

IMPROVING EDUCATIONAL INVESTMENTS: A WELFARE ANALYSIS FOR EUROPE

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Abstract

This paper analyses in a novel way how educational investments can improve human capital formation in Europe, based on a model of age-dependent skill formation featuring dynamic complementarities. Counterfactual investment policies are evaluated with an Atkinson-Sen welfare function. Investments for individuals under the age of eighteen years are traced back to their family and teaching environment, whereas adult individuals optimise their educational investments. The model is calibrated for a population living in 29 European countries. Our findings demonstrate that more educational investments need to be directed at childhood to foster human capital formation across all European countries. Furthermore, if equality is rated high enough in the welfare function, the most disadvantaged people should receive more compensating educational investments during childhood. In a uniform European labour market educational investments yield higher returns in low income countries, since the transformation of human capital to income is improved.

Keywords: Human capital, age-dependent skill formation, educational investment, Europe
JEL Codes: I12, I21, J13

1. Introduction

The European Commission (2010) postulates that improving the education of youth is one of the most prominent policy goals in Europe. Public educational investments shall overcome various forms of market failure in order to provide the optimal quantity and quality of investments in human capital and in addition to equalise educational opportunities.

While most economists and human capital researchers agree with these aims, the last decade has seen an intense discussion about the optimal quantity and timing of educational investments. The priorities in public educational spending are under scrutiny since deep-seated skills are created early in the human developmental process (Amor 2003, Cunha and Heckman 2007, Heckhausen and Heckhausen 2008, among others).

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The formation of cognitive skills, such as intelligence, memory power and reasoning, and self-regulatory skills, such as motivation, delay of gratification and persistence, starts in early childhood. Skill formation is influenced by the quality of parent-child interaction and the family environment (for studies on children at risk see Blomeyer et al. 2009, 2013, Coneus et al. 2012, among others). The level of these skills is decisive for becoming a productive adult member of society and for economic performance (Hanushek and Wößmann 2008, among others).

Typically, human capital investment in childhood is dominated by the family environment. The immense inequality of economic and socio-emotional family resources available for children therefore has a significant impact on the amount and quality of human capital investments as well as the development and inequality of human capital in Europe (and other regions of the world). To better understand the dimension of the problem of human capital formation, a look at indicators of educational inequality and socio-economic outcomes is useful.

In our study Europe either consists of the following 29 countries: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland and United Kingdom or, alternatively, Europe is a hypothetical entity constructed from these 29 European countries. In the latter scenario it is assumed that Europe has only one uniform labour market. Since currently there is no such political entity and aggregate official statistics are not available, these have been created from different sources.

Countries have been selected such that data on educational investment costs and outcomes, demographics, GDP and the inequality of income are available. GDP per capita is calculated for Euro 2006 values using PPP from OECD.stat (2009). The overall population sizes, the age structure and measures of income inequality have been taken from Eurostat (European Commission 2011).

Table 1 displays the population size, age structure, educational expenditures, GDP and income inequality for the European entity scenario as well as the mean, minimum and maximum values for the 29 individual countries. European countries differ significantly in most of the examined variables. For instance, the number of inhabitants varies between 300,000 in Iceland and 82.4 million in Germany. Overall, 508.7 million people live in Europe.

In most European countries the middle-aged group is the largest one. The fraction of inhabitants below the age of 18 varies between 16.1% (Italy) and 24.9% (Iceland). In Scandinavian countries and France the fraction is above 20%, whereas in Germany and Spain, among others, it is less than 17%. This divergent age patterns have immense implications for the causes and consequences of educational policies in Europe.

Table 1: Population size, age distribution, educational expenditures, GPD/capita and income inequality for Europe and the 29 European countries

	Population	fraction below 18	fraction above 65	Publ. ed. expendit. ^{b)}	GDP/ capita ^{b)}	Quintile Inc. Ratio
Europe	508.7 M.	18.5 %	17.6 %	5 631 €	22 329 €	6.05
Mean ^{a)}	17.5 M.	19.0 %	16.6 %	5 769 €	23 168 €	4.67
Min. ^{a)}	0.3 M.	16.1 %	11.9 %	1 453 €	8 307 €	3.40
Max. ^{a)}	82.4 M.	24.9 %	20.8 %	12 168 €	62 268 €	7.90

Source: OECD.stat (2009), own calculations. ^{a)} Rows show the respective mean, minimum and maximum values from the 29 European countries. ^{b)} Public educational expenditures in Euros; real values 2006.

Income inequality is measured with the ratio of the highest and the lowest quintile, which varies from 3.4 (Denmark) to 7.9 (Latvia). In the European entity it is as high as 6, much higher than the simple average of the inequality measures suggest. Therefore, inequality in the European entity is higher than in the US. GDP per capita varies from 8,307 € (Croatia) to 62,268 € in Luxembourg. European countries have around 18 million inhabitants on average, and the hypothetical Europe has an average GDP per capita of 22 329 €. With respect to average GDP per capita and inequality, the hypothetical Europe is more similar to a country like Greece than to France, Germany or Sweden.

