC tests results by age cohort.

is a consequence of the stabilization of cohort results. As mentioned before, further improvements in the aggregate level of human capital would be possible if the demographic or labor market conditions were improving.

According to the PIAAC results, Finland has the labor force with the highest skill level, followed by the Netherlands and Sweden. At the bottom of the rank list there are Greece, Spain and Italy. While in the latter two some improvements are expected, human capital in Greece is projected to oscillate around its initial level from 2015. We do not see a lot of within-country variation in PIAAC results (standard deviation of 7.6 points on average, exceptionally high, around 17 points, in Finland) and this translates into a persisting between-country gap (standard deviation growing from 11.3 to 11.8 points) and little movements in country ranks over time (most countries move at most two positions up or down).

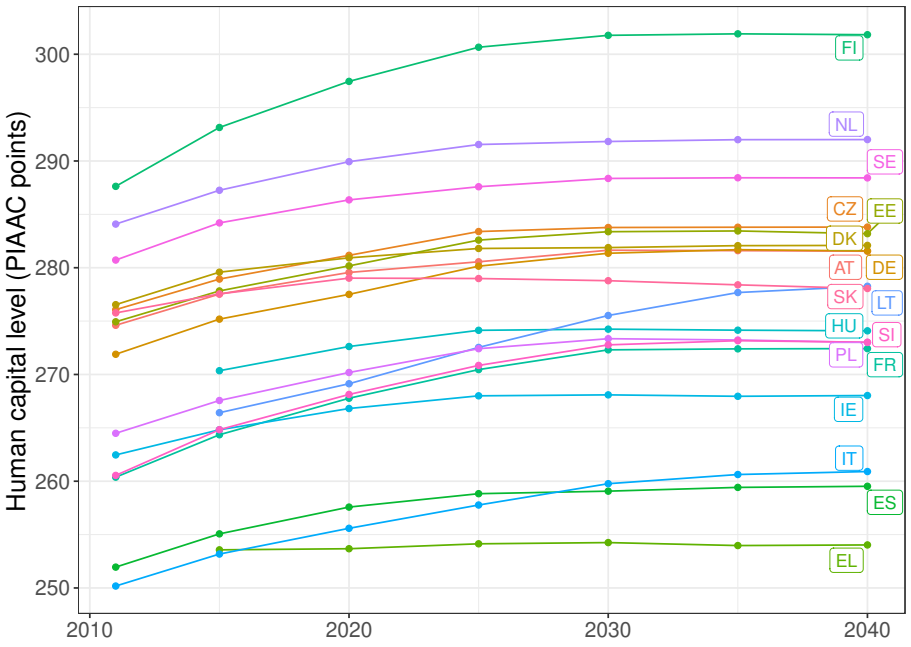


Figure 4: Aggregate human capital projections 2011-2040.

Figure 5 shows the gain from human capital changes calculated as the point difference of the aggregate result in a given country between 2040 and 2011. The black dots mark the total effect, reflecting changes in overall human capital levels. While already starting from the highest position, Finland is also expected to remain on this position in the long run due to the largest projected improvements (by roughly 14 points). The lowest gains are expected in Hungary, Slovakia (of 3.7 and 2.3 points, respectively) and Greece (only 0.5 points).

The total effect can be decomposed into three components: "pure" human capital, economic activity and demographic effect. Improvements in the aggregate human capital come primarily from the first component, reflecting better test results over time. Projected changes in the activity rates are expected to have a negative effect on the aggregate human capital level. This is due to the increasing activity rates of older cohorts whose human capital is lower. In most

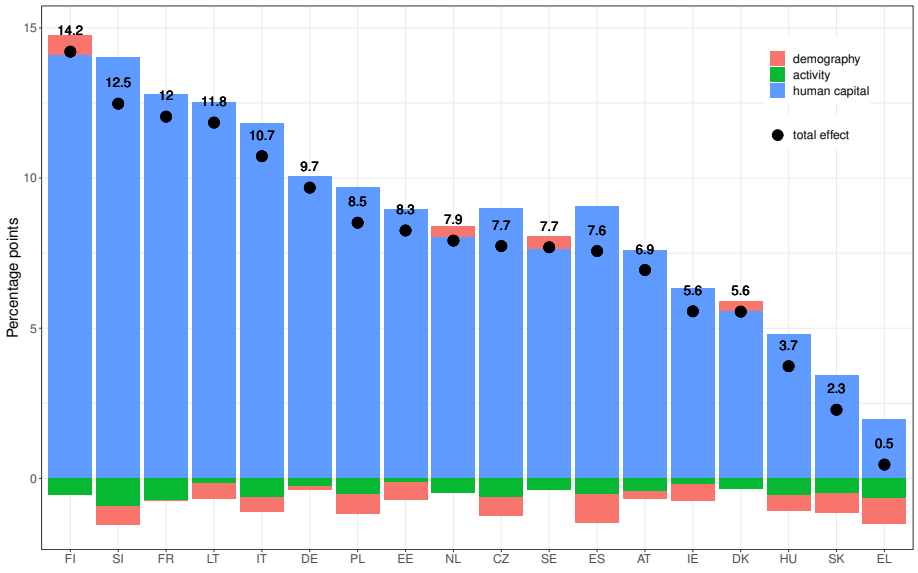


Figure 5: Projected gains/losses from human capital, demography and activity rates improvements in 2040 by country.

countries demographic changes mitigate the beneficial improvements in human capital. There are a few exceptions: Finland, the Netherlands, Sweden and Denmark. In these countries beneficial changes in the age composition of the labor force are expected, strengthening additionally the positive impact of the human capital accumulation.

