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EDUCATION AND ECONOMIC GROWTH IN SLOVENIA: A DYNAMIC GENERAL EQUILIBRIUM APPROACH WITH ENDOGENOUS GROWTH

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Abstract

In the article we model education and human capital as major endogenous growth elements in a small open economy general equilibrium framework and consider several policy scenarios for Slovenia. Decrease of the PIT rate and increase of government spending on education turned out to be the most effective policy measures. It is important, though, to understand its transitory dynamic. Namely, as education expenditure is increased, certain amount of labour is temporarily withdrawn from its productive use and put into the educational system. Higher skill upgrade of labour requires longer and higher short-term labour force decrease, but also provides us with higher long-term growth. The households that would gain more utility from such policy scenarios are those with more skilled labour and thus higher income level.

JEL classification: C68, D58, E24, H52.

Keywords: education, endogenous growth, general equilibrium modelling, Slovenia.

1. Introduction

The topic of economic growth is among the most essential issues in macroeconomics, as it directly affects the living standard of the population and the welfare level. As a result, the search for fundamental determinants behind the growth process is an ongoing research theme. There are broadly speaking two dominant theories; the neoclassical growth approach and the endogenous growth approach (*cf*. Barro and Sala-i-Martin, 2003). Neoclassical growth models assume that productivity growth is exogenous. This view has changed in the early 1980s. According to the new growth theory, the long-run economic growth is affected by deliberate economic behaviour and human actions.

Economists agree that the long-run growth potential in *per capita* growth is determined by advances in productivity. Production can to certain extent be expanded extensively through investment in factor inputs and through employment growth, but in the long run intensive improvements in productivity are required. By working in a more efficient way, more can be produced with given factor inputs. The major determinants of the productivity growth are investments in education and thus human capital, and in research and development (R&D). Along these lines, the theory of economic growth turned into the theory of productivity growth.

While these ideas have been tested in a number of empirical studies, they are struggling to find their way into general equilibrium modelling, which has led to a good deal of criticism. As Ghiglino (2002) pointed out, endogenous growth theory has had some success in explaining the observed data related to the process of economic growth, but the results of the models are typically very sensitive to their microeconomic structure. Therefore, valuable insights can be gained by integrating endogenous growth theory into the framework of general equilibrium theory. The motivation behind our work is to construct and develop a dynamic general equilibrium model with endogenous growth, driven by investment in education and R&D, which will enable us to analyze the impact of these determinants on economic growth in the context of complex mutual activity of economic agents that is taking place in their socio-economic environment. Our contribution to the existing model literature is a focus on a small open economy case of Slovenia, where a large part of the technological change comes from abroad. In this article, we focus on integrating education and human capital as major endogenous growth elements into an inter-temporal general equilibrium framework for Slovenia.

Human capital can be introduced as an additional factor in production primarily contributing either to equilibrium in production levels in a neo-classical growth framework or – as is the case in the present article – to a balanced growth rate in an endogenous growth framework. It can also play a productive role in terms of the absorption capacity to assimilate new technologies. Growth figures indicate that an increase in the average education level of the population by a single year increases the long run per capita output by 6-8 per cent (Dowrick, 2003; Canton *et al*., 2005; Canton, 2007). If education is subject to decreasing returns to scale, the impact on per capita output might be smaller in countries with high

education levels. However, these relationships should also be dependent on the quality of institutions and its regulation (*cf*. Klun and Slabe-Erker, 2009). Nonetheless, while increases in human capital, R&D, and product market competition can improve macroeconomic performance, it takes time before these benefits are realised.

From another perspective, educational attainment is also regarded as one of the key factors influencing the distribution of income across both households and labour categories (*cf*. Yeldan and Voyvoda, 2000). On the one hand, educational attainment and individual's stock of human capital formation enable its owner to obtain better-paying jobs, more bargaining power and flexibility in the job market. On the other hand, initial distribution of wealth and household income have direct impacts on the family's capacity to invest in its offspring's human capital formation, as most of the investments in education are made when agents are young. Under these conditions, provision of public funds to education and the government's ability to invest in education and human capital formation play a crucial role in both attaining greater equality and in promoting growth. Such observations bring issues of human capital formation and optimal design of public policies in terms of investment in education, fiscal debt management and the inter-household and inter-generational burden of taxation into forefront of analysis.

The outline of the article is as follows. In Chapter 2 a current literature overview on education-driven endogenous growth models is presented. In Chapter 3 a broad description of the general equilibrium model of the Slovenian economy is provided, while in Chapter 4 we show in detail how education and human capital are modelled in a dynamic general equilibrium framework. In Chapter 5 the scenarios are described and the results of simulations are presented, where we focus in particular on macroeconomic and welfare aspects. In the final chapter we summarize the main findings of the article.

