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Bank of Finland's Long-Run Forecast Framework with Human Capital

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Abstract

Population ageing constitutes a central challenge to Finland. Understanding the Finnish economy's likely future trajectory and the key sources of growth is important for the design of policies to counteract these adverse long-term trends. For this purpose, we develop a novel long-run forecast framework based on enodogenous growth theory with human and fixed capital. A central result is a pronounced projected decrease in human capital, substantially weighing on the long-run GDP outlook for Finland. To revert these trends substantial policy efforts are needed. Unless the decline in human capital can be prevented by increasing fertility, skilled immigration, education or employment, even reaching a growth rate of one per cent after the 2040s would require significant measures to increase new fixed capital investments with new technology.

Keywords: Forecasting, GDP, Labour productivity, Human capital, Modern growth theory

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*Footnote: *Arto Kokkinen was working as a Senior Economist at the Bank of Finland from Jan 2019 until Dec 2020.*

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1. Introduction

Finland's working age population has been decreasing for a decade and this trend is set to continue in the decades to come. Population ageing together with the diminishing new cohorts is creating immediate pressure on the sustainability of public finances but it also affects the long-term growth prospects of the Finnish economy unfavourably.

The increasing demand for public health care and long-term care increases the demand for labour in the public economy and diminishes the labour input in the high-productivity private production. With a diminishing working age population, the competition between the private and public economy over competent workforce intensifies. Due to shortages of skilled labour in the long-run, investing in Finland may not appear particularly lucrative for domestic or foreign companies.

An acceleration of labour productivity growth would be needed to counter these adverse structural effects. However, labour productivity growth in Finland has been very slow since the Global Financial Crisis, also compared to other advanced economies. Labour productivity could be enhanced by investing in new fixed capital, but the growth of investments has also been modest in Finland.

This paper introduces a new model for long-term growth projections for Finland, in which human capital by education is introduced in addition to fixed capital. The model is consistent with sustained growth in GDP per worker since the return on both types of capital is not diminishing. Instead of using school enrolment data as a proxy for human capital as in earlier literature, human capital is empirically measured in the same National Accounts frame as GDP, fixed capital and hours worked following a similar measurement procedure as for fixed capital.

With this new measure for human capital, the large majority of the observed economic growth can now be actually explained by the reproducible factors of production. In other words exogenous technological change, is not needed to explain Finland's historical growth like in neoclassical growth models which are typically used in policy oriented work in Finland. Instead, growth is driven by human and fixed capital. Better knowledge of the true sources of growth provides better possibilities to forecast growth.

Our aim is to model and forecast long term growth based on national accounts data. A key insight arising from the data is that R&D and the results of R&D are capitalized in fixed capital following the latest standards of the system of national accounts.

This paper outlines a projection for GDP growth in Finland in 2020–2070 based on the expected development of human and fixed capital. With the current trends in population and education, human capital in the Finnish economy will begin to decline slowly in the 2040s and continue to diminish until 2070, despite a fairly optimistic assumption of the development of the labour market participation rate. Three different scenarios for the development of human capital, fixed capital and GDP are then discussed to assess the effect on long-term growth prospects of increased inputs into education, well-educated labour based immigration and stronger investments in fixed capital. It is clear that, unless the decline in human capital can be prevented by increasing fertility, substantial efforts in the field of skilled migration, education or employment rate of the workforce are necessary.

Both the innovation and the implementation of new capital products requires a lot of human capital. Human capital is embodied as skills and knowledge in the persons in the labour force. By formally establishing the link between the quantity and quality of labour, we show that Finland's declining working age population can cause harm via two channels: 1) it reduces the number of workers and at the same time 2) it decreases the amount of knowledge and skills available in the production of GDP. In practice, the decline in the economy's human capital also affects the implementation of imported new technology capital products and innovating them domestically more difficult.

The paper is structured as follows: the next section presents the novel long-run forecasting framework and its relation to the growth theory literature. Section three describes the measurement of human capital and shows how this new variable substantially reduces the unexplained residual of economic growth. Section four describes the projection of the factors of production and presents the results of the long-run projection for 2020–2070. Section five discusses the implications of the analysis for economic policy.

2. New long-run forecasting framework

The Bank of Finland's long-run forecast model for Finland, just as most other corresponding models in use in Finland, has previously been based on the neo-classical growth model with exogenous technological change (Solow 1957)[1]. In that framework, total factor productivity (TFP) is typically an important, or even the most important, source of long-run growth. TFP is usually interpreted as technological progress, but, in the neo-classical growth model, it is independent of, e.g. the country's educational level, innovation policies, and other factors usually thought to affect technological progress.

[1] The model used to estimate potential growth and NAWRU and analyze the output gap at the Bank of Finland also follows a neoclassical production function approach, see Sariola (2019): "An unobserved components model for Finland – Estimates of potential output and NAWRU", BoF Economics Review 2/2019

TFP cannot be observed and it is thus calculated as a residual in growth accounting exercises. This Solow residual has been found to be particularly large for Finland[2], meaning that the bulk of the observed economic growth is explained by an unexplained residual. The difficulty in forecasting with that model was the same as with any neo-classical growth model: the long-run forecasts depended heavily on the forecasters' judgement of future growth in "total factor productivity". Despite the thorough analysis of TFP trends and projections, the sources of this growth remained largely unexplained.

The Bank of Finland's new long-run forecast model belongs to the class of endogenous growth models where the primary aim is to explain the sources of long-run growth within the model, i.e. endogenously. The most important criteria for choosing the specific model is its fit to the data. Our modelling choice is strongly guided by the fact that the endogenous growth model we propose has been able to explain very well historical economic growth in Finland. Increased knowledge about the true determinants of long-run growth also widens the possibilities to study how economic policy affects long-run growth.

Diminishing returns to capital is the fundamental reason why growth models without technological change predict that the economy will eventually converge to a steady state with zero per capita growth. This is why exogenous technological change has had to be added in neoclassical models for them to account for the empirical fact of sustained long-term growth in GDP per capita.

Endogenous growth models have remedied the problem of diminishing returns in roughly two different ways. One way out of this problem is to broaden the concept of capital, notably to include human components, and then assume that diminishing returns do not apply to this broader class of capital. The simplest version of this class of models is the AK-model. Our model broadly follows this approach and is in this sense closely related to the models of Romer (1986), Lucas (1988) and Rebelo (1991).

2.1 The model framework

The model follows the one-sector model with fixed and human capital of Barro and Sala-i-Martin (2004, 240-42). In the spirit of growth accounting, we use primarily the key equation of this model, the production function, as our forecasting equation. While the model framework is fairly standard, the value added is in the empirical application of the model. The most important contribution of the new framework is the introduction of human capital by education which is measured in the National Accounts consistently with the other variables of the model. This empirical human capital variable has been shown to explain a large part of Finland's historical growth in GDP per labour input (Kokkinen 2012).

[2] see e.g. Pohjola (2020)

The economy's output is produced according to the following Cobb–Douglas production function that exhibits constant returns to fixed and human capital, K and H:

$$Y_t = AK_t^{\alpha}H_t^{1-\alpha} = AK_t^{\alpha}\left(\frac{H_t}{L_t}L_t\right)^{1-\alpha} \tag{4.1}$$

where 0 < α < 1

Y_t = GDP

K_t = Fixed capital

H_t = Human capital

L_t = labour hours

A = Solow residual, here a stationary residual

Human capital, H_t, is equal to the number of workers, L_t, multiplied by the human capital of the typical worker, $h_t = H_t / L_t$. The assumption is that the quantity of workers, L_t, and the quality of workers, h_t, are perfect substitutes in production in the sense that only the combination $L_t h_t$ matters for output. The variables can be expressed in relation to the labour input resulting in an equation for labour productivity, or the intensive-form production function.

$$\frac{Y_t}{L_t} = \left(\frac{K_t}{L_t}\right)^{\alpha}\left(\frac{H_t}{L_t}\right)^{1-\alpha} A', \tag{4.2}$$

where A' = Solow residual of the intensive form, here a stationary residual

In the intensive-form production function the exponents of the capital-labour ratio and the human capital per labour ratio still sum up to one implying that long-term per capita growth can be achieved without exogenous technological progress, contrary to neoclassical growth models. This is the key difference between our model and the model by Mankiw, Romer and Weil (1992) which extended the Solow model to include human capital in addition to physical or fixed capital.[3]

In the next section, we show empirically that, once human capital measured in the national accounts frame is included in the model, exogenous technology is not needed to account for

[3] In the Mankiw, Romer and Weil (1992) model, the production function is of the form $Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$, where A_t is exogenous labour-augmenting technological change. From the intensive-form production function or $y_t = k_t^{\alpha} h_t^{\beta} (A_t)^{1-\alpha-\beta}$ (with lower case letters referring to a variable divided by labour) it is apparent that there are diminishing returns to the reproducible factors k_t and h_t, and therefore, sustained growth in income per capita cannot be achieved without assuming exogenous technological progress. Here A_t is not a stationary residual, but an exogenously given variable with non-stationary variation, which is needed in this model for sustained per capita growth in the long-run.

the observed economic growth in Finland. The choice of the current Cobb-Douglas production function is further supported by the fact that Kokkinen (2012, 178-190) shows empirically that the exponents of this production function sum up to one in the Finnish case.

In the Bank of Finland long-run forecast model, the economy is divided into three parts: 1) publicly produced (or financed) services, 2) manufacturing and 3) other private industries than manufacturing. This is a feature that the new long-run forecast model has inherited from its predecessor. This kind of partition of the economy makes it possible to examine, for instance, how population ageing affects the amount of labour needed in the public age-related services versus in private production. It also makes it possible to assess the effects of different labour productivity growth rates in industrial production (manufacturing) and in the rest of the private production activities dominated by private services.

Alongside the broadening of capital, the other way an economy could escape from diminishing returns in the long run would be to assume technological progress in the form of the generation of new ideas, as pioneered by Romer (1990). These models that endogenize the process of technological improvement effectively aim at explaining the origin of the Solow residual, in many cases denoted by A_t. A recent example of such a modelling method is the study by Elfsbacka-Schmöller and Spitzer (2021) which addresses endogenous total factor productivity dynamics in the euro area. Their model also follows the recently developed modelling method where short-term dynamics affect long-term outcomes instead of just analyzing long-term trends. This would be an interesting direction to develop our model and seek to bridge the gap between short-term[4] and long-term forecasts of the Bank of Finland.

Models in which technological progress shows up as an expansion of the number of varieties of capital products also belong to the class of endogenous growth models where the process of technological improvement is endogenized. The driving force of endogenous growth in these models is the renewal of the capital stock. Although our model does not explicitly include this kind of endogenous technological progress, the data to which we aim to fit our model, the empirical K_t in the new national accounts, does include technological advances, as discussed in the next section.

[4] The main model used in short-term forecasting at the Bank of Finland is a medium-sized DSGE model of a small open economy, see Kilponen et al. (2016).