It should be stressed that the aggregate human capital level does not depend on the size of the working-age population, but only on its composition. This means that while shrinking populations do not matter for this aspect, population ageing is a relevant factor, because of the assumed distribution of skills in the population – younger or middle cohorts obtain the maximum level of skills, which later on start depleting after reaching the age of 50. Aggregate human capital is therefore expected to deteriorate with population ageing.

5.2 Growth contribution

We can use our aggregate human capital measure to evaluate the contribution of skills of the labor force to economic growth (see Section 4.3 for details on the methodology). Standard growth accounting considers the impact of capital and labor (expressed in hours worked or employed persons). Other factors are part of the TFP contribution. However, the impact of human capital can be disentangled from the other factors labeled as TFP and treated as a part of the labor input contribution.

Figures 6 and 7 show the total contribution of labor to cumulative GDP growth over the years 2011-2040 divided into two periods: 2011-2020 (historical labor force data) and 2020-2040 (based on projections)[11]. It is also decomposed into three factors: demographic changes, evolution of the activity rates and human capital accumulation. On average in the EU18 countries in our sample, the contribution of labor (including human capital) goes down from 2.7 pp. in 2011-2020 to only 0.5 pp. in 2020-2040.[12] In the period ending in 2020 improvements in the activity rates and the quality of human capital more than compensated the negative demographic trends. Human capital accumulation itself accounted for 1.2 pp. in growth on average, offsetting 80 percent of negative contribution of the working-age population decline. In 2020-2040 the positive impact of human capital accumulation will decrease to 0.7 pp. while the negative impact of demography will increase to 4.2 pp. The contribution of activity rates is projected to amount to 3.9 pp., which means that the total labor contribution will be still positive, but much lower than in the previous decade.

The spread of the overall contribution of labor to growth doubles (ranging from -4.8 to 7.0 pp. in 2011-2020 and between -8.8 and 16.0 pp. in 2020-2040). This is mostly due to stronger demographic and participation rate effects. The

[11] Detailed country results are also presented in Table C.1 in Appendix C.
[12] These are cumulative contributions over the entire time period considered.

range of human capital contribution remains roughly constant (ranging from 0 to 2.2 pp. in 2011-2020 and between -0.2 and 2.2 pp. in 2020-2040).

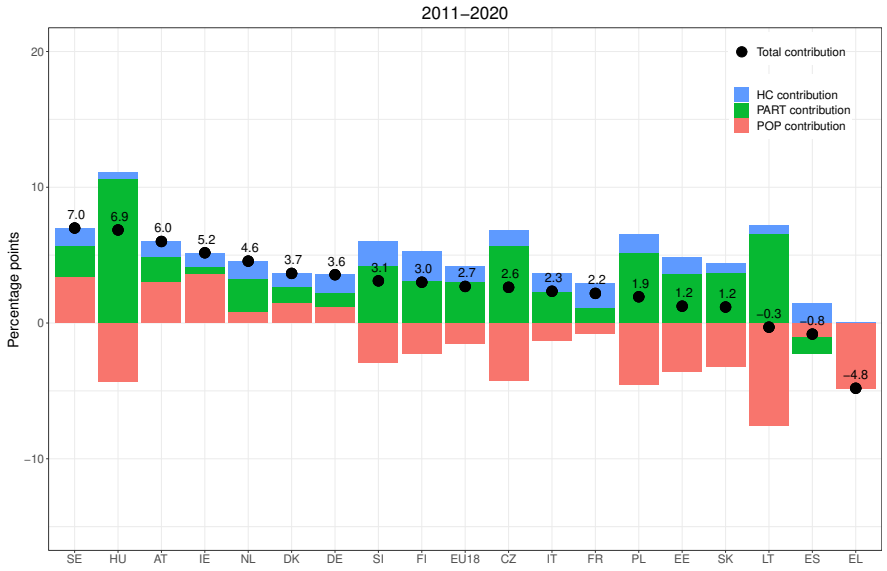


Figure 6: Estimated contribution to economic growth of aggregate human capital, population and activity rate changes – cumulative 2011-2020.

The results show that without further investments in human capital its beneficial contribution to growth might fade away. However, while activity rates cannot go beyond a certain threshold (100 at most), there are no clear limits on knowledge and skill acquisitions. We provide an alternative scenario in the following section and show that we could gain additional growth if we allowed for further positive changes in education over time and reiterate that the results presented here should be treated as a conservative scenario.

6 Scenario – catching up with the top performer

In the baseline results we assume that all future generations will follow the same pattern evolution of skills with age as the young generations in 2011 in