The average of public educational expenditures for Europe amounts to 5,631 € and ranges from 1,453 € (Romania) to more than 10,000 € in Denmark, Norway or Luxembourg, highlighting significant differences in equality of educational opportunities. The measure of educational performance has been calculated from PISA scores 2006 (OECD 2006) averaged for math, science and reading for each of the 29 countries.

Table 2 compares the resulting average PISA scores for Europe and summarises the mean, and the minimum and maximum values for the individual countries. The average Pisa score for Europe is below 500, the average for all OECD countries which participated in PISA. The inequality in educational performance in Europe is higher than the country-specific inequality. On average educational performance is high in Finland (556.5) and the Netherlands (521) and low in Romania (407.6) and Bulgaria (417). As a rule, the inequality of educational performance is inversely related to the average PISA score. For instance, the 90-10 PISA ratio is 2 in Romania compared to 1.5 in Finland. There is a wide variety of educational expenditures per PISA score. In Norway investment amounts to 25 €, while it is only 5 € in Croatia.

Table 2: The distribution of PISA scores for Europe and for 29 European countries

Percentile	5	10	25	50	75	90	95
Europe	332.7	367.4	426.7	490.66	557.9	607.5	634.9
Mean ^{a)}	343.21	375.69	431.17	490.87	553.46	600.8	626.36
Min. ^{a)}	263.2	290.9	344.5	407.6	462.3	511.6	538.4
Max. ^{a)}	425.5	454.6	504	556.5	606.6	645.9	669.9

Source: Own calculations, see text. ^{a)} Rows show the respective mean, minimum and maximum values for the 29 European countries.

There is a plethora of public educational programmes covering preschool, primary and secondary education in all European countries. Furthermore, governments in modern European societies are engaged in post-secondary education and try to promote lifelong learning during adulthood. While each of these educational programmes receives a great deal of attention in research¹, a comprehensive empirical assessment of the patterns of educational investment during the life cycle and its welfare implications for individual countries and Europe is still not available. The question then is in which direction educational investments have to be changed to improve GDP per capita and to reduce the significant amount of lifetime income inequality in Europe.

Our study provides some preliminary answers to this question. We examine educational policies to foster human capital and welfare in Europe based on a model of life cycle skill formation that features dynamic complementarities (Pfeiffer and Reuß 2008).

This model is extended in several dimensions. First, life span now is endogenous and depends on the stream of investments in childhood. Recent research suggests that family environment in early childhood has far-reaching consequences for average life (Castelló-Climent and Doménech 2008 or Frijters et al. 2010, among others). For instance, Frijters et al. (2010) demonstrate that a good instead of a bad family environment resulted in an increase of life expectancy by eleven years in Great Britain.

Second, a welfare function assesses for the first time counterfactual educational investments over the life cycle with different weights put on equality as inequality aversion between European countries may differ. While in Scandinavian countries inequality aversion is high, in more central or southern parts of Europe it seems to be lower.

Counterfactual educational investments aligned to specific regions, ages and competence levels are assessed in terms of GDP per capita and income inequality among Europeans. The model is calibrated for the population of people who live in 29 European countries.

Finally, educational investments are assessed for two policy regimes in Europe: one represents the actual status of diversity in labour markets between the individual countries, the other a hypothetical state of a single labour market.

Our findings indicate that more investment should be directed at childhood to foster human capital formation in individual European countries and in Europe as a whole.

¹ A number of studies deal with selected aspects of educational policies in Europe. For instance, secondary or postsecondary educational investments have been examined by Bergh and Fink (2009) or Wößmann (2008), among others. The relationship between educational investment and economic growth in the America has been investigated by Baldwin et al. (2011). Pfeiffer and Reuß (2008) assess returns to educational investment in Germany, when skill formation is age-dependent.

Investments during childhood will, as a rule, earn higher returns compared to investments in adolescence or young adulthood in terms of GDP per capita.

In addition, if equality is rated high enough, the most disadvantaged people should receive more public investment during childhood to raise European welfare. Such a strategy would improve the equality of educational opportunity among young Europeans. In the long run, it will contribute to a reduction in the inequality of income in Europe. Furthermore, the analyses suggest that all policies that contribute to a reduction in the inequality of human capital would be slightly more effective in a European entity.

The paper is structured as follows. Section 2 introduces the data and the European countries considered. Section 3 discusses the model of human capital formation while Section 4 elaborates the calibration of these functions with the data at hand. Section 5 highlights the welfare implications of alternative educational investment strategies. Section 6 concludes.