2.2 Technological progress in the new forecasting framework

The model employed in this paper only features long-run growth if the Cobb-Douglas parameters add up to one, i.e. diminishing returns to human and fixed capital do not apply. This absence of diminishing returns means that long-term per capita growth is feasible in the absence of exogenous technological progress. As shown later in Section 3.2, the upward trend of the Solow residual, A, vanishes when human capital is introduced into the model and the model is fitted to the data. We cannot therefore think that technological progress would be included in A, in this framework. In the data which our model aims to represent, the new national accounts, R&D and its outputs are nowadays included in the capital stock, i.e. in the empirical K_t. Due to this property of the data for fixed capital, endogenous models with a variety of capital products could be suitable for representing the national accounts data.

In these models, sustained per capita growth is generated by adding new varieties (or vintages[5]) of fixed capital products in the model (see Romer 1987; Barro & Sala-i-Martin 2004 Ch. 6; Crafts 2004). If technology is embodied in the varieties of fixed capital products, and human capital is crucial for the implementation of technologies, the production function can be expressed as[6]:

$$Y_t = AH_t^{1-\alpha}K_t^{\alpha} = AH_t^{1-\alpha}\sum_{j=1}^{N}(k_{j,t})^{\alpha} = AH_t^{1-\alpha}\cdot N\cdot k_{j,t}^{\alpha} \ .$$

From the first equation to the left, it is clear that the production function is identical to our production function (4.1). The input of total fixed capital used in the production K_t can, however, be written as being equal to the sum of the inputs of variety of capital goods, $K_t = \sum_{j=1}^{N}(k_{j,t}) = Nk_{j,t}$. This implies that the aggregate production function can be written as $Y_t = AH_t^{1-\alpha}\cdot N\cdot k_{j,t}^{\alpha}$, where N expresses the number of different varieties (or vintages) of capital products used in the economy in line with Romer (1987).

It is important to notice that, in this case, technological progress takes the form of expansions in N, the number of specialized varieties of capital goods available, rather than increases in some productivity parameter A. To see the effects from an increase in N, the production function can be rewritten as $Y_t = AH_t^{1-\alpha}\cdot N^{1-\alpha}\cdot(Nk_{j,t})^{\alpha} = AH_t^{1-\alpha}\cdot N^{1-\alpha}\cdot(K_t)^{\alpha}$. The latter equation expresses that diminishing returns set in when K_t increases for given N but

[5] On vintage capital growth theories, see e.g. Boucekkine et al (2011).
[6] The production function form is the same as the baseline model with a variety of products in Barro and Sala-i-Martin (2004), ch. 6, only with labour, L, substituted by human capital, H.

not when $N^{1-\alpha}$ rises for given K_t. In other words, if the number of varieties of capital goods increases over time and an increasing number of capital good varieties can be adopted, there does not have to be diminishing returns to fixed capital. Our theoretical production function could easily be modified to include this specification, but the empirical implementation of that model would not be feasible since data for N does not currently exist. [7]

Since 2014, in the national accounts data for fixed capital, also in Finland, research and development is treated as capital formation.[8] R&D, and the results of R&D, are included in the new fixed capital category called intellectual property products. This becomes clear from the SNA 2008[9] definition: "*Intellectual property products are the result of research, development, investigation or innovation leading to knowledge that the developers can market or use to their own benefit in production because use of the knowledge is restricted by means of legal or other protection. The knowledge may be embodied in a free-standing product or may be embodied in another.*" *"Examples of intellectual property products are the results of research and development, mineral exploration and evaluation, computer software and databases, and entertainment, literary or artistic originals."*

As spelled out in the above quotation, by capitalizing R&D and other intellectual property products, the new National Accounts data seems to refer to the idea of technological progress being embodied in multiple varieties of capital products. In addition to intellectual property products, the results of R&D, investigation or innovation can also be embodied in other capital products such as machinery and equipment. Another key observation is that the data for fixed capital products, K_t, includes not only the results of research and development services produced at home but also those imported[10].

The latest standards for National Accounts were implemented in early 2010s in the U.S. (and in the non-EU Anglo-Saxon countries) and in the EU countries in 2014 but the important implications of these new standards for empirical growth models have gone largely unnoticed. Before 2014, R&D expenditure was not treated as investment, it was incorporated in

[7] If all new varieties (or vintages) of fixed capital products (of type *j*) were recorded in the National Accounts as their own $k_{j,t}$ products, N would be the number of new $k_{j,t}$ variants (i.e., new $k_{j,t}$ products) over time, but statistical offices do not (yet) measure fixed capital in this way. Diewert (2009) proposes how to operationalize such a measurement of K_t. If this kind of data would exist, it would be interesting to see whether, in an empirical application with the production function with N included, H and K together would still exhibit constant returns to scale. It is worth noting that accounting for the new variants of $k_{j,t}$ could provide the basis for endogenous growth even if there were diminishing returns to the reproducible factors of production.

[8] See SNA 2008, par 6.230, p. 122.

[9] See SNA 2008, pp. 205-207.

[10] For a small country like Finland, it has not been and will not be possible to produce all the new varieties of fixed capital, or the new better qualities of the same type of capital products (taking into account the wide-ranging composition of fixed capital). Therefore, in addition to the innovations made at home, new technology capital products have been and will be implemented in Finland by importing them. This is reflected in the data for fixed capital.

intermediate inputs in the national accounts data, which may in our view have influenced the way R&D has been modelled in growth theory.

The point that the compilation of modern macroeconomic data for fixed capital has many similarities with endogenous growth models with a variety of capital products is important to make, because we work with a model which is aimed at describing and forecasting the real world as reflected in the national accounts data. Empirical analysis by Kokkinen (2012) on economic growth in Finland also suggests that these types of models could be considered.[11] While our model does not include an explicit description of technological progress, it should be kept in mind that the National Accounts data for K_t includes R&D and refers to capital-augmenting technological change.

One important feature of our framework is that we are describing and forecasting a small open economy's long-term growth. In the empirical application of our model, Finland's Y_t (and Y_t / L_t) depends partly on the international economy since the data for fixed capital products, K_t, include products both produced at home and imported from abroad.

3. Human capital – a key factor for long-run economic growth in Finland

The role of human capital in economic growth has been thoroughly discussed[12] and emphasised in a variety of modern growth theories since the 1980s[13]. Human capital is seen, in those theories, either as an input in production enhancing labour input or as an enabling factor for technical change and as a factor allowing for the implementation of new technology in production[14].

In numerous empirical studies on human capital and economic growth, the school enrolment ratio and average years of schooling in the working age population have been used as proxies for human capital. However, based on these proxy measures, no unambiguous agreement has been reached on the role of increased educational attainment in explaining

[11] In the Cointegrated VAR analysis conducted by Kokkinen (2012) on Finnish data 1910–2000, long-run labour productivity, Y/L, was explained by two cointegration relations in error correction form. The first relation was identified to be the production function in intensive form in equation (4.2) (in natural logarithmic form) with an exponent 0.47 for H/L and 0.53 for K/L. Based on statistical tests, the second relation (in natural logarithmic form) was identified to be $LN\,H_t = 0.74 LN\,K_t + 0.0155t$. In the empirical results, the time trend appeared statistically significantly in the second relation (and not in the first) with the same sign as K. These empirical results were interpreted in such a way that K has grown together with H and vice versa. In addition, it was interpreted that K has become more productive in relation to H over time and that technological progress would be attached to the evolution of K over time.

[12] See e.g. Schultz 1961; Nelson & Phelps 1966; Abramowitz 1986; Lucas 1988; Mankiw, Romer & Weil 1992; Truong and Tran-Nam 2007; Chaudhuri & Maitra 2008.

[13] See e.g. Romer 1986; Rebelo 1991; Barro & Sala-i-Martin 2004; Galor 2005; Benhabib & Spiegel 2005.

[14] See e.g. Benhabib & Spiegel (2005); Goldin and Katz (2008)

differences in economic growth across countries and time. Some of the empirical cross-country comparisons have shown a positive and significant impact of schooling on real GDP growth[15], while other studies have reported a non-significant or even negative effect on economic growth[16].

In these empirical studies, human capital is measured by some proxy measure for educational attainment, while the empirical counterparts for the other key macro variables – GDP, fixed capital and labour input – are compiled within the System of National Accounts (see SNA 2008, ESA 2010). This raises the question whether the measurement of human capital in the same National Accounts framework as the other core variables would be more consistent and lead to different results.

The role of human capital in the context of national accounts for Finland's economic growth has been discussed earlier by e.g. Aulin-Ahmavaara (1987, 1990). She studied a dynamic input-output system where she included the production of human capital and human time. However, her approach broadened the scope of National Accounts far beyond the standard GDP and therefore her estimates of human capital can not be directly linked to standard GDP growth. Relander (1969) had earlier considered the gross value of the stock of educational capital in manufacturing industry by a replacement cost method without depreciation for the years 1950 and 1960. Niitamo (1958) used the evolution of the number of graduates from lower secondary schools for an indication of 'the level of knowledge', or human capital in his study on labour productivity growth in the Finnish manufacturing industries in 1925–1952. Despite these earlier contributions, before Kokkinen (2012), time series of human capital long enough to test quantitatively and thoroughly whether and how human capital has contributed to economic growth in Finland did not exist.

Leiponen (1993) provides an early discussion on how human capital affected economic growth in Finland and in the OECD countries in 1960–1988. Her main analysis was conducted in the context of a neoclassical model augmented with human capital but she also discussed endogenous growth theories. Human capital was measured with the enrolment rate in higher education or the number of researchers per population.

The new forecasting framework presented in this paper follows Kokkinen (2012) who measured – within the systematic National Accounts frame – how much Finland invested in human capital by schooling in the 20th century and analyzed in a modern growth theory framework how this stock of human capital contributed to Finland's economic growth. Human capital by schooling is thus measured in the National Accounts framework in a similar manner

[15] E.g. e.g. Barro 1991; Levine & Renelt 1992; Barro & Sala-i-Martin 2004.
[16] E.g. Lau, Jamison & Louat 1991; Islam 1995; Bosworth & Collins 2003.

as fixed capital. Kokkinen (2012) shows empirically that this new human capital stock variable has been a key factor in Finnish long-run growth in 1910–2000.

3.1 Measurement of human capital in the National Accounts

In Kokkinen's (2012) measurement strategy used in this paper, the volume of general government final consumption expenditure on education services is treated as an investment in the accumulation of human capital[17]. The volume of inputs in education services are allocated to students who use the education services as intermediate inputs in their learning process when producing the human capital embodied in them. The volume of annual education expenditure is allocated to the students according to the type of education they participate in: comprehensive and upper secondary (earlier in primary and secondary schools) education, vocational education as well as polytechnic and university education.[18] The long completion periods of education are taken into account, and consequently the human capital stock is only accumulated as the student graduates from her/his highest education and becomes available for full-time employment in the labour market.[19] In this measurement strategy, human capital by schooling is accumulated by the Perpetual Inventory Method (PIM) starting from zero. Hence, it takes some decades before the stock reaches its own fluctuation level.