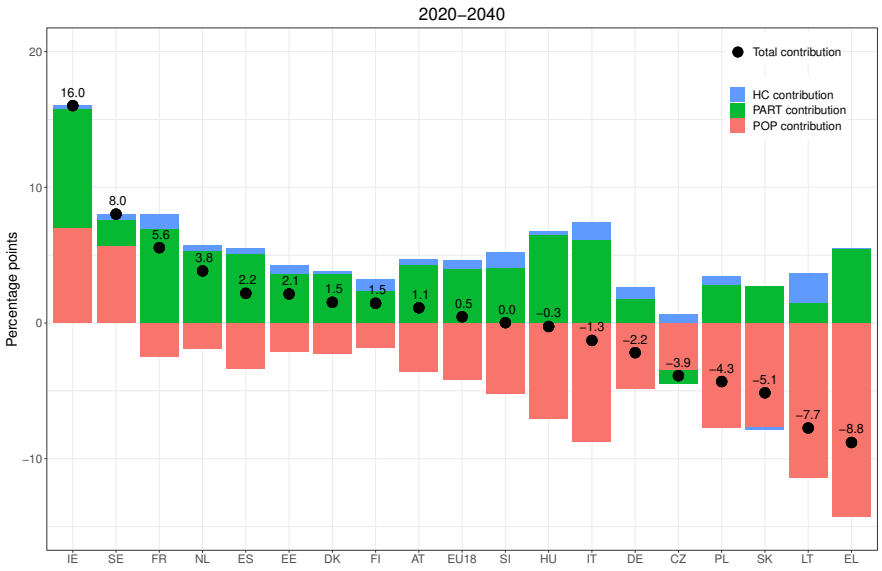


Figure 7: Expected contribution to economic growth of aggregate human capital, population and activity rate changes – cumulative 2020-2040.

each country. This is a rather conservative scenario and may substantially underestimate the contribution of human capital to growth after 2020.

To overcome this problem we propose an alternative scenario. We assume that between 2011 and 2020 countries improve their education system and that in 2020 the 16-19 year-old cohort in each country enters the labor market with the same skills as the Finnish youth in 2011. In the following years these generations stay on the Finnish path, meaning that the 20-24 year-old cohort (y.o.c.) in 2025 have the same skills as their peers in Finland, the 25-29 y.o.c. in 2030, 30-34 y.o.c. in 2035. The highest level of human capital in Finland in 2011 was reached by the 30-34 y.o.c. This assumption is maintained for the other countries, so that the 35-39 y.o.c. in 2040 maintains the same level of human capital as they had in the previous period. We choose Finland as benchmark for this exercise, as it has the highest PIAAC test scores for all cohorts (apart from the 16-19 where the leader is the Netherlands) and consequently the highest aggre-

gate human capital level in 2011 among the eighteen EU countries in our sample (as well as top PISA results, see Appendix D). We call this the "catching-up scenario".

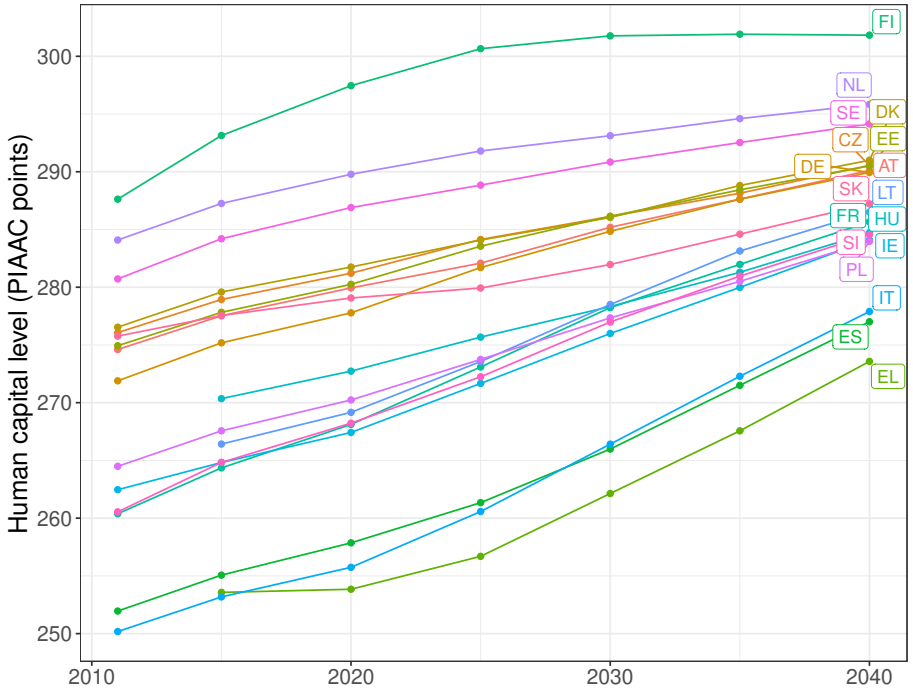


Figure 8: Aggregate human capital projections 2011-2040 – catching-up scenario.

Obviously, this scenario does not affect any of the results for Finland. For other countries, the aggregate level of human capital is affected but gradually – we only alter the results of young generations which constitute a decreasing share in ageing populations.

The average gain in the aggregate human capital in 2040 is equal to roughly 4 percent as compared to the baseline results. The larger the initial distance between a given young cohort in country X and in Finland, the larger the gain. While the aggregate human capital in the Netherlands, the country with the

second-best results, grows by 2 percent in 2040, in Italy and Spain the gain is around $6.5 - 6.7$ percent and in Greece 7.7 percent.

We can also translate the gain in terms of the aggregate human capital into its contribution to growth. We assume that the activity rate and population age structure projections remain the same as in the baseline scenario and calculate the new contribution of human capital to growth.