2. Literature Overview on Education-driven Endogenous Growth Models

The endogenous growth literature captures the insight that the crucial force behind positive growth rates is the elimination of the tendency of diminishing returns to investment in a broad class of capital goods, including human capital. Antecedents of this literature utilize theories of technological progress, innovation and imitation (Romer, 1987; Grossman and Helpman, 1991), learning by doing (Stokey, 1991), and population change, fertility and human capital investment (Becker and Barro, 1988) in order to introduce increasing or constant returns to scale to the cumulative factor of production. Recent advances in the new growth theory identify, among many others, the degree of educational attainment as a crucial determinant of the long-run rate of economic growth (*cf*. Gallipoli *et al*., 2006; Canton, 2007).

Following the lines of Uzawa (1965) and Lucas (1988), many theories have been developed to explain the process of human capital accumulation via investment in education, both public and private. In Uzawa (1965), an individual's productivity depends on how much time she devotes to education. In Lucas (1988), human capital is the engine of growth and is produced by a technology where the only input is human capital itself. Rebelo (1991)

extended this model to add physical capital in the production of human capital. Becker *et al*. (1990) presented a model where human capital is accumulated through parent's home teaching. Romer (1989) and Barro (1991) documented the importance of human capital in the context of conditional convergence and persistent economic growth. Borjas (1992) presented empirical evidence for human capital externalities by showing that the average level of human capital of the previous generations positively affected the current generation's productivity level.

Such developments in endogenous growth theory have opened a new avenue of research to study the influence of government spending on both consumption-saving decisions and, through the education system, on human capital accumulation itself. King and Rebelo (1990), Lucas (1990), Rebelo (1991) and Jones *et al*. (1993) are among the studies of endogenous growth that analyze the consequences of distortionary taxation. While the studies mentioned above employ an infinite-horizon framework, Blanchard (1985) carried the argument of debt management into finite horizons and decisively influenced the stream of general-equilibrium modelling.

Ni and Wang (1994) and Glomm and Ravikumar (1997), both under the assumption of finite lifetimes, let public spending on education directly enter the production function of human capital. Ni and Wang (1994) adopted the theoretical framework of Becker and Barro (1988) and Becker *et al*. (1990), and examined the role of public expenditures on human capital formation. Glomm and Ravikumar (1997), in turn, focused on the growth effects of productive government spending and growth-maximizing level of taxation in a dynamic general equilibrium model.

Azariadis and Drazen (1990) worked in a standard overlapping-generations (OLG) framework, where they modelled identical individuals that make decisions about their schooling. Davies and Whalley (1991) explored how explicit incorporation of human capital affects dynamic general equilibrium analysis of the effects of taxes on capital formation and welfare in a life-cycle growth model. Jones and Manuelli (1992) highlighted the role of government as an income redistributor in an OLG framework that allows for persistent growth. Likewise, Buiter and Kletzer (1991; 1995) used OLG models to present the theoretical analysis of fiscal policies.

Heckman *et al*. (1998; 1999) utilized a dynamic general equilibrium model with heterogeneous agents, where they introduced skill formation and considered both the choice of educational level and the investment in on-the-job training. Their framework extends the analysis of Davies and Whalley (1991), who introduced human capital into the Auerbach-Kotlikoff (1987) model, but assumed only one skill. Bräuninger and Vidal (2000) examined interactions between education policy and growth by an OLG model with two types of individuals – skilled and unskilled. Yeldan and Voyvoda (2000) utilized an OLG model of endogenous growth and investigated the fiscal alternatives of financing public education in a debt constrained economy framework.

Creedy and Gemmell (2005) utilized an endogenous growth model to examine the growth effects of human capital investment achieved through publicly provided, compulsory education. Lee (2005) developed an OLG model of career decisions, where an individual

chooses between working in a white-collar occupation, working in a blue-collar occupation, attending school or remaining at home. Gallipoli *et al*. (2006) examined the effects of alternative policies on the distribution of education in a general equilibrium. They built a life-cycle model with endogenous labour supply and education choices, allowing for agents' heterogeneity in several dimensions, and for incomplete insurance markets. Sequeira and Martins (2008) used an endogenous growth model with human capital and unemployment, based on Mauro and Carmeci (2003), in order to study the effects of subsidies to education on economic growth.

3. Description of the General Equilibrium Model of the Slovenian Economy

The model SIDYN 2.0 is a dynamic endogenous-growth general equilibrium model of the Slovenian economy, based on social accounting matrix (SAM) for the base year, and parameter data on consumer preferences, production technologies, accumulation of human capital and composition of total factor productivity (Verbič *et al*., 2009).

The model incorporates the following economic agents: (1) five households grouped into quintiles according to income level; (2) twenty production sectors of both goods and services; (3) investment sector; (4) national government; and (5) external sector. Each agent in the economy supplies and demands a range of goods, services and factors of production at prices defined by equilibrium on the corresponding markets. There are six types of production factors in the model; country-level human capital differentiated by three skill (education) levels, sector-specific physical capital, sector-specific R&D stock, and sector-specific human capital stock. The output level of the aggregated commodity of each of the twenty sectors is determined by an optimal combination of these production factors.