The evolution of the productive human capital stock for the years 1976–2000 presented in this paper is taken from Kokkinen (2012). For the period 2000–2019, the human capital variable has been constructed by following the same measurement strategy as in Kokkinen (2012) applied with modern more detailed education statstics on qualifications and degrees. When linking the series from Kokkinen (2012) with the series in this study, continuous time series of human capital are now available for 1910–2019[20].

In contrast to the original series in Kokkinen (2012), the figures for human capital in 2000–2019 were constructed using the new education statistics by Statistics Finland. The new

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[17] For a detailed description of the measurement strategy, see Annex 2. Kokkinen (2012) gathered data on Finland's education expenditures in real terms and on the number of students for the period 1877–2000. The human capital stock was accumulated for 1910–2000 by using the volume of education expenditures each generation of students had used in their schooling.

[18]The volume of final consumption expenditure in education means that the impact of cost inflation has been deflated out from final consumption expenditure at current prices. After deflation, the volume of final consumption expenditure in education describes the development of teaching hours and the amount of materials and teaching equipment used in teaching. When the number of students is weighted according to the volume of final consumption expenditure on the specific education and training they consume, differences in investments in education and training at different times are highlighted. See Kokkinen 2012, 110-134.

19 Until graduating from the highest education, human capital is produced to the inventory as any other unfinished (investment) product in the System of National Accounts. When the student has graduated from the highest education, all the accumulated education expenditure volumes that the person has used in her schooling is transferred within Gross capital formation from inventory to actual investments. The human capital stock of the economy is accumulated only at this point. For more information, see Kokkinen 2012, 110-134.

[20] The two pieces of time series were linked together by using the level of human capital calculated from the new education and national accounts statistics and the growth rates of human capital in the former period.

education statistics provide the number of qualifications and degrees in all types of post-comprehensive education by one-year age groups from age 16 onwards. For valuation of the qualifications, the volume of final consumption expenditure in education by the general government in the National Accounts was distributed among students in each type of post-comprehensive education and in comprehensive education. The qualifications were valued by average education expenditure volumes per student in the past years[21]. The volume of education expenditure in comprehensive education was taken into account when valuing post-comprehensive qualifications.[22]

3.2 The Solow residual almost disappears when human capital is included

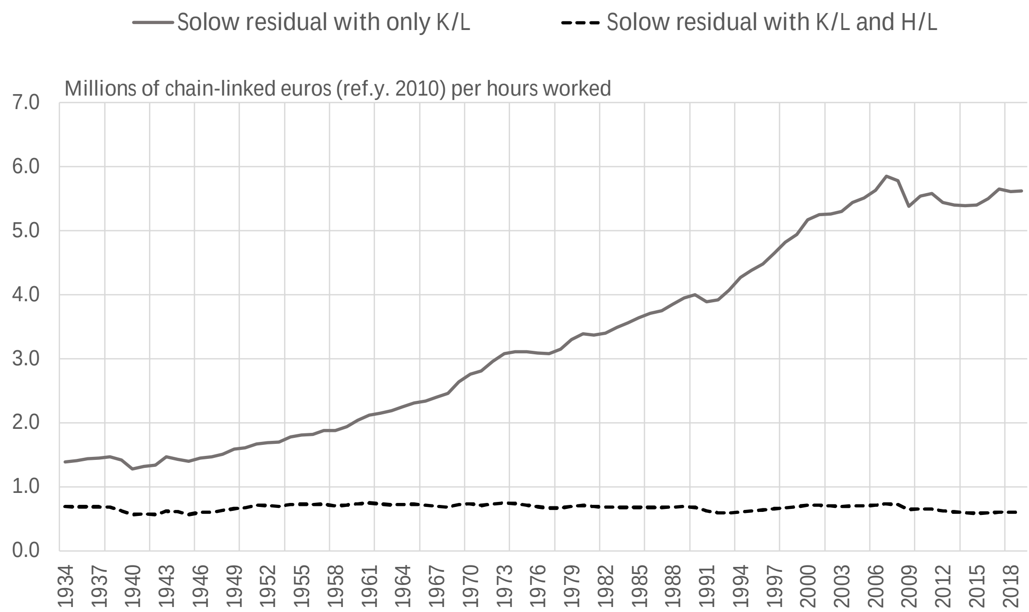
The main reason for including human capital by schooling into the new long-run forecast model is that it has been found to explain such a significant part of the historical economic growth in Finland[23]. This can be illustrated by a simple growth accounting exercise on Finnish data 1934–2019 based on the neo-classical production function typically used in the general Solow model $Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$. In the intensive form of the production function, GDP per hours worked Y_t / L_t is explained by the capital-labour ratio, K_t / L_t, i.e. by fixed capital per hours worked $Y_t / L_t = A_t (K_t / L_t)^{\alpha}$. Using the income share of fixed capital in gross value added (typically the share of Gross Operating Surplus from the national accounts) as a model parameter for the exponent of K_t (and hence K_t / L_t), one can fit the Solow model to the Y_t / L_t growth data. As is typically found in this kind of exercise, the unexplained part of labour productivity growth, the Solow residual A_t, explains a large part of the growth in Y_t / L_t, when the model only includes K_t as the reproducible factor of production (see Figure 3.1).

In contrast, when human capital $H_t = (H_t / L_t) * L_t$ is added to the production function, $Y_t = A_t K_t^{\alpha} ((H_t / L_t) * L_t)^{1-\alpha}$, its intensive form is $Y_t / L_t = A_t (K_t / L_t)^{\alpha} (H_t / L_t)^{1-\alpha}$. When using the same income share parameter, α, for K_t / L_t and the traditional income share of labour compensation, $1-\alpha$, as a parameter for H_t / L_t, the residual, A_t diminishes to a stationary line (Figure 3.1). In other words, the contribution of the Solow residual as a factor explaining growth is dramatically diminished. Therefore, after the inclusion of human capital in the

[21] The number of past years depends on how many years are needed to study for the highest qualification.
[22] The qualifications valued by the used education expenditure volume were treated as investments in human capital also for the period 2000–2019. These investments were accumulated by the perpetual inventory method (PIM) to form a human capital stock starting from zero in the year 1940 for the period 2000–2019.
[23] See the empirical testing in Kokkinen (2012), Ch 4. Granger causality was tested as well. It proved to have run from both H/L and K/L to Y/L in Finland in 1910–2000.

production function, labour productivity (Y_t / L_t) growth can be explained almost completely by the reproducible factors used in the production process. The trend of the Solow residual disappears, which is a desirable feature of any residual in models fitted to data.

Figure 3.1 Explaining the development of Y_t / L_t in 1934–2019 : Solow residual with only K_t / L_t as an explanatory variable and Solow residual with H_t / L_t and K_t / L_t as explanatory variables



Data sources: Hjerppe (1989); Jalava & Pohjola (2007); Kokkinen (2012); Statistics Finland: Population, Education, National Accounts; calculations Bank of Finland, Kokkinen / National Audit Office.

39910@Chart5 (EN)

4. Forecasting the factors of production

In order to construct a projection for long-term growth in Finland, we first forecast the development of the factors of production, human capital and fixed capital. We present then three different scenarios for long-term growth in GDP and GDP per labour input. In the lowest growth scenario, the development of the factors of production is based on their current trends without any assumptions on policy measures to enhance investment in human or fixed capital. In addition to this no-policy-change projection, two scenarios of faster GDP growth are presented. These scenarios are based, in turn, on assumptions on various policy measures to increase human and/or fixed capital.

4.1 The projection for Human Capital (H)

The method for forecasting human capital in 2020–2070 follows and extends the procedure for calculating human capital in 2000–2019 (see sub-section 3.1). In order to forecast the number of qualifications in each one–year age group in ages 16–74 by each education type, the expected number of students is first forecast for each one-year age group in 2020–2070. This forecast is based, on the one hand, on population forecasts for one-year age groups by Statistics Finland. On the other hand, it is assumed that both the school enrolment rate and the ratio of students who pass from the previous year to the next in each type of education stay the same as in the recent 3 to 5 years. Once the number of students is available, the number of post-comprehensive education qualifications in the 16–74 years old population is forecast by assuming a similar qualifying rate in each type of education as in the recent past. Finally, the number of qualifications are valued in the baseline forecast by assuming that the average education expenditure volume per student stays at the 2019 level in each type of education.[24] It is useful to note, that we use the *volume* of education expenditure to describe the volume of education services. For instance, if the volume of teaching hours increases, both the volume of education expenditure and the volume of education services increase.

The entire human capital stock can be decomposed into average skills and knowledge in the labour input multiplied by the size of the labour input, $H_t = (H_t \ / \ L_t) \cdot L_t$. The size of the labour input L_t, measured as total hours worked has already started to decline in the 2010s along with the shrinking of the working age population[25]. The whole stock of human capital H_t of the 16–74 years old working age population has, nevertheless, continued and will continue to grow for some time because H_t / L_t is still growing. For many decades, the young cohorts entering the working age population have had a higher average education level than the old cohorts retiring. In Finland, this favourable trend is, however, at risk of ceasing. The volume of education expenditure in Finland has declined in the 2010s, for the first time since it embarked on an upward trend in the 1920s, and the average education level of the latest young cohorts has recently started to decrease. The latter implies that at some point young cohorts entering the labour market will not anymore have a higher average education level than the retiring age groups, and this will start to weigh on the human capital stock.

It seems that the cohort born at the turn of the 1980s, the members of which are in their forties at the moment, is on average the highest educated cohort so far, (see e.g. Mäki-Fränti

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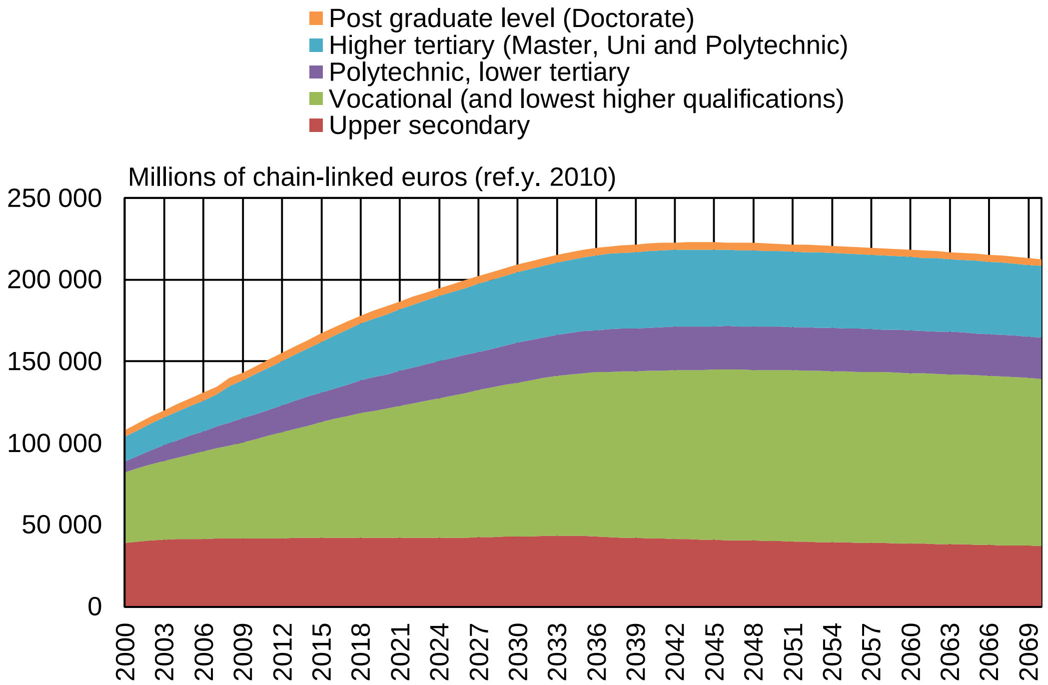
24 It is worth noting that the accumulation of education at all ages is nowadays common in Finland as observed in 2004–2019 in the 16–74 years population. People study for and pass qualifications all the way up to their 50s (some even in their 60s). These qualifications are taken into account in 2000–2019 and the number of qualifications for ages 16–74 were projected for 2020–2070 in the baseline forecast from the number of students in a similar manner for all the ages where qualifications existed in statistics on qualification at the ages 16–74 in 2004–2019.