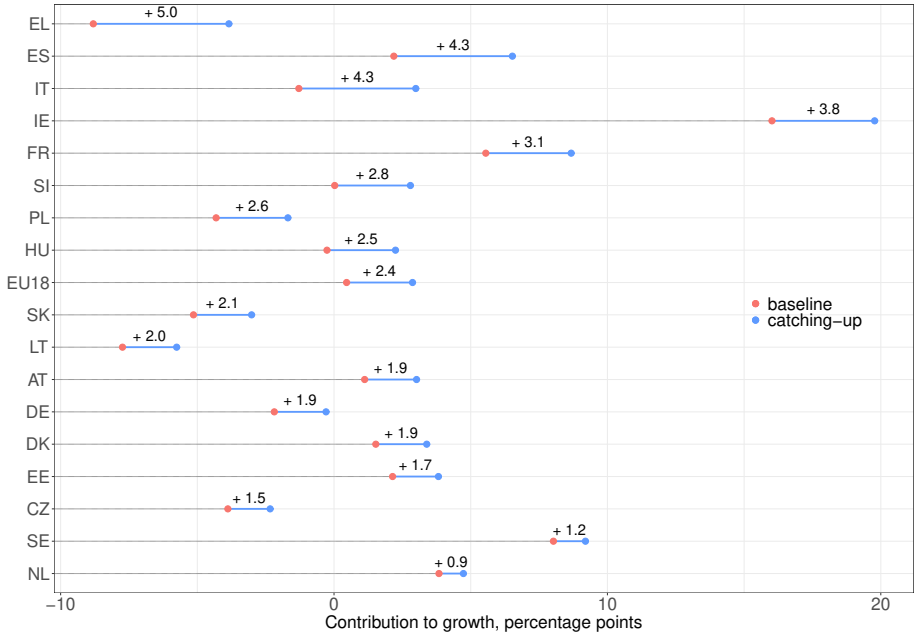


Figure 9: Change in contribution to growth 2020-2040 - catching-up vs. baseline results.

The EU18 average contribution of human capital to growth in 2020-2040 increases by 2.4 pp., from 0.7 to 3.1. It means that under the catching-up scenario the increase in the human capital quality is able to offset 74 percent of the negative contribution of working-age population decline (-4.2 pp.). The total labor contribution to growth increases from 0.5 to 2.9 pp.[13] In the baseline scenario we have eight countries with the overall negative projected labor contribution

[13]Detailed scenario results can be compared with baseline in Appendix C

in 2020-2040. In the scenario of gradual catching up with Finland two countries manage to invert the sign of the overall impact – Italy and Hungary. This means that, according to our projections, reproducing Finnish human capital outcomes would allow to compensate the negative demographic trends.

7 Conclusion and discussion

Human capital accumulation is considered to be one of the main drivers of economic growth. However, this factor is largely overlooked in the long-term forecasts of GDP growth. In our paper we try to close this gap. We construct an aggregate human capital measure for eighteen EU countries and project it until 2040. We show that in all analyzed countries the value of human capital will increase, as skills of younger age cohorts are significantly higher than the skills of older age cohorts. There is, however, a large variation in the aggregate human capital change across countries. We use our measure to calculate the impact of human capital on economic growth. According to our projections the positive contribution of human capital accumulation to GDP can offset the negative contribution of the working-age population decline. Despite the positive impact of the skills' improvement gradually fading away in the next two decades (2020-2040) and the negative impact of ageing accelerating, human capital accumulation has the potential to offset 1/6 of the negative impact of the working-age population decline. With further improvements in the quality of education to the top-performing country, this effect may increase to almost 3/4. We show this in our alternative, less conservative, "catching-up scenario" in which we assume that from 2020 young cohorts in each country enter the Finnish path of human capital evolution. This scenario translates into an additional contribution to growth by 2.4 p.p. on average.

Our paper makes two important contributions. First, we present a solid

argument for including the dynamics of human capital quality in the long-term estimates of GDP growth. We show that it is possible to make projections of human capital development in the long run and augment the labor factor with these estimates in a way that allows for easy interpretations of the results (average test result of the workforce). Given that with the new EU fiscal framework resulting from the Economic Governance Review, long-run potential growth estimates became even more relevant for policy makers, the methodology of these projections should be carefully revised. We propose one way of improving it.

Second, in our paper we highlight that human capital investments may, at least to some extent, mitigate the negative effects of ageing of population on economic growth. This is an important remark for public policy, which is overly focused on counteracting the inevitable decline in the working-age population. The probably more successful solution to ageing is to invest in skills of people who will make up the workforce in the future — so that although this workforce shrinks, its aggregate economic potential will be no less than today. One of the first steps to change the emphasis in public policy would be to include investment in human capital in the formal definition of investment (Paczos et al., 2023).

Finally, the results of our study rely on the assumption that the age cohorts that will enter the labor market in the future will gain similar skills to the young cohorts that were already part of the workforce in 2011. This assumption may be subject to criticism. It is probably too conservative, as, on the one hand, the quality of education in most countries has been constantly improving. On the other hand, we do not take into account the negative impact of the COVID-19 pandemic, lockdowns, and school closures on education[14] and consequently on

[14]Some articles concerning a potential impact of COVID-19 school closures on schooling and learning outcomes: in Germany (Werner and Woessmann), 2023, the Netherlands (Engzell et al., 2021), United States (Kuhfeld et al., 2020) or global estimates (Azevedo et al., 2021). The learning-adjusted years of schooling measure of the World Bank shows that the EU18 average human capital level in 2020 was roughly the same as in 2010 (see Table E.1 in Appendix E).

human capital, counteracting the improvements in education from the previous decade and bringing our baseline scenario closer to reality.

At the moment we do not have arguments for adopting any different assumption. Such arguments may appear when the results of the PIAAC 2nd Cycle, taking place between 2018-2024, are published. Then it will be possible to analyse how the skills of the cohorts that participated in the previous edition of the survey have changed, and what skills the new cohorts entered the labor market with. The results of our study have the potential for further exploration when the new data appear.