2. Skill and human capital formation over the life cycle

Our basic model of human capital formation consists of a set of interrelated equations which have been developed in our previous work (Pfeiffer and Reuß 2008) and some novel extensions designed for the purpose of the current study. In this section we summarise the basic structure of our previous model and elaborate on the novel features only.

There are two equations that describe the development of skills over the life cycle, one for cognitive skills, S_t^C , and one for non-cognitive or self-regulatory skills, S_t^N . Skills in period t are a function of skills from the previous period, S_{t-1} and a function of educational investments, I_t . Educational investments cover all measures that are able to improve skills, regardless of whether they take place in the family, by friends or through teaching, or of whether they are privately or publicly financed.

The process of skill formation is specified in a way that it implies self- and cross-productivity ($\partial S_t / \partial S_{t-1} > 0$) and direct complementarity ($\partial^2 S_t / \partial S_{t-1} \partial I_t > 0$). Direct complementarity means that the skill enhancing effect of educational investments in period t is higher the higher the level of skills already is. Skill formation thus is said to be a synergetic and cumulative process.² Investment later in life is no longer able to enhance the skill level as much as in early childhood, even though higher skill levels complement investment. Furthermore, the two difference equations specify skill depreciation.

The formation of human capital, $H_{t,n,j}$, of with individual n , living in country j at time t , in a given year is modelled as a function of cognitive, S_t^C , and self-regulatory skills, S_t^N , of the previous period, taking into account that human capital may accumulate or depreciate, for example, due to technological progress or economic competition:

² For a detailed discussion on the technology of skill formation see Cunha and Heckman (2007).

$$H_{t,n,j} = f(S_{t-1,n,j}^C, S_{t-1,n,j}^N, H_{t-1,n,j}) \quad (1)$$

Educational investments thus enhance human capital indirectly via skill formation. It is assumed that the basic structure explains human capital formation in all European countries. However, countries differ in their returns to educational investment and their distribution of income relative to the skill heterogeneity due to differences in the functioning of labour market.

In one country an individual with a certain human capital level will earn less than he or she would earn in another country. In some countries human capital heterogeneity is small relative to the income heterogeneity, whereas in other countries it may be rather large. For the transformation of human capital into individual incomes the cumulated income of the country plays as role, specified in Equation 2:

$$Y_{t,n,j} = f(H_{t,n,j}, \phi_j, \gamma_j) \quad (2)$$

Two parameters are employed to model income patterns: ϕ_j governs the transformation of human capital into income in country j . If, for instance, $\phi_j = 1$, one unit of human capital in the country will earn one Euro, for $\phi_j = 2$ two Euros. Individual income depends on the country-specific parameter γ_j . For the average individual i , the term equals one for all γ_j . For individuals whose human capital differs from the mean, γ_j will either lead to an income above or below the average resulting from the stock of human capital. If $\gamma_j = 0$, all individuals in one country will earn the same amount of money irrespective of their particular skill levels. If $\gamma_j = 1$, individuals will earn exactly their level of human capital times ϕ_j . As $\lim \gamma_j \rightarrow \infty$, the person with the highest level of human capital will earn all the income generated in a country.

Until the age of 18, the amount of educational investments $I_{1...18,n,j}$ (for individual n in country j) is assumed to depend on the quality of the family and teaching environment.³ Since information on educational investments over the early life cycle is scarce, it is assessed indirectly from educational performance.

We assume that educational investments vary in such a way that they explain student performance at the age of sixteen, given the process of skill formation. Empirical calibration is discussed in Section 4. After the age of 18 years, individuals choose the amount of investment that maximises their expected lifetime income. They can either invest $I_{t,n,j}$ units into their skills or earn an income at the labour market with the available level of human capital and given the income of the country. If the available time is invested in education, no income can be earned. In addition, it is assumed that after the age of 65 all investments will be zero because no further income can be earned from that age on.

³ For research on parental educational investments and children's achievement in school see Cheadle (2008, 2009) and Blomeyer et al. (2009, 2013), among others.

The welfare from counterfactual educational investments for the society is assessed with the Atkinson-Sen welfare function (Sen and Forster 1997):

$$W(Y) = (1 - A_\varepsilon(Y)) \cdot \sum_{i=1}^N y_n, \text{ with}$$

$$A_\varepsilon(Y) = 1 - \left[\left(\sum_{j=1}^J N_j \right)^{-1} \cdot \sum_{n=1}^N (y_n / \mu)^{1-\varepsilon} \right]^{-(1-\varepsilon)}. \quad (3)$$

A_ε denotes the Atkinson index (Atkinson 1970) which illustrates trade-offs between efficiency and equality in educational policy. The index is a discrete measure of inequality for an income distribution of a population with N European citizens.

Lifetime income is calculated as $y_n = \sum_{t=18}^{65} r_t \cdot Y_t$. It represents the discounted individual income accumulated over the working life. The parameter μ denotes the average human capital of the population and ε is the parameter for different degrees of equality preferences in the society.