Both households and firms make their decisions under the assumption of an infinite horizon with perfect foresight (rational forward-looking expectations). All prices in the model are relative prices, which is the usual assumption of general equilibrium modelling. The inter-temporal problem is formulated in discrete time for the purpose of numerical implementation. To keep the derivation and calibration simple, all transactions are assumed to take place at the end of each period, while decisions are made or planned at the beginning of each period.

Households maximize their inter-temporal utility given the budget constraint. They decide how much time and money to invest into a particular type of human capital at each period of time. The consumers' decisions associated with spending of their money and time are independent of each other. The use of money positively influences consumer utility via an increase in consumption, whereas the use of time for education and work exerts a negative influence upon the consumers' utility level. Households do not invest in the sector-specific stocks. The human capital stock owned by the households is freely traded on the labour market and is mobile between the sectors. Sector-specific human capital is not mobile between the sectors and thus not traded. Different income categories in the economy correspond to different consumption patterns and governmental transfers.

The firms choose investments into their physical capital, human capital and R&D stocks, as well as labour inputs such as to maximize its present discounted value, i.e. the present value of all dividend payments. Investments made by the firms are financed using the total savings available in the economy. The stocks of sector-specific capital are accumulated over time via the new investments made by firms and the government. Gross prices for final goods are calculated as the sum of the producer price, transport and trade margins and various taxes and subsidies, where the transport and trade margins are the spending on transport and trade services, consumed in a certain proportion to the commodity itself.

Investments into physical capital are financed by the national investment agent with total savings and are used to buy different capital goods. The split of the total physical capital investment between the particular types of capital goods, such as machinery and buildings, is done so as to maximise the utility of the investment agent, which decides on how much of various capital goods are to be bought.

Economic growth is endogenously determined in the model by the development of households' human capital stock, stock of sector-specific human capital and R&D, used as factors of production by the firms, as well as the development over time of the overall total factor productivity (TFP). Sector-specific R&D investments have country-level spillover effects via an increase of TFP for all sectors. The country-level TFP depends positively both upon the total output of the R&D sector and the openness of the economy, represented by the share of foreign trade in the GDP.

The public sector is represented by a national-level government, which collects a range of taxes, receives its share of dividends, and pays subsidies and transfers to households and firms, as well as transfers abroad. The revenues of the government consist of receipts from personal income tax, corporate income tax, VAT, payroll tax, social contributions, and import tariffs. The government subsidies support investment, production, intermediate consumption, household consumption, and exporting. The government also consumes a range of goods and services, and makes investments in national-level human capital and sector-specific R&D stocks.

The external sector incorporates the representation of exports and imports, as well as annual labour inflows from EU15, new member states and the rest of the world. Modelling of the external sector is based on the assumption of a small open economy, meaning that the prices of exports and imports are exogenously fixed in the model. Exports and imports are defined by Slovenian output and income levels, as well as by the ratio between the prices of domestic and exported goods and services, and elasticities of substitution between domestic and foreign goods. Inflows of labour to Slovenia are defined by the changes in domestic real after-tax wages and the elasticity of the labour supply, which is assumed to be higher for the rest of the world than for the EU15 and the new member states.

The model is build within the general algebraic modelling system (GAMS), which has become both most widely used programming language and most widespread computer software for construction and solving large and complex general equilibrium models. Within the GAMS framework, the dynamic general equilibrium model is written in Mathiesen's (1985) formulation of the Arrow-Debreu (1954) equilibrium model, i.e. as a mixed

complementarity problem (MCP). The key advantage of this formulation is the compact presentation of the general equilibrium problem, which is achieved by treating variables implicitly and thus significantly reducing the computation time for higher-dimensional problems. To solve the model, i.e. to achieve convergence, a recent version of the PATH solver (Ferris and Munson, 2000) is used, which is renowned for its computational efficiency.

In contrast to simpler models, such a large-scale model enables one to consider simultaneous changes in a variety of policy instruments and provides ways to understand short-to-medium run responses by making it possible to observe the transition paths of the modelled economy from one steady state to possible-other. With assumptions of longer time-spans on the part of each agent, such a model provides a more realistic setup that points to the income distribution effects of permanent policy changes.