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A Detailed HC projections by cohort and year

	16-19	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-65**
2011	271.84	283.59	284.99	276.69	281.21	275.42	272.60	267.95	255.04	252.41
2015	271.84	283.59	284.99	284.99	276.69	281.21	275.42	272.60	267.95	255.04
2020	271.84	283.59	284.99	284.99	284.99	276.69	281.21	275.42	272.60	267.95
2025	271.84	283.59	284.99	284.99	284.99	284.99	276.69	276.44	275.42	270.74
2030	271.84	283.59	284.99	284.99	284.99	284.99	284.99	276.44	276.44	270.74
2035	271.84	283.59	284.99	284.99	284.99	284.99	284.99	276.44	276.44	270.74
2040	271.84	283.59	284.99	284.99	284.99	284.99	284.99	276.44	276.44	270.74

Table A.1: Austria

	16-19	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-65**
2011	271.41	285.02	286.84	288.03	277.45	274.68	269.51	268.23	265.92	260.31
2015	271.41	285.02	286.84	288.03	288.03	277.45	274.68	269.51	268.23	265.92
2020	271.41	285.02	286.84	288.03	288.03	288.03	277.45	274.68	269.51	268.23
2025	271.41	285.02	286.84	288.03	288.03	288.03	288.03	277.45	274.68	269.51
2030	271.41	285.02	286.84	288.03	288.03	288.03	288.03	279.39	277.45	273.63
2035	271.41	285.02	286.84	288.03	288.03	288.03	288.03	279.39	279.39	273.63
2040	271.41	285.02	286.84	288.03	288.03	288.03	288.03	279.39	279.39	273.63

Table A.2: Czechia

	16-19	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-65**
2011	272.64	281.23	285.48	277.53	275.02	278.44	269.51	261.98	262.14	247.51
2015	272.64	281.23	285.48	285.48	277.53	275.02	278.44	269.51	261.98	262.14
2020	272.64	281.23	285.48	285.48	285.48	277.53	275.02	276.91	269.51	261.98
2025	272.64	281.23	285.48	285.48	285.48	285.48	277.53	275.02	276.91	269.51
2030	272.64	281.23	285.48	285.48	285.48	285.48	285.48	276.91	275.02	271.20
2035	272.64	281.23	285.48	285.48	285.48	285.48	285.48	276.91	276.91	271.20
2040	272.64	281.23	285.48	285.48	285.48	285.48	285.48	276.91	276.91	271.20

Table A.3: Germany

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	268.00	281.02	285.94	283.00	287.05	284.29	274.21	267.84	263.50	255.59
2015	268.00	281.02	285.94	283.00	287.05	287.05	284.29	274.21	267.84	263.50
2020	268.00	281.02	285.94	283.00	287.05	287.05	287.05	278.44	274.21	267.84
2025	268.00	281.02	285.94	283.00	287.05	287.05	287.05	278.44	278.44	272.70
2030	268.00	281.02	285.94	283.00	287.05	287.05	287.05	278.44	278.44	272.70
2035	268.00	281.02	285.94	283.00	287.05	287.05	287.05	278.44	278.44	272.70
2040	268.00	281.02	285.94	283.00	287.05	287.05	287.05	278.44	278.44	272.70

Table A.4: Denmark

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	276.81	286.82	285.58	283.98	277.52	275.31	270.62	267.18	261.38	258.80
2015	276.81	286.82	286.82	285.58	283.98	277.52	275.31	270.62	267.18	261.38
2020	276.81	286.82	286.82	286.82	285.58	283.98	277.52	275.31	270.62	267.18
2025	276.81	286.82	286.82	286.82	286.82	285.58	283.98	277.52	275.31	270.62
2030	276.81	286.82	286.82	286.82	286.82	286.82	285.58	278.21	277.52	272.48
2035	276.81	286.82	286.82	286.82	286.82	286.82	286.82	278.21	278.21	272.48
2040	276.81	286.82	286.82	286.82	286.82	286.82	286.82	278.21	278.21	272.48

Table A.5: Estonia

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2015	254.43	256.66	252.66	258.32	254.61	252.74	256.41	250.57	247.22	245.17
2020	254.43	256.66	252.66	258.32	258.32	254.61	252.74	250.57	250.57	245.40
2025	254.43	256.66	252.66	258.32	258.32	258.32	254.61	250.57	250.57	245.40
2030	254.43	256.66	252.66	258.32	258.32	258.32	258.32	250.57	250.57	245.40
2035	254.43	256.66	252.66	258.32	258.32	258.32	258.32	250.57	250.57	245.40
2040	254.43	256.66	252.66	258.32	258.32	258.32	258.32	250.57	250.57	245.40

Table A.6: Greece

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	255.18	263.06	259.41	260.55	260.16	254.25	248.70	241.58	226.63	220.43
2015	255.18	263.06	263.06	259.41	260.55	260.16	254.25	248.70	241.58	226.63
2020	255.18	263.06	263.06	263.06	259.41	260.55	260.16	254.25	248.70	241.58
2025	255.18	263.06	263.06	263.06	263.06	259.41	260.55	255.17	254.25	248.70
2030	255.18	263.06	263.06	263.06	263.06	263.06	259.41	255.17	255.17	249.91
2035	255.18	263.06	263.06	263.06	263.06	263.06	263.06	255.17	255.17	249.91
2040	255.18	263.06	263.06	263.06	263.06	263.06	263.06	255.17	255.17	249.91