If $\varepsilon = 0$, a society does not care about equality at all. For $\varepsilon = \infty$, the index depends only on the welfare of the poorest individual within the society. The Atkinson Index is normalised between 0 and 1. If $A_\varepsilon(Y) = 0$, equality is reached, while inequality is at its maximum if $A_\varepsilon(Y) = 1$.

The society is assumed to maximise the Atkinson-Sen welfare function for the life-cycle welfare of the European population. In the case of $\varepsilon = 0$ the society will maximise the sum of income without considering inequality. On the other hand, if $\lim \varepsilon \rightarrow \infty$, only the income of the poorest person in the society is relevant for governing counterfactual investments. In social reality equality considerations may vary between $0.5 \leq \varepsilon \leq 1.5$ (Atkinson 1970).

3. Calibration of model parameters

To investigate the welfare consequences of alternative educational policies in Europe, the model parameters have been calibrated with existing data. In order to test the sensitivity of the analysis and to take policy regimes properly into account, some parameters have been calibrated for two different labour market regimes in Europe.

In the first regime, Europe consists of heterogeneous labour markets and educational costs; in the second one, a homogeneous labour market and homogenous educational costs are presumed.

In a first step, the PISA scores for all individuals i younger than 18 years in each country j have been obtained by a cubic spline interpolation. The PISA-score at age 15 (P_{15}) is assumed to result from cognitive and self-regulatory skills:

$$P_{15,n,j} = \psi \cdot \sqrt{S_{15,n,j}^C \cdot S_{15,n,j}^N} \cdot \quad (4)$$

Equation 4 models the performance of an individual in performing a task as a function of his or her cognitive and self-regulatory skills at the age of 15 years. Both skills in the Cobb Douglas function are assumed to be equally important and may interact in complex ways (Duckworth and Seligman 2005). A person with a low level of cognitive skills can nevertheless produce high test-scores if his or her motivation is high and vice versa.

The factor ψ is an adjustment factor for different normalisations of performance scores and their respective distributions. Investment levels $I_{0...18,n,j}$ are calculated in a way that in each country the PISA 2006 test score distributions for 29 European countries are generated by the above equation. They vary from 0.16 to 2.06 (Table 3) demonstrating a significant inequality of educational investments in families and schools.

Table 3: The amount of educational investments $I_{0...18,i,j}^k$ across percentiles ($\theta = 0$)

Percentile	5	10	25	50	75	90	95
Europe	0.16	0.27	0.51	1	1.37	1.8	2.06
Mean	0.2	0.3	0.54	0.98	1.33	1.73	1.97
Std	0.09	0.11	0.15	0.18	0.24	0.25	0.25
Min	0.03	0.07	0.19	0.5	0.71	1.03	1.22
Max	0.51	0.67	0.97	1.39	1.79	2.17	2.41

After the age of 18 investments are assumed to result from individual optimisation. The heterogeneity of income for the same amount of skills is a consequence of heterogeneous national labour markets. Based on the investments in young age, the model ϕ_j is calibrated such that all working individuals between the age of 18 and 65 years annually produce the GDP of the country (the sum of incomes in each country is equal to the total GDP).

The GDP per capita results from the division of a country's GDP by the number of inhabitants. The parameter γ_j is calibrated to match the observed income inequality in Europe (see Introduction).

Table 4 displays the calibrated parameters. ϕ_j indicate how much larger income in a country is compared to its human capital; γ_j shows how much larger income inequality is compared to human capital inequality. ϕ_j is large in high income countries like Luxembourg (9.77), Norway and Ireland, which have average levels of investments ($\phi_{0...18}$ being close to 1). ϕ_j is low in Poland (1.33), Croatia and Romania. Croatia's human capital is only slightly below the average, but the GDP per capita is much lower.

Romania, on the other hand, has a low level of human capital leading to a low income. γ_j is high in countries with low human capital inequalities and high income inequality, which holds in particular for the Baltic countries (e.g. Latvia has the maximum value of

3.63). γ_j is small in countries with high human capital inequalities and low income inequality, e.g. in Bulgaria (1.42).

Table 4: Calibrated values of labour market parameters for heterogeneous European countries

Country	ϕ_j	γ_j
Europe	3.51	2.71
Mean	3.49	2.41
Min	1.33	1.42
Max	9.77	3.63

If a single European labour market is assumed, there is only one ϕ and one γ for all 29 European countries. The calibration results in $\phi = 3.51$ and $\gamma = 2.71$. The average value of γ is relatively high for a homogenous labour market in Europe compared to the average value in the case of a heterogeneous labour market ($\gamma_j = 2.41$).

Thus, if Europe is assumed to have a homogenous labour market, income inequality should be higher.