25 Hours per person also exhibit a longer downward trend which contributes to the decline in total hours.

2019). If the population and education trends continue as in the recent past, the growth of human capital in Finland will gradually decelerate in the 2020s and 2030s, and turn slightly negative around the year 2045 (Figure 4.1.). The decline of -0.2 to -0.3 per cent a year in the stock of human capital in the 2050s and 2060s is dramatically different from the continuous exponential growth of human capital in Finland in the 20th century (see Kokkinen 2012, p. 132). As for the composition of the human capital stock, it is worth to note the increased share of vocational education during the past two decades and the decreased share of the highest types of education. This has a negative effect on the growth of H_t since workers with vocational qualications use cumulatively less education services than workers with higher degrees and qualifications.

In the forecasting framework, the same growth rate of human capital is assumed in each three parts of the economy: both in publicly produced services and in private industries, manufacturing and other. In Finland, this is deemed a reasonable assumption given that all the students enroll with equal opportunities the nine-year comprehensive schooling and a good majority enrolls secondary schooling as well. Everyone is entitled to apply to further studies as an adult in the continuous education. Furthermore, we are not aware of significant educational backround differences between employees in the public and the private economy.

Figure 4.1 Human capital by type of education in 2000–2070



Data sources: Kokkinen (2012); Statistics Finland: Population, Education, National Accounts; calculations and forecasts for 2020–2070: Bank of Finland, Kokkinen / National Audit Office.

39910@Chart1 (EN)

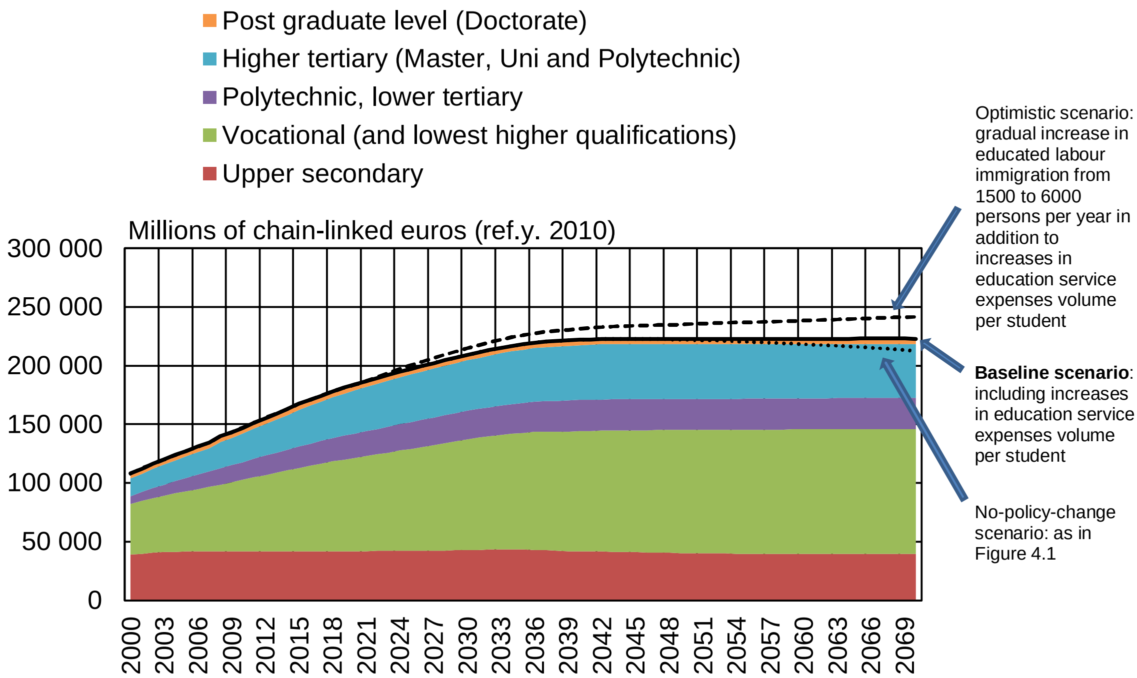
The projection for human capital presented in Figure 4.1 is a no-policy-change scenario as it assumes, for instance, that the unfavourable development of the working age population continues and the young age groups to be educated continuously decrease. Given the very unfavourable consequences of this kind of development for growth and especially for the financing of welfare services, we consider as our baseline scenario a projection where additional investments in education per student are implemented to prevent the human capital stock from decreasing. This would mean more hours taught and/or more teaching material provided per student. This baseline, or middle scenario includes an increase in the volume of education expenditure per student in the 2050s and 2060s to levels that correspond to their level at the turn of 1980s and 1990s. In this scenario, growth in human capital would still slow significantly by the 2040s, and come to a complete halt in the 2050s but it would not decrease as in the no-policy-change scenario.

In the third, optimistic scenario, education expenditure develops as in the baseline scenario but labour migration is also gradually increased from 1500 in the 2020s to 6000 more per year in 2050–2070 than at present. The immigrants are expected to have the same education level as domestic graduated workers according to the 2019 education statistics.[26] The children of the immigrants also add to the labour force growth, as they enter the labour market after acquiring education. Under these more optimistic assumptions, human capital would continue to grow until the end of the forecast period, even if growth slows significantly in the 2040s. All the scenarios are presented together in Figure 4.2. and in Table 5.1.

The different scenarios for human capital will be used in section 4.2 and chapter 5 to make projections for the fixed capital stock and GDP respectively.

[26] It is assumed that net immigration in 2022–2030 is 1500, in the 2030s 2000, in the 2040s 3000 and in 2050–2070 6000 individuals higher compared to its currently projected level. These immigrants are assumed to be in the age group 28-53 years old and have an education level similar to those graduated in Finland in 2019. Half of the immigrants are female with the same fertility rate of 1.41 as Finnish women on average. The children (=1.41*(n/2) of the immigrants are assumed to acquire the same level of education as their parents and they will become employed as they enter the labour market.

Figure 4.2 Baseline scenario: increase in education service expenses volume per student to 1990 level



Data sources: Statistics Finland: National Accounts; forecasts for 2020-2070 Bank of Finland, Kokkinen / National Audit Office.

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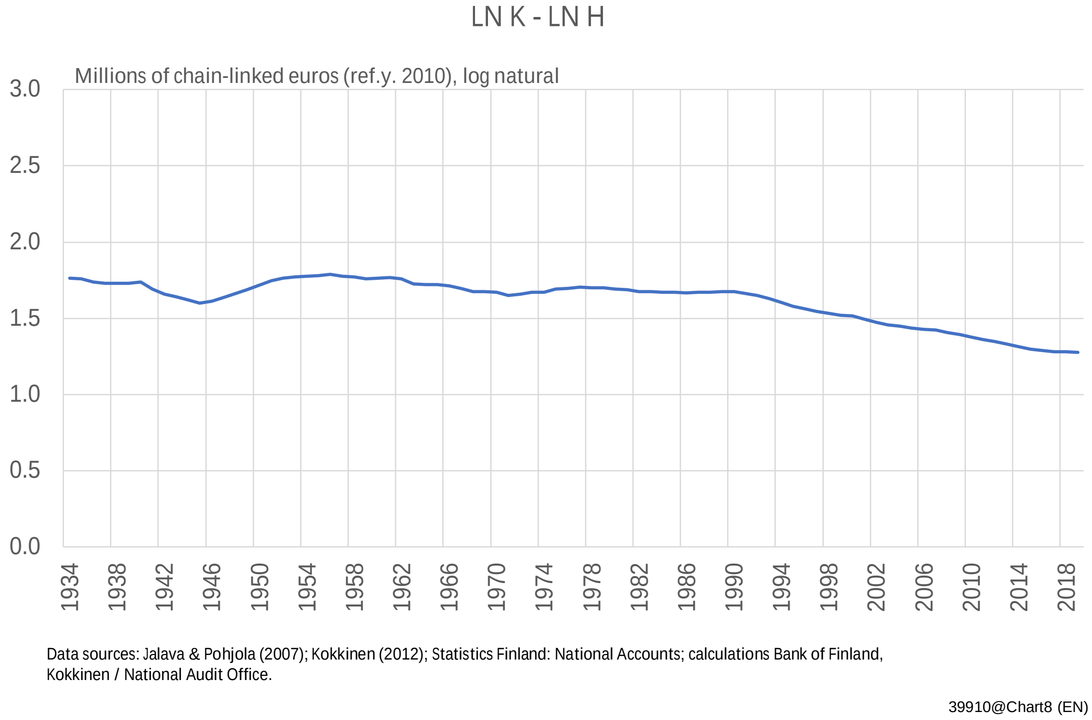
4.2 Projections for the fixed capital stock (K)

In the basic closed economy theory model including both fixed capital and human capital of Barro and Sala-i-Martin (2004), the two types of capital are assumed to grow at the same pace in the steady state, leaving the relation K_t / H_t constant. In the model, the two capital types have the same accumulation equation. In the empirical work of this paper, both K_t and H_t are accumulated with Perpetual Inventory Method (PIM), but with different depreciation rates. (See also Annex 1. equations 5a and 5b.)

In the 20th century, in Finland, however, the two types of capital have not grown at the same pace (Figure 4.3). Fixed and human capital developed on average more or less hand in hand from 1934 to the early 1990s but, from the severe depression of the 1990s onwards, fixed capital has grown more slowly than human capital.