Table A.7: Spain

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	282.49	298.09	304.31	306.92	300.71	290.27	287.69	275.00	264.04	256.40
2015	282.49	298.09	304.31	306.92	306.92	300.71	290.27	287.69	275.00	264.04
2020	282.49	298.09	304.31	306.92	306.92	306.92	300.71	290.27	287.69	275.00
2025	282.49	298.09	304.31	306.92	306.92	306.92	306.92	297.71	290.27	287.69
2030	282.49	298.09	304.31	306.92	306.92	306.92	306.92	297.71	297.71	290.27
2035	282.49	298.09	304.31	306.92	306.92	306.92	306.92	297.71	297.71	291.57
2040	282.49	298.09	304.31	306.92	306.92	306.92	306.92	297.71	297.71	291.57

Table A.8: Finland

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	264.68	273.67	275.79	271.65	269.69	259.80	250.29	249.37	238.63	237.36
2015	264.68	273.67	275.79	275.79	271.65	269.69	259.80	250.29	249.37	238.63
2020	264.68	273.67	275.79	275.79	275.79	271.65	269.69	259.80	250.29	249.37
2025	264.68	273.67	275.79	275.79	275.79	275.79	271.65	267.52	259.80	250.29
2030	264.68	273.67	275.79	275.79	275.79	275.79	275.79	267.52	267.52	259.80
2035	264.68	273.67	275.79	275.79	275.79	275.79	275.79	267.52	267.52	262.00
2040	264.68	273.67	275.79	275.79	275.79	275.79	275.79	267.52	267.52	262.00

Table A.9: France

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2015	266.77	273.92	277.95	277.75	275.02	275.44	271.55	262.35	253.78	249.32
2020	266.77	273.92	277.95	277.95	277.75	275.02	275.44	269.61	262.35	253.78
2025	266.77	273.92	277.95	277.95	277.95	277.75	275.02	269.61	269.61	262.35
2030	266.77	273.92	277.95	277.95	277.95	277.95	277.75	269.61	269.61	264.05
2035	266.77	273.92	277.95	277.95	277.95	277.95	277.95	269.61	269.61	264.05
2040	266.77	273.92	277.95	277.95	277.95	277.95	277.95	269.61	269.61	264.05

Table A.10: Hungary

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	260.04	268.36	268.64	271.98	266.99	264.55	254.51	254.37	245.57	243.25
2015	260.04	268.36	268.64	271.98	271.98	266.99	264.55	254.51	254.37	245.57
2020	260.04	268.36	268.64	271.98	271.98	271.98	266.99	263.82	254.51	254.37
2025	260.04	268.36	268.64	271.98	271.98	271.98	271.98	263.82	263.82	254.51
2030	260.04	268.36	268.64	271.98	271.98	271.98	271.98	263.82	263.82	258.38
2035	260.04	268.36	268.64	271.98	271.98	271.98	271.98	263.82	263.82	258.38
2040	260.04	268.36	268.64	271.98	271.98	271.98	271.98	263.82	263.82	258.38

Table A.11: Ireland

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	260.90	249.90	265.08	258.18	252.59	251.08	246.97	245.37	236.89	227.66
2015	260.90	249.90	265.08	265.08	258.18	252.59	251.08	246.97	245.37	236.89
2020	260.90	249.90	265.08	265.08	265.08	258.18	252.59	251.08	246.97	245.37
2025	260.90	249.90	265.08	265.08	265.08	265.08	258.18	252.59	251.08	246.97
2030	260.90	249.90	265.08	265.08	265.08	265.08	265.08	257.13	252.59	251.08
2035	260.90	249.90	265.08	265.08	265.08	265.08	265.08	257.13	257.13	251.82
2040	260.90	249.90	265.08	265.08	265.08	265.08	265.08	257.13	257.13	251.82

Table A.12: Italy

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2015	277.67	281.66	282.02	273.75	266.87	266.59	263.16	255.27	254.10	254.19
2020	277.67	281.66	282.02	282.02	273.75	266.87	266.59	263.16	255.27	254.10
2025	277.67	281.66	282.02	282.02	282.02	273.75	266.87	266.59	263.16	255.27
2030	277.67	281.66	282.02	282.02	282.02	282.02	273.75	266.87	266.59	263.16
2035	277.67	281.66	282.02	282.02	282.02	282.02	282.02	273.56	266.87	266.59
2040	277.67	281.66	282.02	282.02	282.02	282.02	282.02	273.56	273.56	266.87

Table A.13: Lithuania

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	284.61	294.40	295.43	295.61	293.31	288.49	279.94	274.09	262.08	260.79
2015	284.61	294.40	295.43	295.61	295.61	293.31	288.49	279.94	274.09	262.08
2020	284.61	294.40	295.43	295.61	295.61	295.61	293.31	286.75	279.94	274.09
2025	284.61	294.40	295.43	295.61	295.61	295.61	295.61	286.75	286.75	279.94
2030	284.61	294.40	295.43	295.61	295.61	295.61	295.61	286.75	286.75	280.83
2035	284.61	294.40	295.43	295.61	295.61	295.61	295.61	286.75	286.75	280.83
2040	284.61	294.40	295.43	295.61	295.61	295.61	295.61	286.75	286.75	280.83

Table A.14: Netherlands

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	273.08	276.39	275.76	271.54	266.45	263.13	261.96	251.64	246.99	245.80
2015	273.08	276.39	276.39	275.76	271.54	266.45	263.13	261.96	251.64	246.99
2020	273.08	276.39	276.39	276.39	275.76	271.54	266.45	263.13	261.96	251.64
2025	273.08	276.39	276.39	276.39	276.39	275.76	271.54	266.45	263.13	261.96
2030	273.08	276.39	276.39	276.39	276.39	276.39	275.76	268.10	266.45	262.57
2035	273.08	276.39	276.39	276.39	276.39	276.39	276.39	268.10	268.10	262.57
2040	273.08	276.39	276.39	276.39	276.39	276.39	276.39	268.10	268.10	262.57