As a new further feature, the life span depends on educational investments. The underlying empirical relationship (equation 6) is estimated by OLS for the 29 countries:

$$\log(le) = \beta_0 + \beta_1 \cdot \log(GDP/capita) \quad (5)$$

The total population size is used as a weight. The estimated value of β_1 is 0.07. It is significant at the 99 % level, uncovering a strong relationship between educational investment (indicated by GDP per capita) and average life span in the sample of European countries.

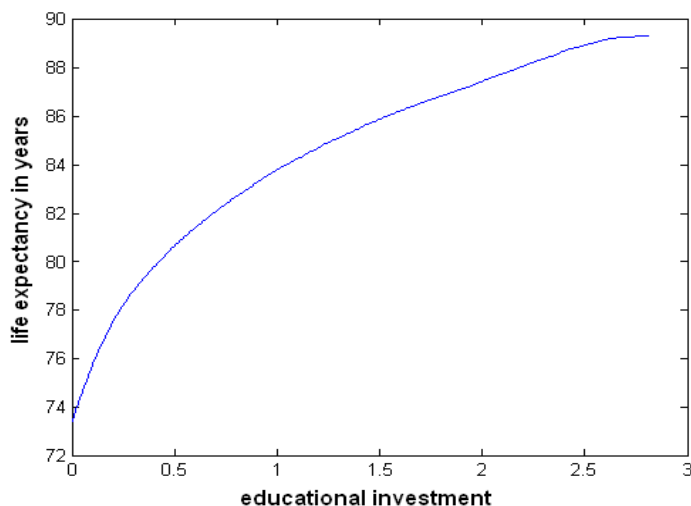
All combinations of income and life span that result from the estimate of parameter β_1 yield the function $le(I)$ shown in Figure 1.

Life cycle skill formation in Europe is diagrammed in Figure 2. The figure includes all 29 countries and demonstrates substantial heterogeneity. In the upper left it shows cognitive skills for a population of 100,000 representative European individuals of one age cohort. All individuals are assumed to start with the same stock of cognitive skills, i.e. a value of 180, but receive divergent investments until the age of 18 years (different initial conditions are discussed by Pfeiffer and Reuß, 2008).

Cognitive skills peak in the early 20s and then decline continuously. Individuals with fewer educational investments and a lower skill level have a shorter life span. The beginning of the decline in cognitive skills depends on the life span. In the case of self-regulatory skills, all individuals start with the value of 180, too, but skills peak later between the ages of 50 and 60 years. Self-regulatory skills are assumed to be more

malleable throughout childhood and adolescence (Caspi et al. 2005, Cunha and Heckman 2007).

Figure 1: Relationship between educational investments and life span



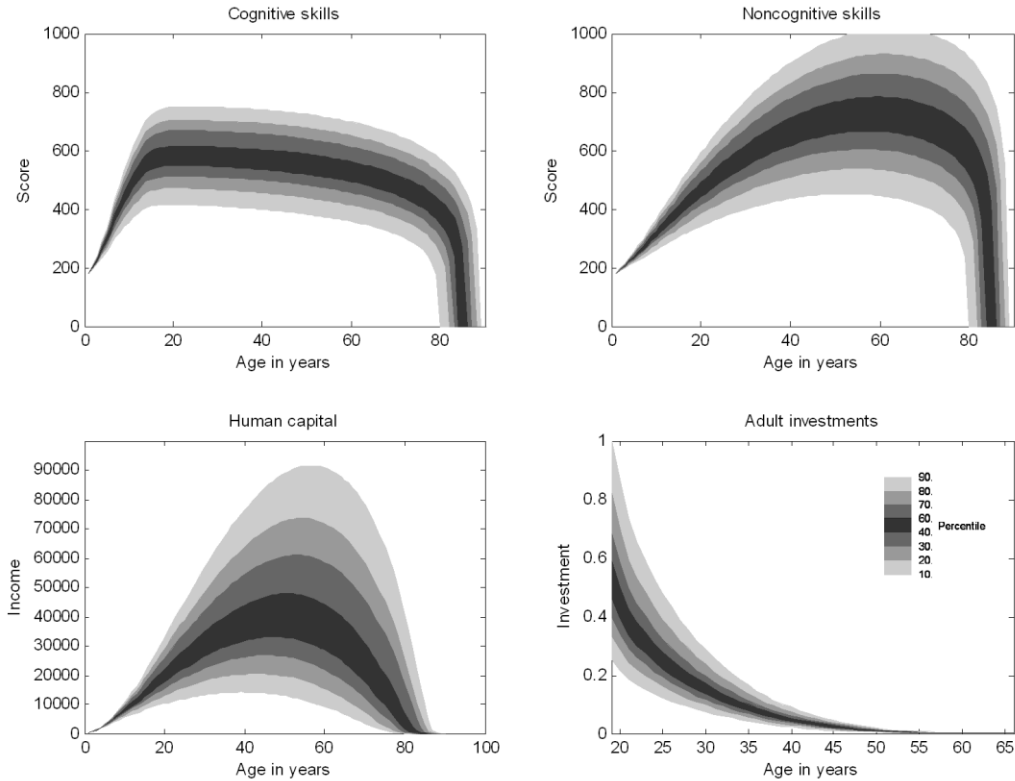
In the lower left part of Figure 2 the development of income of a European population cohort is shown. For given human capital, the figure shows the incomes that an individual could receive if he or she worked full time between the ages of 18 and 65 years.