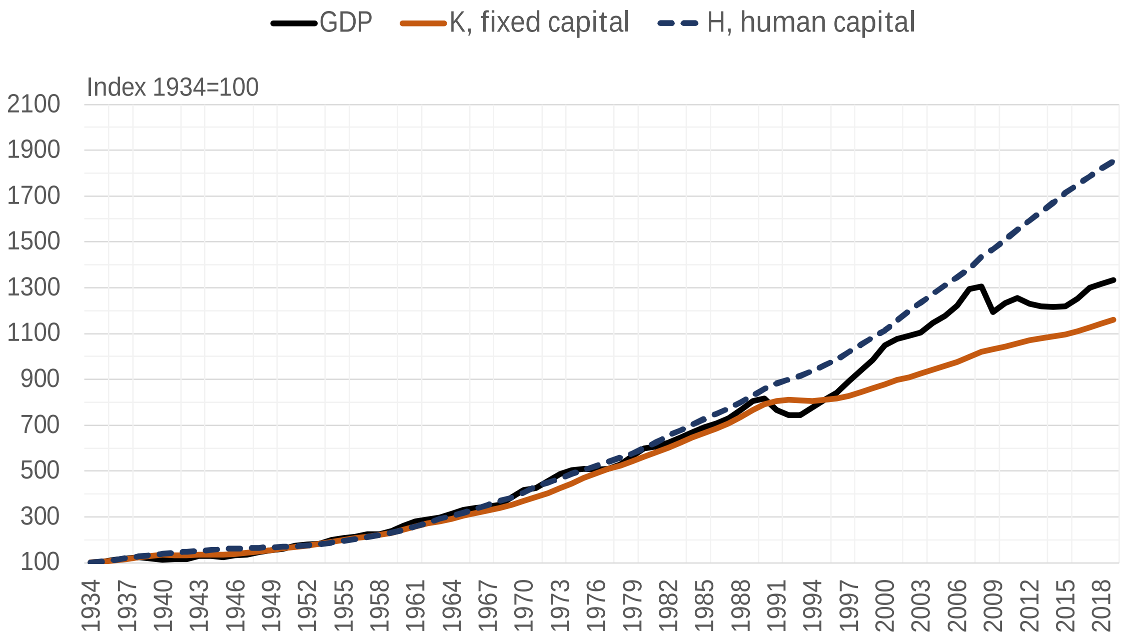
Figure 4.3 The proportion K/H in Finland in 1934–2019



Looking at the developments of GDP, human capital and fixed capital in 1934–2019 more in detail, reveals that the growth of fixed capital ceased temporarily in the early 1990s and embarked subsequently on a slower growth path than before the depression, while human capital continued to grow swiftly (Figure 4.4). This is the case despite the fact that Nokia was starting to break through globally in the early 1990s with its mobile phones, and increased strongly its research and development investments.

It seems that there is a structural change in the relation between K_t and H_t in the early 1990s. Indeed, according to Statistics Finland, non-financial corporations have increased the share of investments in intellectual property products (IPP, e.g. R&D, computer software, intellectual data bases) in all their fixed capital investments from 11% to 34% from 1990 to 2010. This was reflected strongly also in the composition of fixed capital investments in the whole economy where the share of IPP investment increased from 10% to 23% in the same time period. This development is closely linked to the rise of the electrical and electronics industry and the mobile phone and network production of Nokia, in particular.

Figure 4.4 The evolution of GDP, fixed capital and human capital in Finland in 1934–2019



Data sources: Hjerppe (1989); Jalava & Pohjola (2007); Kokkinen (2012); Statistics Finland: Population, Education, National Accounts; calculations Bank of Finland, Kokkinen / National Audit Office.

39910@Chart9 (EN)

These investments, for instance R&D projects, require even more human capital than investments in traditional machines and equipment. The rapid growth in Finnish IPP investments ended at the time of the Global Financial Crisis (GFC) whereafter their volume even decreased for several years. They resumed growth in 2017 but their volume is now still somewhat lower than in the previous peak year 2008. The growth in machinery and equipment investment, in turn, was rapid in the recovery from the deep depression of the 1990s but from the early 2000s onwards the pace slowed down and was markedly slower than that of IPP investments until the GFC. While machinery and equipment investments experienced a large and persistent drop after the financial crisis, they did, however, recover more rapidly than IPP investments. The halt in the increase of IPP investments since then reflects the permanent nature of the negative shock to the Nokia cluster at the time of the Global Financial Crisis. All in all, It seems that the weakness in the accumulation of the capital stock in Finland from the 1990s onwards could be attributed to negative shocks to fixed capital-intensive industries and a shift towards investments in fixed capital which have required more human capital than before.[27]

[27] In addition to the reasons mentioned in the text, the disruption between the development of K and H could be exacerbated by measurement issues especially in capturing the new variants including new technology in fixed capital products. See also discussion on the measurement of K in sub-sections 2.1 and 2.2.

Even if the empirical relation between K_t and H_t has not been constant in Finland in 1990–2019, it might be that the relationship is stationary in the long run as in the steady state of Barro and Sala-i-Martin's model. In the very long horizon, there has been times when the K_t / H_t -proportion has on average slightly increased (as in 1949–1980), and times when it has decreased (in 1991-2019). If the K_t / H_t relationship is stationary in the long run it should be mean-reverting. This would suggest that K/H could start growing again, and reach little by little the long-term average value.

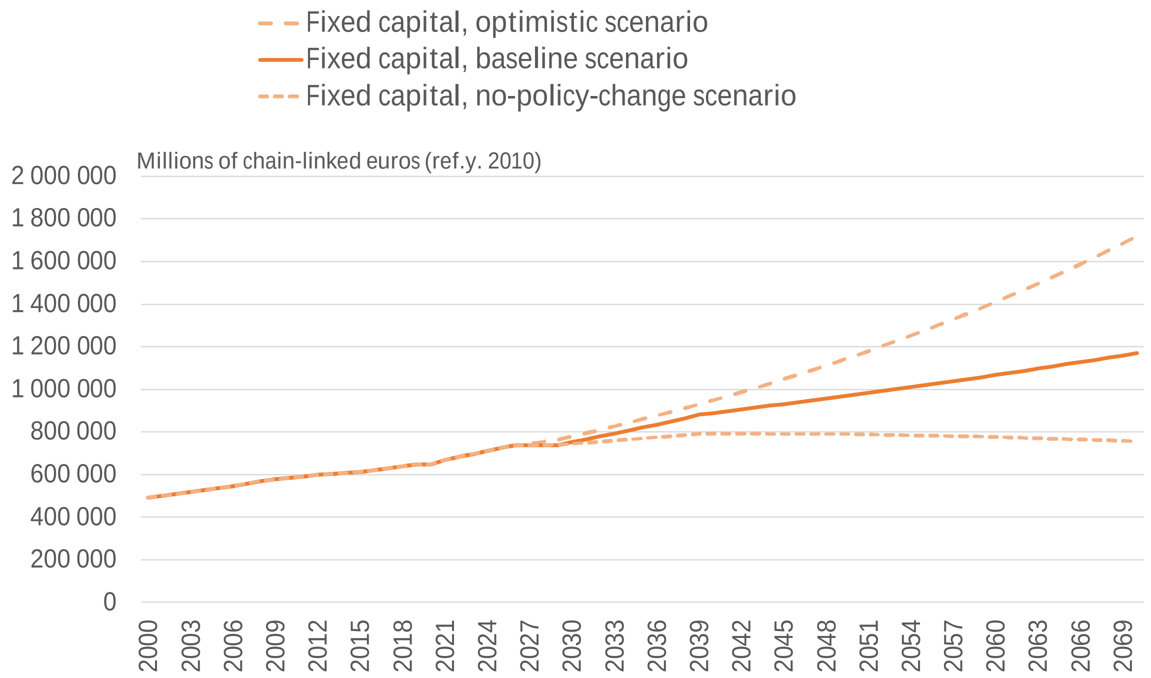
Three alternative paths for the development of fixed capital are depicted in Figure 4.5. In the first alternative, it is assumed that the K_t / H_t ratio stays at the current level and does not recover to its long-term average. As a result, K_t only slightly increases in the near future and portrayes, in the longer term, the declining pattern of H_t. The development of fixed capital thus follows the no-policy-change projection for human capital. The growth of both H_t and K_t would in this case gradually slow down in the 2020s and 2030s and the growth of both factors of production would turn slightly negative from the middle of the 2040s onward.

In the second scenario, the K_t / H_t proportion is assumed to begin to gradually revert towards its long-run mean. In addition, this second scenario follows the baseline scenario for human capital, in which the volume of education service expenses per student is increased to prevent the human capital stock from decreasing. It is assumed that the K_t / H_t ratio would gradually grow in 2020–2070, so that in the end it reaches the K_t / H_t ratio which prevailed in 1990. Given the past modest increase in K_t, this would already require new active measures to promote investments in fixed capital, such as e.g. tax reductions on R&D and other investments.

In the third alternative, investment in K_t is even faster and corresponds to K_t increasing at the same pace as in 1976–2019 on average, i.e. 2.0 % p.a., until the end of the projection horizon, all the way to 2070. This scenario would obviously require even more radical measures to turn fixed investments into this projected steeper growth path.

Finally, the forecast growth rates for aggregate K_t in each scenario are distributed to each sub-section of the economy based on recent developments. Accordingly, K_t in manufacturing and other private economy is expected to grow somewhat faster than K_t in the public economy.

Figure 4.5 Three alternative paths for the development of fixed capital (K_t) in 2020–2070



Data sources: Statistics Finland: National Accounts; forecasts for 2020-2070 Bank of Finland, Kokkinen / National Audit Office.

39910@Chart7 (EN)

4.3. The forecast for the labour input (L)

Total supply of labour in the model is measured by the number of hours worked, which in turn depends on the developments of the working age (15-74 years old) population, the labour market participation rate, the employment rate, and finally, average hours worked.

The development of the working age (15-74) population is taken from the 2021 population forecast of Statistics Finland. As the ageing of the Finnish population will continue, the number of people in the working age population will sharply decrease. In 2040, it is 180 000 persons smaller than in 2020, and by the end of the forecast period, in 2070, the number of 15-74 years old will have already decreased by 490 000 persons, or nearly 12 per cent. The decline of the working age population is, however, in the projection, partly compensated by by the expected increase in the labour force participation rate.

The development of the participation rate has been projected by dividing the working age population into age groups of ten year intervals and extrapolating the trend growth of the age group specific participation rates into the future. Together with the population projections, this gives us an estimate of the labour force until 2070. Mainly due to the expected increasing participation rates of the over 55 years old, the decrease in the labour force is less than the decrease in the working age population. Between 2020 and 2070, the labour force is projected to decrease by 200 000 persons. The medium term path of the employment rate for 2020–

2025 is, in turn, consistent with the forecast of structural unemployment of around 8%, based on the model by Obstbaum and Juvonen (2018).

Average hours worked have been on a downward trend in Finland as in many other advanced economies, and average hours per worker are expected to further modestly decline annually by 0,1% until the end of the forecast period in 2070.

With these assumptions, the number of employed is expected to rise somewhat during the first decades of the forecast period, but to turn into a decline after that. In 2040, the number of employed is roughly 70 000 higher than in 2020, but by 2070, it will have decreased by 185 000. Measured by the total number of hours worked, the labour input cumulatively decreases by 12% in 2020–2070 with the current population projections. Obviously, a higher than projected participation rate or lower than projected structural unemployment rate could slow down this decline substantially. The projection of *L* in this sub-section is used later in the lowest growth and baseline scenarios. In the high growth scenario, the labour input is expected to increase as a result of labour-based migration.