Table A.15: Poland

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	268.11	289.64	292.72	285.26	289.32	284.40	281.35	270.75	272.10	260.89
2015	268.11	289.64	292.72	292.72	285.26	289.32	284.40	281.35	270.75	272.10
2020	268.11	289.64	292.72	292.72	292.72	285.26	289.32	283.94	281.35	270.75
2025	268.11	289.64	292.72	292.72	292.72	292.72	285.26	283.94	283.94	278.09
2030	268.11	289.64	292.72	292.72	292.72	292.72	292.72	283.94	283.94	278.09
2035	268.11	289.64	292.72	292.72	292.72	292.72	292.72	283.94	283.94	278.09
2040	268.11	289.64	292.72	292.72	292.72	292.72	292.72	283.94	283.94	278.09

Table A.16: Sweden

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	269.25	276.59	274.11	268.32	266.48	263.66	255.90	243.32	231.25	236.44
2015	269.25	276.59	276.59	274.11	268.32	266.48	263.66	255.90	243.32	231.25
2020	269.25	276.59	276.59	276.59	274.11	268.32	266.48	263.66	255.90	243.32
2025	269.25	276.59	276.59	276.59	276.59	274.11	268.32	266.48	263.66	255.90
2030	269.25	276.59	276.59	276.59	276.59	276.59	274.11	268.29	266.48	262.76
2035	269.25	276.59	276.59	276.59	276.59	276.59	276.59	268.29	268.29	262.76
2040	269.25	276.59	276.59	276.59	276.59	276.59	276.59	268.29	268.29	262.76

Table A.17: Slovenia

	16-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-65
2011	274.36	278.93	279.36	277.86	283.02	275.55	276.20	268.82	266.04	265.15
2015	274.36	278.93	279.36	277.86	283.02	283.02	275.55	274.53	268.82	266.04
2020	274.36	278.93	279.36	277.86	283.02	283.02	283.02	274.53	274.53	268.82
2025	274.36	278.93	279.36	277.86	283.02	283.02	283.02	274.53	274.53	268.87
2030	274.36	278.93	279.36	277.86	283.02	283.02	283.02	274.53	274.53	268.87
2035	274.36	278.93	279.36	277.86	283.02	283.02	283.02	274.53	274.53	268.87
2040	274.36	278.93	279.36	277.86	283.02	283.02	283.02	274.53	274.53	268.87

Table A.18: Slovakia

B Aggregate human capital projections

	2011	2015	2020	2025	2030	2035	2040
AT	274.61	277.53	279.56	280.56	281.64	281.60	281.55
CZ	276.07	278.94	281.16	283.39	283.77	283.79	283.81
DE	271.89	275.18	277.50	280.15	281.36	281.69	281.57
DK	276.54	279.58	280.93	281.80	281.89	282.07	282.09
EE	274.94	277.82	280.17	282.59	283.37	283.44	283.19
EL		253.57	253.67	254.14	254.25	253.97	254.03
ES	251.95	255.07	257.58	258.83	259.07	259.42	259.52
FI	287.62	293.14	297.46	300.66	301.77	301.91	301.83
FR	260.38	264.35	267.77	270.46	272.31	272.40	272.42
HU		270.35	272.62	274.14	274.25	274.15	274.09
IE	262.46	264.82	266.81	268.00	268.09	267.96	268.03
IT	250.18	253.18	255.59	257.77	259.77	260.63	260.91
LT		266.42	269.13	272.53	275.52	277.68	278.26
NL	284.09	287.26	289.94	291.54	291.83	292.00	292.01
PL	264.49	267.56	270.19	272.41	273.35	273.23	273.00
SE	280.72	284.20	286.36	287.59	288.36	288.43	288.42
SI	260.54	264.83	268.13	270.85	272.77	273.16	273.02
SK	275.77	277.55	279.02	278.99	278.78	278.40	278.05

Table B.1: Aggregate human capital projections.

	2011	2015	2020	2025	2030	2035	2040
AT	274.61	277.79	279.98	280.92	282.23	282.23	282.23
CZ	276.07	279.33	281.88	284.16	284.85	285.06	285.06
DE	271.89	275.57	277.97	280.41	281.76	281.96	281.96
DK	276.54	279.76	281.46	282.13	282.13	282.13	282.13
EE	274.94	278.11	280.79	282.91	283.68	283.91	283.91
EL		253.57	254.17	255.01	255.54	255.54	255.54
ES	251.95	255.92	258.81	260.06	260.54	261.01	261.01
FI	287.62	293.18	297.76	300.62	301.64	301.73	301.73
FR	260.38	265.01	268.78	271.54	273.12	273.18	273.18
HU		270.35	273.16	274.68	275.14	275.17	275.17
IE	262.46	265.27	267.39	268.62	268.79	268.79	268.79
IT	250.18	254.04	257.17	259.71	261.60	262.02	262.02
LT		266.42	269.80	273.09	275.91	278.15	278.94
NL	284.09	287.96	290.84	292.08	292.13	292.13	292.13
PL	264.49	268.12	270.93	272.91	273.98	274.20	274.20
SE	280.72	283.96	286.17	287.48	288.38	288.38	288.38
SI	260.54	265.82	269.77	272.35	274.08	274.57	274.57
SK	275.77	277.62	279.19	279.19	279.19	279.19	279.19

Table B.2: Aggregate "pure" human capital projections (holding constant the labor force composition).