4. Modelling Education and Human Capital in a Dynamic CGE Framework

The inter-temporal utility function of the household, U, is assumed to be time-separable and time-additive. Given that the model has a finite simulation time horizon, $\{1, \ldots, T\}$, where T is the last simulated time period[1], we obtain the following utility function:

$$U = \sum_{t=1}^{T-1} \frac{(1+g)^{t-1}}{(1+\rho)^{t}} U_t + \frac{1}{\rho - g}\left(\frac{1+g}{1+\rho}\right)^{T-1} U_T , \qquad (1)$$

where ρ is the time preference rate; g is the steady state growth rate; and U_t is the temporal utility function defined in the following way:

$$U_t = CBUD_t - \sum_{ts} BH_{ts} LSH_{ts,t} \left(SHL_{ts,t} + SHE_{ts,t}\right)^{\gamma} , \qquad (2)$$

where $CBUD_t$ is the consumption budget of the household in period t; $1/(\gamma - 1)$ is the inter-temporal elasticity of substitution in labour supply[2]; BH_{ts} is the scale parameter of work disutility function; $LSH_{ts,t}$ is the stock of human capital (efficient labour units) of type ts owned by the household at time t; $SHL_{ts,t}$ is the share of human capital used for work; and $SHE_{ts,t}$ is the share of human capital used for studying. The right-hand-side expression $BH_{ts} LSH_{ts,t} \left(SHL_{ts,t} + SHE_{ts,t}\right)^{\gamma}$ represents the disutility of working or studying as opposed to having leisure time.

The total households' consumption budget at each period of time consists of the dividends received from all the sectors in the economy, wages received from the domestic

[1] After time period T it is assumed that the economy will be on the steady-state path where all real economic variables grow with the same annual rate until infinity.

[2] This inter-temporal elasticity represents the households' preferences for working more at present *vis-à-vis* working in the future.

economy and from abroad, (negative) personal income tax, unemployment benefits and other transfers received from the government, (negative) households' savings, and (negative) households' spending on education. Each period of time the household thus operates under the following budget constraint:

$$\begin{aligned} CBUD_t = \sum_{sec} DIV_{sec,t} + PLSK_{ts,t}\left(\sum_{ts} LSH_{ts,t}SHL_{ts,t} + LMEU25_{ts,t} + LMROW_{ts,t}\right) + \\ + shareLH_{ts}LROW_{ts,t}PLROW_{ts,t}ER_t + trepv_{ts,t}UNEMPH_{ts,t}PLSK_{ts,t} - \\ - tyv_t\left(1 - stEXv_t\right)PLSK_{ts,t}\sum_{ts}\left(LSH_{ts,t}SHL_{ts,t} + LMEU25_{ts,t} + LMROW_{ts,t}\right) - \\ - SH_t - P_{edus,t}\sum_{ts} EDU_{ts,t} + TRF_t DGDP_t, \end{aligned} \tag{3}$$

where $DIV_{sec,t}$ are the dividends paid by sector *sec* to the households; $PLSK_{ts,t}$ is the wage of labour of type *ts*; $LMEU25_{ts,t}$ is the flow of labour of type *ts* from EU25; $LMROW_{ts,t}$ is the flow of labour of type *ts* from the rest of the world (ROW); $shareLH_{ts}$ is the share of domestic labour of type *ts* supplied to the ROW, which belongs to the household; $LROW_{ts,t}$ is the labour of type *ts* supplied to the ROW; $PLROW_{ts,t}$ is the wage of labour supplied to the rest of the world; ER_t is the exchange rate; $trepv_{ts,t}$ is the replacement rate by type of labour; $UNEMPH_{ts,t}$ is unemployed labour by type *ts*; tyv_t is the household's personal income tax rate; $stEXv_t$ is the personal income tax standard relief; SH_t are the household's savings; $EDU_{ts,t}$ is the household demand for education services devoted to accumulation of human capital of type *ts*; $P_{edus,t}$ is the after-tax price of one unit of education services; TRF_t are the governmental transfers to the household; and $DGDP_t$ is the GDP deflator.

The stock of country-level human capital, $LSH_{ts,t}$, is an increasing function of last-period stock, investments in human capital by both government and households, and time, devoted by households to education. It therefore develops over time according to the following law of motion:

$$LSH_{ts,t} = AH_{ts}LSH_{ts,t-1}^{1-\delta h_{ts}}\left(EDU_{ts,t-k} + EDUG_{ts,t-k}\right)^{\delta h_{ts}} SHE_{ts,t-k}^{\mu h_{ts}}, \tag{4}$$

where the parameters AH_{ts}, δh_{ts} and μh_{ts} are non-negative technical parameters of the law of motion for the human capital accumulation; and $EDUG_{ts,t}$ is the government spending on education. The new stock is equal to the surviving stock and an amount of human capital generated during *k* periods of time in the past, i.e. the amount of time necessary for a person to obtain the corresponding skill level. Parameter δh_{ts} denotes the share of human capital that depreciates each period of time; when equal to one, the human capital fully depreciates during *k* time periods. The number of periods *k* depends upon the skill level of the type of human capital; the higher the skill level the more periods of time should pass until additional labour is added to the current labour stock.

By substituting the expression for human capital (4) in the household budget restriction (3) one gets the expression for the utility function of the representative household. In order to optimize the discounted utility function *U*, it is sufficient to choose the optimal bundle of households' decision variables, $\left\{SHL_{ts,t}, SHE_{ts,t}, EDU_{ts,t}\right\}$, such as to maximize the utility given the households' budget constraint.