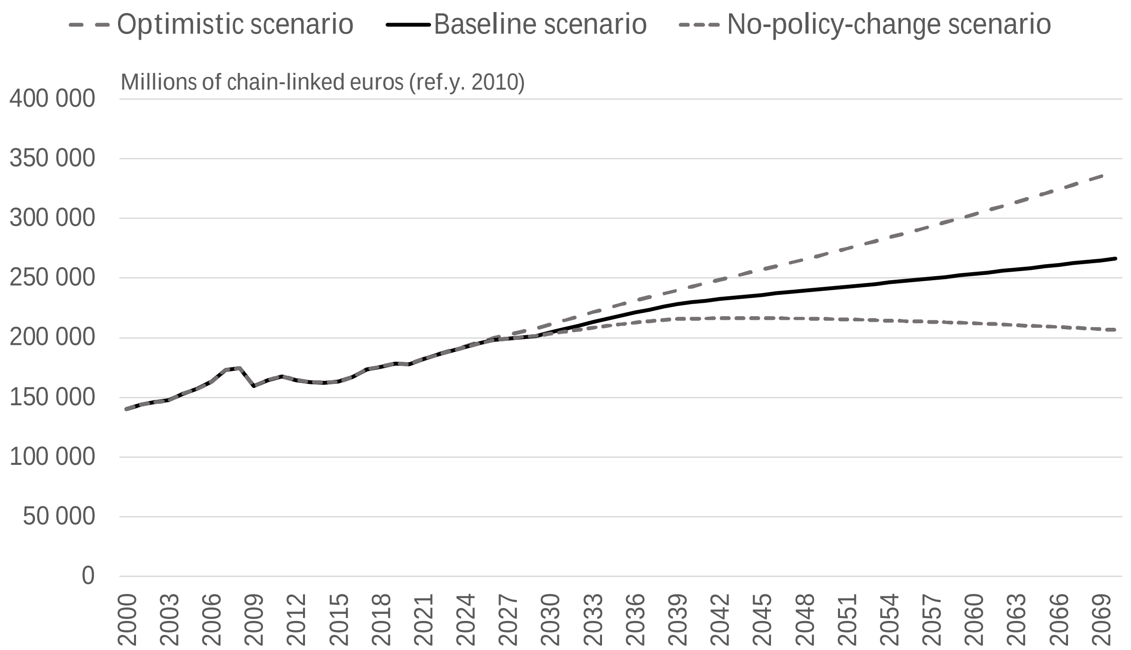
The growth prospects of the economy also affected by how the labour input is divided between the industries. In our model, the labour input of the General Government sector is directly determined by the expected demand for age-related publicly produced services[28]. It is assumed that there is no productivity growth in the public services, implying a one-to-one relationship between the demand of public services and the labour input needed to produce them. Because of ageing population, the need for social and health care services is expected to sharply increase especially during the next two decades. As a result, the labour input needed to produce these public services is assumed to grow by roughly 0.4 to 0.5% a year in 2020 – 2070. The remaining part of the available labour input is shared between the other two sections of the economy according to their shares of the value added of the economy.

[28] Source: Bank of Finland calculations; data: EU COM The 2018 Ageing Report (Ageing Working Group); Statistics Finland, Population projections and General Government expenditure by COFOG classification

5. Three scenarios for Finland's long-run GDP growth

The growth prospects of the Finnish economy turn out to be even weaker according to the new forecast model with human capital than in the previous BoF long-term forecasts (see Mäki-Fränti and Obstbaum 2018). The lowest growth scenario represents the case with no policy changes. In this scenario, human capital starts to decline in the 2040s, and the relation of fixed and human capital is assumed to stay at its current level. This means that the development of K_t going forward follows the development of H_t as in the first alternative outlined above in section 4.2. As a result, GDP would still grow modestly in the 2020s and 2030s (1.2% and 0.6% p.a.), but come to a halt already in the 2040s. GDP growth in the 2050s and 2060s would be -0.2% and -0.3%, respectively. (see Figure 5.1, and Table 5.1).

Figure 5.1 Three forecast scenarios for GDP in 2020–2070



Data sources: Statistics Finland: National Accounts; forecasts for 2020-2070 Bank of Finland, Kokkinen / National Audit Office.

39910@Chart6 (EN)

At the end of the day, growth is only important because it is the way a nation can achieve prosperity, or economic wellbeing. What we are really interested in is thus the growth of GDP per person. Table 5.1 shows also the projected growth rates of GDP per labour input, Y_t / L_t. In Finland, economic wellbeing, measured by GDP per capita has historically grown more or less in line with labour productivity Y_t / L_t but we will later also discuss the implications of measuring the results in GDP per capita terms.

In the lowest growth scenario, Y_t / L_t grows closely at the same pace as Y_t in the next two decades. From the 2040s onwards, however, labour productivity growth stays positive (0.3 %, 0.4 %, 0.3 % in the 2040s, 2050s and 2060s) as the growth in Y_t is less negative than the decrease in the labour input. This is due to the fact that while L_t already starts to decrease in the 2020s, human capital continues to grow for a few decades before starting to decrease. Fixed capital grows at the same rate as H_t since it was assumed that K_t / H_t stays constant.

The middle scenario, which we consider as our baseline scenario, uses the more positive scenario for human capital development described in section 4.1 where the volume of education service expenditure per student is increased. This scenario assumes also that measures to boost the accumulation of fixed capital are implemented. This is taken to be the baseline scenario because it is unrealistic to assume that the government would not implement any measures to boost growth if the development would turn out to be as gloomy as in the no-policy-change case.

Accumulation of fixed capital is assumed to speed up in the baseline scenario following alternative 2 presented in sub-section 4.2 according to which the ratio of fixed capital to human capital K_t / H_t is expected to grow between 2020–2070, gradually reverting back towards its level in 1990.

In the baseline scenario, GDP will grow by 1.2% in the 2020s and 2030s. This growth rate is similar to the projected growth rates in the 2020s and 2030s obtained from the former long-term forecasting framework of the Bank of Finland and it represents our view for baseline potential GDP growth for the next two decades. From the 2040s onwards, however, growth slows down to only 0.5% per annum, reflecting the modest developments of both human and fixed capital. Labour productivity growth is slightly faster, 0.8 - 1.0% thanks to the increasing human capital to labour and fixed capital to labour ratios.

Our most optimistic growth scenario is grounded on the assumptions on labour-based immigration and increased education service volume per student. Fixed capital is now expexted to grow by 2.0% p.a. for the whole period of 2020–2070.

With this faster accumulation of both H_t and K_t, GDP growth in the 2020s and 2030s would be slightly higher (1.5 % and 1.4 %, respectively) than in the baseline. The boost to GDP growth would be slightly stronger than in the baseline from the 2040s onwards, but even in this most optimistic scenario, the growth rates of the Finnish economy would remain just over 1.0% after the 2030s. GDP per hours worked would, however, grow at a higher pace, i.e. 1.4% p.a. in 2020–2070. Compared with the baseline, the higher labour productivity growth is mainly a result from faster fixed capital to labour growth. Labour based immigration increases both human capital and labour, hence human capital to labour ratio grows roughly as in the baseline.

TABLE 5.1. Main results, total economy, forecast scenarios in 2020–2070

No policy change, low growth scenario	g(Y/L resid)	g(K/L)	g(L)	g(H/L)	g(Y/L)	g(Y resid)	g(H)	g(K)	g(Y)
2010-2019	-0.6 %	0.8 %	0.4 %	2.0 %	0.8 %	-0.6 %	2.3 %	1.2 %	1.1 %
2020-2029	-0.1 %	1.2 %	0.1 %	1.2 %	1.1 %	-0.1 %	1.3 %	1.3 %	1.2 %
2030-2039	0.0 %	0.7 %	-0.1 %	0.7 %	0.7 %	0.0 %	0.6 %	0.6 %	0.6 %
2040-2049	0.0 %	0.3 %	-0.3 %	0.4 %	0.3 %	0.0 %	0.0 %	0.0 %	0.0 %
2050-2059	0.0 %	0.4 %	-0.5 %	0.4 %	0.4 %	0.0 %	-0.2 %	-0.2 %	-0.2 %
2060-2070	0.0 %	0.3 %	-0.5 %	0.3 %	0.3 %	0.0 %	-0.3 %	-0.3 %	-0.3 %

Baseline, middle growth scenario	g(Y/L resid)	g(K/L)	g(L)	g(H/L)	g(Y/L)	g(Y resid)	g(H)	g(K)	g(Y)
2010-2019	-0.6 %	0.8 %	0.4 %	2.0 %	0.8 %	-0.6 %	2.3 %	1.2 %	1.1 %
2020-2029	-0.1 %	1.2 %	0.1 %	1.2 %	1.1 %	-0.1 %	1.3 %	1.3 %	1.2 %
2030-2039	0.0 %	1.8 %	-0.1 %	0.7 %	1.3 %	0.0 %	0.6 %	1.7 %	1.2 %
2040-2049	0.0 %	1.3 %	-0.3 %	0.4 %	0.8 %	0.0 %	0.1 %	0.9 %	0.5 %
2050-2059	0.0 %	1.4 %	-0.5 %	0.5 %	1.0 %	0.0 %	0.0 %	0.9 %	0.5 %
2060-2070	0.0 %	1.4 %	-0.5 %	0.5 %	1.0 %	0.0 %	0.0 %	0.9 %	0.5 %

High growth scenario	g(Y/L resid)	g(K/L)	g(L)	g(H/L)	g(Y/L)	g(Y resid)	g(H)	g(K)	g(Y)
2010-2019	-0.6 %	0.8 %	0.4 %	2.0 %	0.8 %	-0.6 %	2.3 %	1.2 %	1.1 %
2020-2029	-0.1 %	1.5 %	0.1 %	1.4 %	1.4 %	-0.1 %	1.6 %	1.6 %	1.5 %
2030-2039	0.0 %	2.0 %	0.0 %	0.8 %	1.4 %	0.0 %	0.8 %	2.0 %	1.4 %
2040-2049	0.0 %	2.2 %	-0.2 %	0.4 %	1.4 %	0.0 %	0.2 %	2.0 %	1.1 %
2050-2059	0.0 %	2.3 %	-0.3 %	0.4 %	1.4 %	0.0 %	0.1 %	2.0 %	1.1 %
2060-2070	0.0 %	2.3 %	-0.3 %	0.4 %	1.4 %	0.0 %	0.1 %	2.0 %	1.1 %

During most of the forecast period of 2020–2070, the development of the factors of production in the different parts of the economy is rather similar in all the three scenarios mostly since we assume that there are no initial differences in human capital between the private and public economy (see Tables A, B and C at the end of the text). There are, however, differences in the annual growth rates of fixed capital between the private and public economy in the middle and high growth scenarios due to the assumption that investment growth would be stronger in the private economy. This is particularly visible in the high growth scenario. These differences in annual growth rates of K_t accumulate to significant differences in the capital stock in the course of several decades.