In contrast to skills, income does not only depend on educational investments, but also on conditions stemming from the labour market and the general productivity in a country. In some countries, such as Luxembourg and Norway, income is high relative to human capital, while in others, such as Poland and Romania, it is low.

Human capital is produced by both cognitive and self-regulatory skills and peaks between the ages of 40 and 57 years. As individuals with higher skills live longer, they reach their maximum later in life. In skill-intensive, high-income professions income peaks up to 17 years later than in low-income professions.

In the lower right part of Figure 2 the amount of educational investments in adulthood that individuals choose to maximise their expected lifetime income is shown. Generally, individuals experience a trade-off. They have to decide to either start working or invest more in their education.

In early adulthood when returns to education are still high, individuals tend to invest more in their education. The amount decreases with age and becomes negligible with time. Individuals with higher human capital and individuals living in countries with a high income inequality tend to invest more in education at young age.

Figure 2: Cognitive and noncognitive skills, human capital and investments in adulthood

4. Counterfactual educational investments

1.1. Educational policies

In order to analyse the consequences of alternative educational investments, the welfare effects of three counterfactual educational policies for two policy regimes in Europe are assessed.

Policy one aims at reducing country heterogeneity within Europe. According to this policy, each student who is younger than 18 years and comes from a country with PISA scores below the average PISA score receives the amount of investments that is needed to reach the European average of educational investments during their first 18 years of life. This amount is greater than zero for all European countries that invest less than the mean value of educational investments in Europe. The additional investments differ significantly between countries.

Policy two aims at increasing investments at certain ages while treating students of all European countries in the same way. In all countries, individuals under the age of 18 receive an additional investment either in their preschool or their primary or secondary school. By our definition, the preschool investment lasts from the age of 0 to 5 years, the primary investment from the age of 6 to 11 years and the secondary investment from the age of 12 to 17 years.

Policy three provides educational investments either to the lower, medium or highest third of the PISA achievement distribution for the first 18 years of life.

The amount of investments for policies *two* and *three* are calculated in a way that discounted accumulated costs equal those of *policy one*.

The three policies are investigated for two policy regimes. In the *first regime*, European labour markets are assumed to be heterogeneous. Hence, 29 different countries with distinct parameters ϕ_j and γ_j , are used in the model. Further, educational costs differ in each country. In the *second regime*, there is one homogeneous European labour market with one ϕ and one γ . In the second regime educational costs are assumed to be uniform across Europe. Obviously, these two regimes are idealised polar forms. Reality presumably meets the conditions of a market structure which somewhere in between one of the assumed polar regimes.

1.2. Heterogeneity in European labour markets

Policy one aims at reaching the average level of educational investments in all countries. To make such an investment, 0.19 % of the total annual European GDP (42.31 € per capita) has to be spent (see Table A1 in the Appendix).

For *policy two*, the investment amounts to 0.51 % (preschool), 0.57 % (primary) and 0.64 % (secondary) of the total annual European GDP (113.00 € to 144.00 € per capita annually). These differences result from discounting educational investments, which takes place at different ages.

The largest net income effect can be achieved with an additional preschool investment (19,127 € per capita), followed by an investment in education for all low-skilled students under 18 years (18,524 €). Supporting low-skilled individuals instead of low-skilled countries leads to higher net benefits. In the long run, the largest net income effect (GDP per capita) is about 515 € annually if all cohorts benefit from *policy one*. Hence, spending 113 € per capita annually would result in an increase of 515 €. The smallest returns stem from additional investments in secondary education.

Results for inequality issues are displayed in Table 5. The largest effect on the reduction of inequality is achieved if investments are directed to the low-skilled as intended by *policy three* (see Table 5). If equality considerations become more important in the welfare function, supporting the low performing students becomes a welfare optimising strategy.

Table 5: Changes in inequality for a heterogeneous Europe

Policy	before policy	after policy	change
Policy one , region	6	5.31	-0.69
Policy two , preschool	6	5.53	-0.47
Policy two , primary school	6	5.65	-0.35
Policy two , secondary school	6	5.80	-0.20
Policy three , low-skilled	6	4.92	-1.08
Policy three , medium-skilled	6	5.92	-0.08
Policy three , high-skilled	6	6.30	+0.30

Finally, Table 6 summarises the welfare changes depending on the degree of inequality aversion in a society. Societies with a zero inequality aversion ($\varepsilon=0$) should shift more investments to younger children (*policy two*) while societies with a greater inequality aversion ($\varepsilon>0$) should support mainly the low performing students (*policy three*, low-skilled).