Optimal bundle of the labour used for education and spending on education is thus given, after some simplification, by the respective first-order conditions:

$$\begin{aligned} BH_{ts} LSH_{ts,t} \gamma \left(SHL_{ts,t} + SHE_{ts,t}\right)^{\gamma-1} SHE_{ts,t} = \\ = \frac{1+g}{1+\rho} LSH_{ts,t+k} \mu h_{ts} SHL_{ts,t+k} PLSK_{ts,t+k} \left(1 - tyv_{t+k}\left(1 - stEXv_{t+k}\right)\right), \end{aligned} \tag{5}$$

$$P_{edus,t} EDU_{ts,t} = \frac{1+g}{1+\rho} LSH_{ts,t+k} \delta h_{ts} SHL_{ts,t+k} PLSK_{ts,t+k} \left(1 - tyv_{t+k}\left(1 - stEXv_{t+k}\right)\right). \tag{6}$$

It is evident from equations (5) and (6) that the optimal levels of time and monetary investment in education are chosen such that the benefits of investment are equal to its costs. The right-hand sides represent the benefits of time and money invested in education, i.e. the discounted after-tax wage of a particular type of labour multiplied by the amount of human capital, generated as the result of the investment, while the left-hand sides represent the costs of time (time disutility) and money (costs of educational services) invested in education, respectively. After the household decides upon the share of its labour endowment spent on work and education, the rest of labour endowment is labelled as leisure activities and represents in the model the level of voluntary unemployment in the economy.

The formulation of the model ensures that the share parameters δh_{ts} and μh_{ts} are less than one, as the following relationships hold:

$$SHE_{ts,0} < SHL_{ts,0}, \tag{7}$$

$$P_{edus,0} EDU_{ts,0} < LSH_{ts,0} SHL_{ts,0} PLSK_{ts,0} \left(1 - tyv_0\left(1 - stEXv_0\right)\right). \tag{8}$$

Relationships (7) and (8) mean that the share of human capital used on education is less the its share used on working, which is true for standard economies and that amount of money spent on education is less the amount of money earned by the household, which is also true, since household's consumption budget is assumed to be positive.

The firms, on the other hand, are faced with the inter-temporal profit maximization problem and with the formulation of their investment decisions, related to education and human capital (*cf*. Cassou and Lansing, 2004). In each period of time the firms produce one commodity by sector, using physical capital, labour, sector-specific human capital and sector-specific R&D stock as inputs. It is assumed that the firms operate under the following

constant returns to scale Cobb-Douglas technology function:

$$XD_{sec,t} = TFP_t aF_{sec} K_{sec,t}^{\alpha F_{sec}} L_{sec,t}^{\alpha FL_{sec}} HCS_{sec,t}^{\alpha FHC_{sec}} RDS_{sec,t}^{\alpha FRD_{sec}}, \quad (9)$$

where $XD_{sec,t}$ is the total output of the domestic sector *sec*; TFP_t is the total factor productivity level in the economy; aF_{sec} is the scale parameter of the Cobb-Douglas production function; $K_{sec,t}$ is the input of physical capital; $L_{sec,t}$ is the input of labour; $HCS_{sec,t}$ is the input of sector-specific human capital stock; $RDS_{sec,t}$ is the input of sector-specific R&D stock; αF_{sec} is the share parameter of the production function, associated with physical capital; αFL_{sec} is the share parameter of the production function, associated with labour; αFHC_{sec} is the share parameter of the production function, associated with human capital stock; and αFRD_{sec} is the share parameter of the production function, associated with R&D stock.

The stock of human capital, used as input by firms each period of time is determined according to the following law of motion:

$$HCS_{sec,t} = AHCS_{sec} HCS_{sec,t-1}^{1-\delta HCs_{sec}} HC_{sec,t-1}^{\delta HCs_{sec}}, \quad (10)$$

where $AHCS_{sec}$ is the scaling parameter of the human capital stock accumulation function; δHCs_{sec} is the share parameter of the human capital stock accumulation function, associated with the new human capital investment[3]; and $HC_{sec,t}$ are the education services, bought by the sector *sec* for investment in its human capital stock.