In the General Government production, the labour input grows more rapidly, which directly reflects the increasing demand for labour particularly in elderly care and health services. In the private production, in turn, the total labour input is determined as a residual that is left after the labour needs of the public economy have been satisfied. Thus, economic growth in the private economy reflects the growth of labour productivity measured as the value added per labour input in private industrial classes. The difference in the structure of growth becomes pronounced particularly from the beginning of the 2040s onwards, when the labour input in the private production turns to a noticeable decline in all of our three scenarios, and the growth of production in private industrial classes becomes solely based on the growth of labour productivity.

The growth of human capital and fixed capital in proportion to the labour input enables the productivity growth in the private economy. While the differing development of $H_t \ / \ L_t$ reflects our technical assumption of initially similar human capital inputs in the private and public economy, it may well be that this relationship changes in the future.

Conclusions and discussion of growth-enhancing policies

The outlook for long-term growth in Finland is weak due to the forthcoming decline of human capital driven by demography and adverse education trends. This is the key result of the Bank of Finland's new long-term forecasting framework, where long-run growth is determined by the development of human capital and fixed capital. As a result of the shrinking skilled working age population, the projected decline in human capital is rather dramatic if no new growth-enhancing policies are implemented. Since the new generations, one after another, are projected to be smaller than the previous ones, a smaller number of educated people enter the labour force and the human capital stock than retires. The decrease in the volume of education expenditure in the 2010s and the decline in the average education level of the youngest cohorts entering the labour market further aggravate the situation. Therefore, taking human capital seriously in the new model, as suggested by empirical evidence on Finland's long-run growth, has revealed how weak the preconditions for sustained economic growth are in an ageing economy. An acceleration in the accumulation of fixed capital could compensate for the weak outlook for human capital accumulation but investments in fixed capital have remained modest in the past decades.

A no-policy-change scenario would result in economic growth coming to a halt in the 2040s and turning slightly negative thereafter. A question on its own is, whether with the current unfavourable development of the population structure, we should prepare for a situation where GDP would not necessarily grow anymore. After all, it is GDP per capita that determines the level of economic wellbeing in the long-term, and therefore policies should target the improvement of labour productivity Y/L which has historically been driving GDP per capita developments. From this point of view, it is not the labour input, L, as such but the average skills, or education level, embodied in the labour input, H/L, we should worry about. Even in the lowest growth scenario presented in this paper, GDP per labour input would still grow.

To avoid the decrease in human capital in the long term, policy focus has to be shifted to the skilled workforce. All new cohorts should be well-educated and the development seen in the 2010s, namely that the younger cohorts are less educated than the older ones, needs to be turned. The aim should be clearly higher growth rates of human capital per unit of labour input with policies that increase the number of students at the highest possible education level. While promoting the completion of education at all levels and thus increasing the number of qualifications is an important objective, priority should be given to increasing tertiary education since those qualifications add more to human capital than lower level qualifications. Naturally, the share of tertiary education in any age group cannot be increased infinitely but, in Finland, there is still plenty of room for improvement as indicated by its mediocre ranking among advanced economies in international comparisons. This requires an increase in the volume of education expenditure per student, but as the number of students inevitably decreases with the current population trends, the total volume of education expenditure does not necessarily need to increase.

Policies which increase the domestic skilled workforce are essential to implement but they might be difficult to design (fertility) or are effective only with a significant lag (education). Therefore, employment-related immigration of educated labour becomes important already in the short term. The scenarios presented in this paper reveal, however, that despite labour migration, GDP growth remains weak and, if the immigrants are not more educated than the existing workforce, labour productivity may not improve. Yet, labour migration improves the economic dependency ratio and therefore helps significantly in counteracting the deterioration of public finances brought about by the continuing shrinking of the domestic working age population.

Even with targeted policies to increase the skilled workforce, economic growth risks remain very weak if investments in fixed capital are not also increased. Unlike the development of human capital, the new forecasting framework introduced in this paper does not explicitly model how investments in fixed capital are generated in the economy, and, therefore, the forecast development of fixed capital relies on simple assumptions about its relation with human capital or on past average growth rate. While when forecasting human capital we can rely on population forecasts and recent trends in education, there is a lot more uncertainty related to the projected development of fixed capital. We emphasize in this paper that R&D and the results of R&D – produced at home or abroad – are included in fixed capital in the new National Accounts data. For a small open economy like Finland, it is of huge importance to implement new fixed capital products by importing them in addition to innovating and producing a smaller part of them domestically.

In addition to being an input in production, human capital is described, in modern growth theories, to enhance economic growth by enabling domestic innovations and technological progress but also by enabling the transfer of new technology from abroad and implementing it in production at home. This means that the two key factors of labour productivity, the fixed capital to labour ratio and the human capital to labour ratio, may be even more closely related than implied by the current production function in the new forecasting framework. If human capital would decline after the 2040s as in the lowest growth scenario presented in this paper, this could, therefore, also decelerate the implementation of new fixed capital products in Finland. Higher human capital would, in contrast, allow for a faster implementation of new technology products from abroad and innovating them at home. Possible modifications to the model to account for this relation are left for further work.

Growing demand for age-related public services puts great pressure on the sustainability of public finances. In addition, as the total labour input in the private production is determined as a residual that is left after the labour needs of the public economy have been satisfied, the growing demand for labour input in public services erodes the growth potential of the private production. The problem could be alleviated by measures to increase the historically low productivity in the age-related services. Thus, more investment in both human and fixed capital will also be needed in the public production of the economy.

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Table A. Scenario with no policy changes, low growth scenario.

Total economy	g(Y/L resid)	g(K/L)	g(L)	g(H/L)	g(Y/L)		g(Y resid)	g(H)	g(K)	g(Y)
2010-2019	-0.6 %	0.8 %	0.4 %	2.0 %	0.8 %		-0.6 %	2.3 %	1.2 %	1.1 %
2020-2029	-0.1 %	1.2 %	0.1 %	1.2 %	1.1 %		-0.1 %	1.3 %	1.3 %	1.2 %
2030-2039	0.0 %	0.7 %	-0.1 %	0.7 %	0.7 %		0.0 %	0.6 %	0.6 %	0.6 %
2040-2049	0.0 %	0.3 %	-0.3 %	0.4 %	0.3 %		0.0 %	0.0 %	0.0 %	0.0 %
2050-2059	0.0 %	0.4 %	-0.5 %	0.4 %	0.4 %		0.0 %	-0.2 %	-0.2 %	-0.2 %
2060-2070	0.0 %	0.3 %	-0.5 %	0.3 %	0.3 %		0.0 %	-0.3 %	-0.3 %	-0.3 %
S1 Private Sector										
2010-2019	-0.2 %	0.7 %	0.4 %	1.9 %	1.1 %		-0.2 %	2.3 %	1.1 %	1.4 %
2020-2029	-0.1 %	1.4 %	-0.1 %	1.4 %	1.3 %		-0.1 %	1.3 %	1.3 %	1.3 %
2030-2039	0.0 %	0.8 %	-0.2 %	0.9 %	0.8 %		0.0 %	0.6 %	0.6 %	0.7 %
2040-2049	0.0 %	0.6 %	-0.6 %	0.6 %	0.6 %		0.0 %	0.0 %	0.0 %	0.0 %
2050-2059	0.0 %	0.7 %	-0.9 %	0.7 %	0.7 %		0.0 %	-0.2 %	-0.2 %	-0.2 %
2060-2070	0.0 %	0.7 %	-1.0 %	0.7 %	0.7 %		0.0 %	-0.3 %	-0.3 %	-0.3 %
S13 General Gov.										
2010-2019	-2.1 %	1.2 %	0.2 %	2.1 %	-0.5 %		-2.1 %	2.3 %	1.4 %	-0.3 %
2020-2029	-0.1 %	0.6 %	0.6 %	0.7 %	0.5 %		-0.1 %	1.3 %	1.2 %	1.2 %
2030-2039	0.0 %	0.3 %	0.4 %	0.3 %	0.3 %		0.0 %	0.7 %	0.6 %	0.7 %
2040-2049	0.0 %	-0.4 %	0.4 %	-0.3 %	-0.4 %		0.0 %	0.0 %	0.0 %	0.0 %
2050-2059	0.0 %	-0.6 %	0.4 %	-0.6 %	-0.6 %		0.0 %	-0.2 %	-0.2 %	-0.2 %
2060-2070	0.0 %	-0.8 %	0.5 %	-0.7 %	-0.7 %		0.0 %	-0.3 %	-0.3 %	-0.3 %

Table B. Baseline, middle growth scenario.

Total economy	g(Y/L resid)	g(K/L)	g(L)	g(H/L)	g(Y/L)		g(Y resid)	g(H)	g(K)	g(Y)
2010-2019	-0.6 %	0.8 %	0.4 %	2.0 %	0.8 %		-0.6 %	2.3 %	1.2 %	1.1 %
2020-2029	-0.1 %	1.2 %	0.1 %	1.2 %	1.1 %		-0.1 %	1.3 %	1.3 %	1.2 %
2030-2039	0.0 %	1.8 %	-0.1 %	0.7 %	1.3 %		0.0 %	0.6 %	1.7 %	1.2 %
2040-2049	0.0 %	1.3 %	-0.3 %	0.4 %	0.8 %		0.0 %	0.1 %	0.9 %	0.5 %
2050-2059	0.0 %	1.4 %	-0.5 %	0.5 %	1.0 %		0.0 %	0.0 %	0.9 %	0.5 %
2060-2070	0.0 %	1.4 %	-0.5 %	0.5 %	1.0 %		0.0 %	0.0 %	0.9 %	0.5 %
S1 Private Sector										
2010-2019	-0.2 %	0.7 %	0.4 %	1.9 %	1.1 %		-0.2 %	2.3 %	1.1 %	1.4 %
2020-2029	-0.1 %	1.4 %	-0.1 %	1.4 %	1.3 %		-0.1 %	1.3 %	1.3 %	1.2 %
2030-2039	0.0 %	1.8 %	-0.2 %	0.9 %	1.4 %		0.0 %	0.6 %	1.7 %	1.3 %
2040-2049	0.0 %	1.5 %	-0.6 %	0.6 %	1.1 %		0.0 %	0.1 %	0.9 %	0.5 %
2050-2059	0.0 %	1.8 %	-0.9 %	0.9 %	1.4 %		0.0 %	0.0 %	0.9 %	0.5 %
2060-2070	0.0 %	1.9 %	-1.0 %	1.0 %	1.5 %		0.0 %	0.0 %	0.9 %	0.5 %
S13 General Gov.										
2010-2019	-2.1 %	1.2 %	0.2 %	2.1 %	-0.5 %		-2.1 %	2.3 %	1.4 %	-0.3 %
2020-2029	-0.1 %	0.6 %	0.6 %	0.7 %	0.5 %		-0.1 %	1.3 %	1.2 %	1.1 %
2030-2039	0.0 %	1.3 %	0.4 %	0.3 %	0.8 %		0.0 %	0.7 %	1.7 %	1.2 %
2040-2049	0.0 %	0.5 %	0.4 %	-0.3 %	0.1 %		0.0 %	0.1 %	0.9 %	0.5 %
2050-2059	0.0 %	0.5 %	0.4 %	-0.4 %	0.0 %		0.0 %	0.0 %	0.9 %	0.5 %
2060-2070	0.0 %	0.4 %	0.5 %	-0.4 %	0.0 %		0.0 %	0.0 %	0.9 %	0.5 %

Table C. High growth scenario.