Policy one is dominated by either the first variant of *policy two* or the first variant of *policy three*. However, *policy one* is always better compared to the second and third variant of *policy two* and *three*.

Table 6: Welfare changes in policy regime one depending on inequality aversion ε

	$\varepsilon = 0$	$\varepsilon = 0.5$	$\varepsilon = 1$	$\varepsilon = 1.5$
Policy 1	1.45%	1.92%	4.38%	10.82%
Policy 2, preschool	1.73%	2.33%	5.57%	14.35%
Policy 2, primary	1.19%	1.61%	3.83%	9.77%
Policy 2, secondary	0.41%	0.60%	1.54%	4.00%
Policy 3, low-skilled	1.67%	3.08%	10.65%	32.32%
Policy 3, medium-skilled	0.90%	0.89%	0.54%	-0.73%
Policy 3, high-skilled	0.58%	0.28%	-0.94%	-3.30%

1.3. Homogeneous labour markets in Europe

Although labour market policies are divergent in Europe, tendencies exist to unify these policies to a greater extent. The second policy regime of a unified Europe therefore might become more realistic in the coming decades. Results of investments and net benefits are displayed in Table A2 (Appendix).

In case of a European entity, the educational investment intended by *policy one* can only be financed to an extent that leads to 93.5 % of the average European investment due to the fact that education for countries with amounts below the average sum of investments becomes more expensive.

For *policy two* the investments amount to 0.51 % (preschool), 0.57 % (primary) and 0.64 % (secondary) of the total annual European GDP and are equal to the results for the regime assuming a heterogeneous labour market within Europe.

For *policy three* the annual spending complies with the expenditures of *policy one*. Investments of 0.115 educational units can be financed for each level of productivity. In a homogeneous labour market, the effectiveness of educational investments aimed at reducing inequality increases, as shown in Table 7.

The human capital of the low-skilled increases out of proportion and this helps to reduce inequality.

However, if additional investments are directed at the high-skilled students, inequality will rise again. Alternative educational investment strategies have different welfare consequences for the two regimes, depending on the degree of inequality aversion in a society (see Table 8).

Table 7: Changes in inequality for a homogeneous Europe

Policy	before Policy	after Policy	change
Policy one , region	6	5.52	-0.48
Policy two , preschool	6	5.44	-0.56
Policy two , primary school	6	5.58	-0.42
Policy two , secondary school	6	5.77	-0.23
Policy three , low-skilled	6	4.68	-1.32
Policy three , medium-skilled	6	6.01	+0.01
Policy three , high-skilled	6	6.36	+0.36

Societies with a smaller inequality aversion ($\varepsilon=0$) should shift more investments to younger children (*policy two*) while societies with a greater inequality aversion ($\varepsilon>0$) should support mainly the low performing students (*policy three*, low-skilled). *Policy one* is dominated by either the first variant of *policy two* or the first variant of *policy three*, irrespective of the inequality aversion. *Policy one* is furthermore dominated by the second variant of *policy two*. However, *policy one* is always better compared to the third variant of *policy two* and the second and third variants of *policy three*.

Table 8: Welfare changes in regime one depending on inequality aversion ε

	$\varepsilon = 0$	$\varepsilon = 0.5$	$\varepsilon = 1$	$\varepsilon = 1.5$
Policy one , region	1.23%	1.72%	4.38%	12.59%
Policy two , preschool	1.76%	2.57%	7.06%	19.65%
Policy two , primary	1.21%	1.77%	4.81%	13.09%
Policy two , secondary	0.43%	0.66%	1.89%	5.09%
Policy three , low-skilled	1.65%	3.45%	13.58%	44.37%
Policy three , medium-skilled	0.91%	0.90%	0.39%	-1.56%
Policy three , high-skilled	0.60%	0.18%	-1.58%	-4.96%

2. Conclusion

The paper analyses alternative investment policies and their consequences for the evolution of human capital in Europe based on an extended model of age-dependent skill formation that features dynamic complementarities and endogenous life expectancy. Calibration is performed to match a population living in 29 European countries. Counterfactual policies are evaluated with an Atkinson-Sen welfare function.

We model Europe either as the sum of these individual countries with the actual state of diversity in labour markets or as a hypothetical entity with a homogeneous labor market. What makes the approach special is the life-cycle analysis of the returns to education of alternative educational policies targeted at certain countries, ages or productivity levels for

two counterfactual policy regimes. Investments for young individuals under the age of eighteen years are traced back to their family and teaching environment. In adulthood individuals optimise the amount of educational investments to maximize their expected lifetime earnings.