The firms choose investments in their physical capital, human capital and R&D knowledge stocks at each time period, as well as labour inputs such as to maximize the present discounted value of the firm. Investments made by the firms are financed using the total savings available in the economy, i.e. the savings of households, the government, retained profits of the firms and the savings from abroad. Investment level in human capital is thus chosen such that the firms' discounted profits resulting from these investments are equal to the costs of the investments:

$$\begin{aligned} & HC_{sec,t}\left(P_{edus,t} + tmicv_{edus,t} PTM_t\right)\Big[\left(1 - sicv_{edus,t} - tkv_{sec,t} shareHCv_t + \right. \\ & \left. + \left(1 - sicv_{edus,t}\right)\left(ticv_{edus,t} + vaticv_{edus,t} + exsticv_{edus,t}\right)\right)\Big] = \\ & = \frac{1}{1+r}\Big[\left(1 + spv_{sec,t+1} - (1 - spv_{sec,t+1}) txdv_{sec,t+1}\right) PD_{sec,t+1} XD_{sec,t+1} - \\ & - \sum_{secc \neq sechr}\Big[io_{secc,sec} XD_{sec,t+1}\left(P_{secc,t+1} + tmicv_{secc,t+1} PTM_{t+1}\right)\left(1 - sicv_{secc,t+1} + \right. \\ & \left. + \left(1 - sicv_{secc,t+1}\right)\left(ticv_{secc,t+1} + vaticv_{secc,t+1} + exsticv_{secc,t+1}\right)\right)\Big]\Big] \alpha FHC_{sec} \delta HCs_{sec}, \end{aligned} \quad (11)$$

[3] Note that the share parameters of the laws of motion, associated with new investments, are interpreted as depreciation rates for different types of capital used as input by the firms.

where *secc* is an alias of sector *sec*; *edus* is a subset of commodity types, consisting of education services; *sechr* is a subset of commodity types, consisting of education and R&D services; *r* is the steady-state interest rate; $spv_{sec,t}$ is the output subsidy rate; $txdv_{sec,t}$ is the output tax rate; $tkv_{sec,t}$ is the corporate income tax rate; PTM_t is the composite price of trade and transport margin; $PD_{sec,t}$ is the domestic producer price of composite output; $P_{sec,t}$ domestic sales price of commodity; $io_{secc,sec}$ is an input-output coefficient of commodity *secc* used for production in the sector *sec*; $tmicv_{secc,t}$ is the intermediate consumption trade and transport margin; $sicv_{secc,t}$ is the intermediate consumption subsidy rate; $ticv_{secc,t}$ is the intermediate consumption tax rate; $vaticv_{secc,t}$ is the intermediate consumption VAT rate; $exsticv_{secc,t}$ is the intermediate consumption excise tax rate; and $shareHCv_t$ is the share of sectoral investment in human capital stock, deductible from the corporate income tax.

Left hand side of expression (11) represents the total cost of the investment in the human capital, and is equal to the right hand side of the expression, which represents the additional discounted dividends of firms, resulting from the investment in the human capital. The value of additional dividends depends positively upon the Cobb-Douglas share of the human capital in the production function, $aFHC_{sec}$, and the Cobb-Douglas share, which represents the contribution of the new human capital investment to the total stock of sector-specific human capital, δHCs_{sec}.

In the government sector we model explicitly the tax revenues, the government subsidies and the government consumption of goods and services. The tax revenues of the government, associated with education and human capital, consist of the following expressions, respectively:

$$\left(1-scv_{edus,t}\right)\left[\left(tcv_{edus,t}+vatcv_{edus,t}\right)\left(1+exstv_{edus,t}\right)+exstv_{edus,t}\right]\cdot \cdot\left(P_{edus,t}+tmcv_{edus,t}PTM_t\right)\sum_{th}EDU_{th}, \tag{12}$$

$$\left(1-sicv_{edus,t}\right)\left(ticv_{edus,t}+vaticv_{edus,t}+exsticv_{edus,t}\right)\cdot \cdot\left(P_{edus,t}+tmicv_{edus,t}PTM_t\right)\sum_{secc}HC_{secc,t}, \tag{13}$$

where *th* represents the type of household; $scv_{sec,t}$ is the houshold consumption subsidy rate; $tcv_{sec,t}$ is the tax rate on consumption goods; $vatcv_{sec,t}$ is the VAT rate on consumption goods; $exstv_{sec,t}$ is the household consumption excise tax rate; and $tmcv_{sec,t}$ is the trade and transport margin on household consumption of commodity *sec*. The government subsidies, associated with household spending on education and firm spending on human capital have the

following form:

$$\begin{aligned}&\left(scv_{edus,t}+tyv_{th,t}shareEv_t\right)\left(P_{edus,t}+tmcv_{edus,t}PTM_t\right)\sum_{th,ts}EDU_{th,ts,t}+\\&+\left(sicv_{edus,t}+tkv_{sec,t}shareHCv_t\right)\left(P_{edus,t}+tmicv_{edus,t}PTM_t\right)\sum_{sec}HC_{sec,t},\end{aligned}\tag{14}$$

where $shareEv_t$ is the share of households' investment in education, deductible from the personal income tax.

Finally, the equilibrium in the market for education services is determined by the following condition:

$$\begin{aligned}&\sum_{th,ts}EDU_{th,ts,t}+\sum_{th,ts}EDUG_{th,ts,t}+I_{edus,t}+\sum_{secc\notin sechr}\left(io_{secc,sec}XD_{sec,t}\right)+\\&+\sum_{sec}HC_{sec,t}+SVX_{edus,t}+TMX_{edus,t}=X_{edus,t},\end{aligned}\tag{15}$$

where $I_{sec,t}$ is the private demand for investment goods of sector *sec*; $SVX_{sec,t}$ are the changes in stocks of sector *sec*; $TMX_{sec,t}$ is the consumption of sector *sec* for transport and trade margins; and $X_{sec,t}$ are domestic sales of the good of sector *sec* of domestic and foreign origin.