Total economy	g(Y/L resid)	g(K/L)	g(L)	g(H/L)	g(Y/L)	g(Y resid)	g(H)	g(K)	g(Y)
2010-2019	-0.6 %	0.8 %	0.4 %	2.0 %	0.8 %	-0.6 %	2.3 %	1.2 %	1.1 %
2020-2029	-0.1 %	1.5 %	0.1 %	1.4 %	1.4 %	-0.1 %	1.6 %	1.6 %	1.5 %
2030-2039	0.0 %	2.0 %	0.0 %	0.8 %	1.4 %	0.0 %	0.8 %	2.0 %	1.4 %
2040-2049	0.0 %	2.2 %	-0.2 %	0.4 %	1.4 %	0.0 %	0.2 %	2.0 %	1.1 %
2050-2059	0.0 %	2.3 %	-0.3 %	0.4 %	1.4 %	0.0 %	0.1 %	2.0 %	1.1 %
2060-2070	0.0 %	2.3 %	-0.3 %	0.4 %	1.4 %	0.0 %	0.1 %	2.0 %	1.1 %
S1 Private Sector									
2010-2019	-0.2 %	0.7 %	0.4 %	1.9 %	1.1 %	-0.2 %	2.3 %	1.1 %	1.4 %
2020-2029	-0.1 %	1.6 %	0.0 %	1.6 %	1.5 %	-0.1 %	1.6 %	1.6 %	1.5 %
2030-2039	0.0 %	2.1 %	-0.1 %	1.0 %	1.5 %	0.0 %	0.8 %	2.0 %	1.5 %
2040-2049	0.0 %	2.4 %	-0.4 %	0.6 %	1.6 %	0.0 %	0.2 %	2.0 %	1.2 %
2050-2059	0.0 %	2.5 %	-0.5 %	0.7 %	1.7 %	0.0 %	0.1 %	2.0 %	1.1 %
2060-2070	0.0 %	2.6 %	-0.6 %	0.7 %	1.7 %	0.0 %	0.1 %	2.0 %	1.1 %
S13 General Gov.									
2010-2019	-2.1 %	1.2 %	0.2 %	2.1 %	-0.5 %	-2.1 %	2.3 %	1.4 %	-0.3 %
2020-2029	-0.1 %	1.1 %	0.6 %	0.9 %	0.9 %	-0.1 %	1.6 %	1.8 %	1.6 %
2030-2039	0.0 %	1.5 %	0.4 %	0.5 %	1.0 %	0.0 %	0.8 %	1.8 %	1.4 %
2040-2049	0.0 %	1.5 %	0.4 %	-0.2 %	0.7 %	0.0 %	0.2 %	1.8 %	1.1 %
2050-2059	0.0 %	1.4 %	0.4 %	-0.3 %	0.6 %	0.0 %	0.1 %	1.8 %	1.0 %
2060-2070	0.0 %	1.4 %	0.5 %	-0.3 %	0.6 %	0.0 %	0.1 %	1.8 %	1.0 %

Annex 1. Assessing Human capital by schooling in the National Accounts frame[29]

Human capital is currently not treated as an asset inside the asset boundary of the core system of National Accounts, SNA 2008.[30] Excluding human capital from the core of the SNA is not an accident but a logical consequence of the definitions of production and assets in this system.

At the same time in the real world, hours worked include the knowledge and skills acquired by the individuals in the labour force with the help of education when producing the standard GDP. Wages and salaries are gradually less and less paid on the basis of physical hours worked, and more on the basis of the skills and knowledge embodied in the employee. This is not reflected in the standard National Accounts figures at the moment.

In the SNA, non-financial assets are either produced assets or non-produced assets. As Aulin-Ahmavaara (2002, 2004) has emphasized in her comprehensive work on human capital, learning new skills and knowledge requires inputs. Therefore, if we want to see human capital as an asset similarly to fixed capital, it has to be produced (Aulin-Ahmavaara, 2002, p. 3). Hence, including human capital inside the National Accounts necessitates moving its production inside the production system where output (including produced assets, e.g. fixed capital) is produced.

The production system in the SNA is described with six equations following Aulin-Ahmavaara's (2002) representation

1. O + M = U + C + G + I + X
2. GDP = O − U = C + G + I + X – M
3. O = U +W + R
4. GDP = O − U = W + R
5. $\frac{dK}{dt} = I_t - \delta K_t$
6. $L = \overline{L}$

Where

O = gross output,
M = imports
U = intermediate uses / intermediate inputs
C = final consumption expenditure
G = general government final consumption expenditure
X = exports
W = labour compensation
R = operating surplus (or mixed income)
L = labour input

[29] For a more thorough presentation for the compilation of the human capital variable, see Kokkinen (2012).
[30] It is stated in the SNA 2008 (par 3.48) that "Human capital is not treated by the SNA as an asset. It is difficult to envisage "ownership rights" in connection with people, and even if this were sidestepped, the question of valuation is not very tractable". SNA 2008 proposes human capital to be handled in an additional voluntary satellite account outside the core system. Agreement has not been reached on how to incorporate human capital in the core accounts.

I_K = gross fixed capital formation
K = stock of fixed capital
δ_K = rate of depreciation of fixed capital

Equation (1) defines the supply and demand in the economy within a time unit: Output (O) is the value of produced goods and services at home, including goods and services used for own fixed capital formation and changes in inventories (for unfinished, or finished but not yet sold, goods and services). Imports (M) include the value of goods and services imported to the country. The use (or demand) of these products is on the right hand side of this equation: These products can be used as intermediate inputs (U) or in the formation of gross fixed capital (I_K) which also includes changes in inventories and own fixed capital formation[31]. A good part of them is used as private final consumption (C) or general government final consumption (G), or exported (X).

As already mentioned, changes in inventories and goods and services used for own gross fixed capital formation are included in the output. Aulin-Ahmavaara (2002) notes that this means that goods and services that are used outside the time unit during which they are produced are also included in the output. This will be relevant for human capital formation. All the variables are expressed in monetary terms, here in fixed prices or volumes, meaning that the price changes from the previous year have been deflated out. The second equation shows how GDP (or value added) can be calculated through output minus intermediate inputs or through net-demand, i.e. C+G + I + (X-M).

The third equation emphasises that the value of output can also be calculated through the incomes generated in the production process, namely through intermediate inputs (U) plus the compensations for labour (W) and capital (R, operating surplus of producers). As a consequence, the same GDP as in equation 2 can alternatively be calculated as the sum of the compensation for labour and the compensation for capital as shown in the equation (4). The fifth equation describes the accumulation of gross fixed capital: investments in fixed capital increase the accumulated stock and the depreciation decreases the value of the stock. The labour input is treated as an exogenous variable as households decide whether they are available in the labour market and how much they are willing to work (equation 6).

The second set of equations below presents the modifications done by Kokkinen (2012) to include human capital by schooling in the production system and in the produced assets of National Accounts. In equation 1, the education expenditures of the publicly produced education services are deducted from the general government final consumption expenditures and reclassified as intermediate inputs (education services are used in the learning process of students). The new skills embodied in the students within a year are treated as produced

[31] Own capital formation refers to a situation, where e.g. a car producer takes a car for its own use in addition to selling cars to other companies and households.

human capital by schooling (O_H), which is valued through expenses in education (in real terms). On the demand side, each year a student continues in schooling, the amount of produced human capital by schooling is recorded in gross human capital formation (I_H) in the form of change in inventories in own capital formation.

The intermediate inputs, the new produced human capital and the gross human capital formation (so far in the form of change in inventories in own capital formation) all equal the value of education expenditures. This means that the accounts are balanced and GDP does not change in equations 2 and 4. It is worth noticing that in equations 3 and 4 the compensation for labour (W) includes compensation for skills and knowledge by education used in the production. Following the seminal work by John Kendrick (1976), the depreciation of human capital by schooling of the labour force is assumed to be included in their wages and salaries as part of the compensation for the skills accumulated and used on the labour market.

Modified production system including human capital by schooling (Kokkinen 2012)

1. *[O+**O_H**] + M = [U **+ education expenditure**] + C + [G **- education expenditure**] + [I_K **+ I_H**] + X*
2. *GDP = [O+**O_H**] - [U **+ education expenditure**] =C +[G **- education expenditure**] + [I_K **+ I_H**] + X - M*
3. *[O **+ O_H**] = [U **+ education expenditure**] + W + R*
4. *GDP = [O **+ O_H**] - [U **+ education expenditure**] = W + R*

5a $\frac{dK}{dt} = I_{Kt} - \delta_K K_t$ 5b $\frac{dH}{dt} = I_{Ht} - \delta_H H_t$

6. $L = \overline{L}$

Where
I_H = gross human capital formation
δ_H = rate of depreciation of human capital
H = stock of intangible human capital stock by schooling

Both in Aulin-Ahmavaara's original representation and in the above goods and services used for own gross capital formation and change in inventories are included in the output. The gross capital formation for both types of capital contains the change in inventories and own capital formation. The equations are simplified in the sense that taxes and subsidies are ignored and a simple geometric rate of depreciation is assumed.

When a student has graduated from his/her highest education and enters the labour force, all the produced human capital up to that date will be moved from the intermediate inventories to (actual) investments in gross human capital formation (I_H). At that time, the stock of intangible human capital by schooling is accumulated with the perpetual inventory method by that investment, i.e. by the amount of all accumulated education expenditures the student has used up to that date (I_{Ht} , in equation 5b). Therefore, the long graduation times in education are taken into account in accumulating the stock of human capital by schooling. The entire stock of human capital reflects people of different working ages with different education acquired at different times. It takes into account the volume of the resources used to educating each student cohort with different educational paths until they have graduated from their highest education.

The productive stock of intangible human capital by schooling decreases according to its rate of depreciation, calculated separately in basic, upper secondary, professional, polytechnic and university education in accordance with the average service lives, i.e. the period which they are available for use on the labour market. The stock of human capital was adjusted by those deceased in wars and by net migration for 1910–2000 in Kokkinen (2012).[32] The whole human input in the modified system is equal to aggregate labour input times the average human capital by schooling in proportion to the labour input $(\frac{H_t}{L_t} * L_t)$.

[32] It is worth mentioning that the educational system in Finland up to the present day has been by far mostly financed by the general government. Therefore, the minute part of privately financed education has been neglected in estimating the evolution in education expenditures backwards until 1877. In the countries with a private educational system, education expenditures in private final consumption would, of course, be used as investments.

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