C Projected contributions to growth

	2011-2020				2020-2040				catching-up	
	HC	AR	POP	Total	HC	AR	POP	Total	HC	Total
AT	1.2	1.8	3.0	6.0	0.5	4.2	-3.5	1.1	2.4	3.0
CZ	1.2	5.7	-4.2	2.6	0.6	-1.1	-3.4	-3.9	2.2	-2.3
DE	1.3	1.1	1.1	3.6	1.0	1.7	-4.9	-2.2	2.8	-0.3
DK	1.0	1.2	1.5	3.7	0.3	3.5	-2.3	1.5	2.1	3.4
EE	1.2	3.6	-3.6	1.2	0.7	3.6	-2.1	2.1	2.4	3.8
EL	0.0	0.0	-4.8	-4.8	0.1	5.4	-14.3	-8.8	5.1	-3.8
ES	1.5	-1.3	-1.0	-0.8	0.5	5.0	-3.3	2.2	4.8	6.5
FI	2.2	3.0	-2.3	3.0	1.0	2.3	-1.8	1.5	1.0	1.5
FR	1.8	1.1	-0.8	2.2	1.1	6.9	-2.4	5.6	4.3	8.7
HU	0.5	10.6	-4.3	6.9	0.4	6.5	-7.1	-0.3	2.9	2.2
IE	1.1	0.5	3.6	5.2	0.3	8.7	7.0	16.0	4.1	19.8
IT	1.4	2.2	-1.3	2.3	1.4	6.1	-8.7	-1.3	5.6	3.0
LT	0.7	6.6	-7.5	-0.3	2.2	1.4	-11.4	-7.7	4.2	-5.8
NL	1.3	2.4	0.8	4.6	0.5	5.3	-1.9	3.8	1.4	4.7
PL	1.4	5.1	-4.6	1.9	0.7	2.7	-7.7	-4.3	3.3	-1.7
SE	1.3	2.4	3.3	7.0	0.5	1.9	5.6	8.0	1.6	9.2
SI	1.9	4.2	-2.9	3.1	1.2	4.0	-5.2	0.0	4.0	2.8
SK	0.8	3.6	-3.2	1.2	-0.2	2.7	-7.6	-5.1	1.9	-3.0
EU18	1.2	3.0	-1.5	2.7	0.7	3.9	-4.2	0.5	3.1	2.9

Table C.1: Labor contribution decomposition – detailed country results (in percentage points).

Note: "catching-up" refers to the projected contribution of HC and of labor (Total) over the time period 2020-2040 in the alternative scenario from Section 6.

D PISA test results

	Country	code	2000	2003	2006	2009	2012	2015	2018
1	Estonia	EE			3	3	2	1	1
2	Finland	FI	1	1	1	1	1	2	2
3	Poland	PL	11	12	12	6	4	8	3
4	Ireland	IE	6	9	9	9	6	7	4
5	Slovenia	SI			5	5	7	3	5
6	Sweden	SE	4	6	10	13	16	11	7
7	Netherlands	NL		2	2	2	3	4	7
8	Denmark	DK	3	4	9	7	10	6	8
9	Germany	DE	8	9	6	4	5	5	9
10	Czech Republic	CZ	7	3	5	11	9	12	10
11	France	FR	2	5	13	9	11	10	11
12	Austria	AT	6	7	7	12	8	9	12
13	Spain	ES	10	13	16	16	12	13	13
14	Lithuania	LT			15	17	14	16	14
15	Hungary	HU	9	12	11	11	15	15	15
16	Italy	IT	12	14	17	15	13	14	16
17	Slovakia	SK		10	14	14	17	17	17
18	Greece	EL	13	15	18	18	18	18	18

Table D.1: PISA results – country rankings 2000-2018 (in our EU18 sample).

E Learning-adjusted years of schooling

	LAYS value				Cummulative growth		
Code	2010	2017	2018	2020	2010-2020	2010-2017	2017-2020
AT	10.8	11.7	11.3	10.9	0.6	7.6	-6.5
CZ	10.8	11.7	11.3	11.1	2.5	7.4	-4.6
DK	11.1	11.4	11.4	11.1	0.1	3.0	-2.8
EE	11.2	11.4	11.7	11.7	4.3	1.1	3.2
FI	12.2	12.1	12.0	11.7	-3.9	-1.3	-2.6
FR	11.2	11.3	11.2	11.3	0.2	0.5	-0.3
DE	11.3	11.7	11.3	11.0	-2.0	4.2	-6.0
EL	10.5	9.8	10.1	10.0	-4.8	-6.6	2.0
HU	10.7	10.7	10.7	10.3	-3.9	0.5	-4.4
IE	11.3	11.8	12.0	11.6	2.6	4.4	-1.7
IT	10.9	11.2	10.9	10.5	-4.4	2.1	-6.3
LT	11.0	11.2	11.4	11.0	0.2	2.0	-1.7
NL	11.7	11.7	11.8	11.5	-1.7	-0.3	-1.5
PL	10.7	11.3	11.5	11.4	6.4	6.1	0.3
SK	10.2	10.4	10.1	9.8	-4.3	1.3	-5.6
SI	11.2	11.6	11.6	11.4	1.7	3.8	-2.1
ES	10.3	10.8	10.7	10.5	2.4	5.0	-2.5
SE	11.1	11.7	11.7	11.6	4.1	4.9	-0.8
EU18	11.0	11.3	11.3	11.0	0.0	2.5	-2.4

Table E.1: Learning-adjusted years of schooling – World Bank data.