5. Results of the Simulations

The groundwork for our analysis is the dynamic calibration of the model and consequently preparation of the reference solution. In the framework of performing the dynamic calibration of the model SIDYN 2.0, we follow the strategy of using the model to generate the entire dynamic path of endogenous variables in order to accurately reproduce the values of every endogenous variable in the base year. In this way we obtain the reference scenario, which represents the authentic state of the economy. Analysis of the Slovenian economy, where we take into account possible developments with respect to the education and human capital policies, is then performed by forming counterfactual scenarios and comparing their outcomes to the results of the reference scenario. The counterfactual scenarios are based on varying the parameters of SIDYN 2.0, which are related to the modelling of education and human capital.

For the purpose of our analysis we distinguish between model parameters and policy parameters; the former are of technical nature and subject to sensitivity analysis, while the latter are of economic nature and subject to policy analysis. In this article we focus on the latter. Policy parameters, involved in modelling education and human capital decisions in a dynamic CGE framework, used in SIDYN 2.0, are the following: (1) the personal income tax (PIT) rate of household type *th*, $tyv_{th,t}$; (2) the share of households' investment in education that is deductible from the PIT, $shareEv_t$; (3) the corporate income tax (CIT) rate in sector

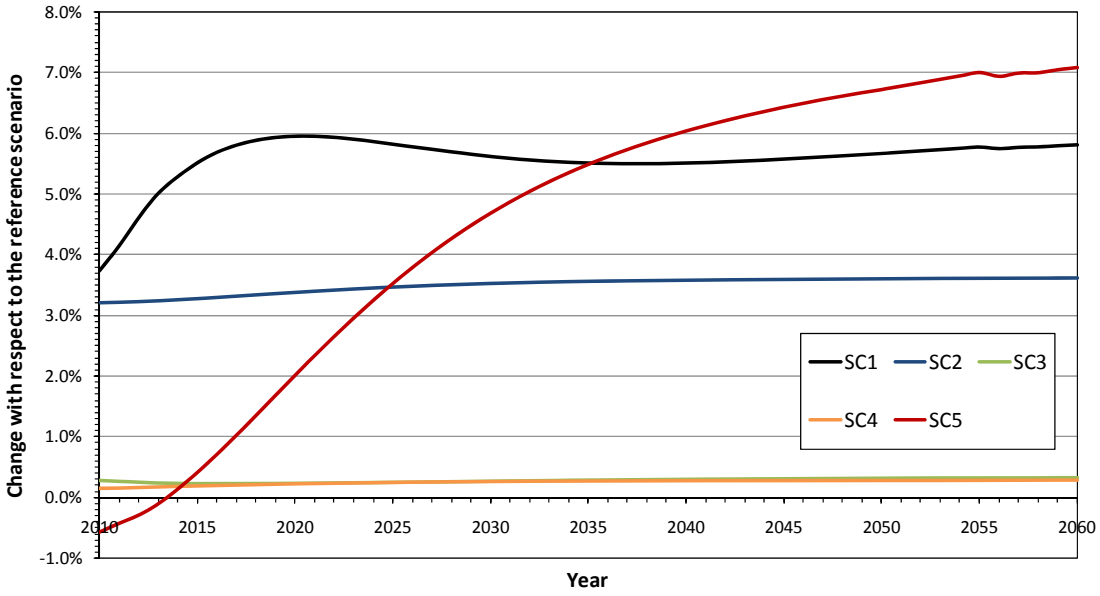
sec, $tkv_{sec,t}$; (4) the share of sectoral investment in human capital stock that is deductible from the CIT, $shareHCv_t$; and (5) government spending on education of human capital type *ts* of household type *th*, $EDUG_{th,ts,t}$. Description of the scenarios examined in this article is given in Table 1.

Table 1: Scenarios of the model for the analysis of impacts of education and human capital on economic growth

Scenario	Description of the scenario
SC1	Decrease of the personal income tax rate, $tyv_{th,t} = tyv_t$, by 10% from 2009
SC2	Increase of the share of households' investment in education that is deductible from the personal income tax, $shareEv_t$, by 25% from 2009
SC3	Decrease of the corporate income tax rate, $tkv_{sec,t} = tkv_t$, by 25% from 2009
SC4	Increase of the share of sectoral investment in human capital stock that is deductible from the corporate income tax, $shareHCv_t$, by 25% from 2009
SC5	Increase of government spending on education, $EDUG_{th,ts,t} = EDUG_t$, by 10% *per annum* from 2009