The results demonstrate that designing optimal investment strategies, whether they are oriented towards age, regions or skill levels, crucially depend on the weights a society puts on equality. If equality is important enough, more investments during childhood are needed for disadvantaged children in Europe. If the aim of equality is less important, additional investments need to be directed more generally at people of younger ages. Given the technology of human capital formation with self-productivity and dynamic complementarities in skill formation over the life cycle more investment in childhood will increase GDP per capita and equality of educational opportunity as well. Furthermore, it turns out that high levels of income inequality and a high skill level increases the optimal amount of investments, especially during younger adulthood. In a uniform European labour market, supporting specific age and skill groups should be relatively more effective. The main reason is that the transformation of human capital to income is improved in the low-income countries.

There is still a significant amount of inequality in educational investments and human capital in Europe. New Europe-wide investment strategies targeted to young and disadvantaged people will increase the returns to investment and contribute to reducing inequalities in Europe. To realise such investments strategies, policies in Europe have to be better coordinated in the future.

Our preliminary findings result from the idea of age-dependent skill formation with decreasing marginal returns to investment in the skill production function, high returns to investments in early childhood and dynamic complementarities over the life cycle. Further research is needed, first, for empirically assessing the skill multiplier from childhood in the different European countries with improved data. Second research on the question how educational policies can be better coordinated to improve the future welfare of Europeans would be helpful. Third, additional research is needed to investigate the welfare consequences of public and private investment processes and alternative assumptions about their interdependencies in social reality.

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Annex

Table A1: Costs and returns for counterfactual educational investments in a heterogeneous Europe

Policy		Duration in years	Investments	Annual average GDP per capita increase	Net income benefit per student
Policy one, region	Europe	18	0.06	434 €	16 018 €
	Mean	18	0.06	452 €	16 302 €
	Min	18	0	0 €	0 €
	Max	18	0.48	2 489 €	102 725 €
Policy two, preschool	Europe	6	0.10	515 €	19 127 €
	Mean	6	0.10	521 €	19 269 €
	Min	6	0.10	199 €	7 799 €
	Max	6	0.10	1 492 €	61 545 €
Policy two, primary school	Europe	6	0.12	389 €	13 119 €
	Mean	6	0.12	394 €	13 224 €
	Min	6	0.12	151 €	5 458 €
	Max	6	0.12	1 138 €	44 055 €
Policy two, secondary school	Europe	6	0.13	207 €	4 583 €
	Mean	6	0.13	209 €	4 587 €
	Min	6	0.13	81 €	818 €
	Max	6	0.13	606 €	18 672 €
Policy three, low- skilled	Europe	18	0.04	488 €	18 524 €
	Mean	18	0.04	482 €	18 263 €
	Min	18	0.01	116 €	3 639 €
	Max	18	0.08	1 508 €	62 287 €
Policy three, medium- skilled	Europe	18	0.04	312 €	9 942 €
	Mean	18	0.04	326 €	10 345 €
	Min	18	0.03	122 €	4 577 €
	Max	18	0.04	908 €	33 733 €
Policy three, high- skilled	Europe	18	0.04	236 €	6 361 €
	mean	18	0.04	240 €	6 379 €
	min	18	0.01	22 €	850 €
	max	18	0.07	596 €	20 536 €

Table A2: Costs and returns for counterfactual educational investments in a homogeneous Europe

Policy		Duration in years	Investments	Annual average GDP per capita increase	Net income benefit per student
Policy one,	Europe	18	0.04	385 €	13 554 €
region	mean	18	0.04	392 €	13 851 €
	min	18	0	0 €	0 €
	max	18	0.42	4 208 €	148 473 €
Policy two,	Europe	6	0.10	523 €	19 521 €
preschool	mean	6	0.10	521 €	19 390 €
	min	6	0.10	411 €	14 030 €
	max	6	0.10	715 €	29 136 €
Policy two,	Europe	6	0.12	395 €	13 396 €
primary	mean	6	0.12	393 €	13 319 €
school	min	6	0.12	311 €	9389 €
	max	6	0.12	534 €	20 155 €
Policy two,	Europe	6	0.13	210 €	4 729 €
secondary	mean	6	0.13	209 €	4 687 €
school	min	6	0.13	160 €	2 506 €
	max	6	0.13	284 €	8 127 €
Policy	Europe	18	0.04	482 €	18 221 €
three,	mean	18	0.04	470 €	17 761 €
low-skilled	min	18	0.01	111 €	3 960 €
	max	18	0.08	1 107 €	44 075 €
Policy	Europe	18	0.04	314 €	10 043 €
three,	mean	18	0.04	322 €	10 307 €
medium-	min	18	0.03	231 €	7 449 €
skilled	max	18	0.04	386 €	12 309 €
Policy	Europe	18	0.04	243 €	6 680 €
three,	mean	18	0.04	241 €	6 624 €
high-skilled	min	18	0.01	44 €	1 295 €
	max	18	0.07	425 €	11 408 €