Let us first examine the effects of these policy scenarios on education expenditure in Slovenia. As can be seen from Figure 1, three scenarios (SC1, SC2 and SC5) have a significant effect on education expenditure of households, while the effect of the remaining two scenarios is negligible, as it does not provide enough incentive to change the behaviour of households. Decreasing the PIT rate by 10% (SC1) increases progressively the education expenditure of households in the first ten years with respect to the reference scenario and then stabilizes close to 6%. On the other hand, the effect of increasing the share of households' investment in education that is deductible from the PIT by 25% (SC2) is quite stable and amounts to 3.2-3.6% with respect to the reference scenario. The effect of increasing government spending on education by 10% *per annum* (SC5) on education expenditure of households has the most interesting dynamic. Namely, as can be seen from Figure 1, it is negative the first couple of years of implementation and then rises to 7.1%.

Figure 1: Education expenditure of households in Slovenia, 2010-2060



Source: Authors' simulations using SIDYN 2.0.

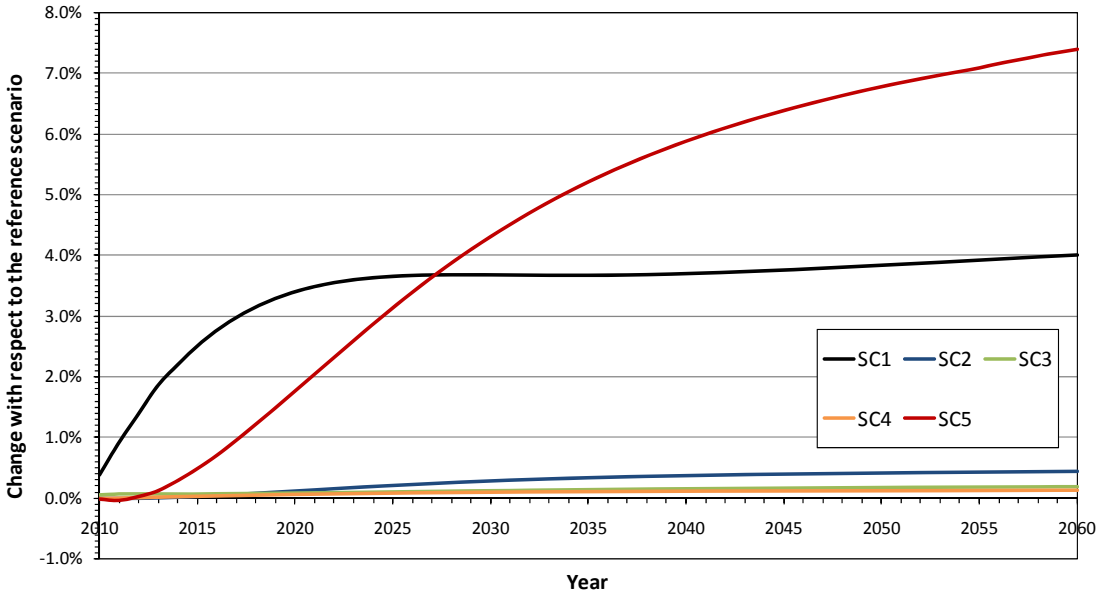
The effects of the policy scenarios on human capital expenditure (not shown) have a very similar dynamic. Deviations arise in case of increasing the CIT rate by 25% (SC3), where human capital expenditure increases by 0.5% with respect to the reference scenario, and especially in the case of increasing the share of sectoral investment in human capital stock that is deductible from the CIT (SC4) by 25%, where human capital expenditure increases by as much as 6.2%. These scenarios represent obvious incentives for firms to invest in human capital, which is particularly noticeable in scenario SC5, where it turned out to be rational to withheld realised profits for investment in human capital in order to increase future profits. Scenario SC3 exhibits a much less profound effect, which can be inferred by observing the general government account, where the CIT revenues are much less significant than e.g. the PIT revenues.

What is the rationale behind the interesting dynamics of scenario SC5? First, one needs to note that we only observe in Figure 1 the education expenditure change of households with respect to the reference scenario, i.e. the response of the households to economic policy, and not the total education expenditure change. Production of education services (not shown), which represents the total supply of education services in the economy, increases by 0.5% in scenarios SC2 and SC4, by 1.2% in scenario SC1, and up to 9.5% in scenario SC5 with respect to the reference scenario. The latter scenario therefore demonstrates the dynamics of increasing the education expenditure on the Slovenian economy most distinctly.

Figures 1 and 2 reveal that the effects of the policy scenarios on labour supply and on education expenditure are quite similar. As education expenditure increases and more education services are consumed in the economy, certain amount of labour is temporarily withdrawn from its productive use and put into the educational system to increase its yield (and consequently future utility of households) on one side and its productivity (and therefore

future profits of firms) on the other. The extent of this phenomenon depends on the nature and size of the policy measure (see Figure 2). Scenario SC5, which comprises the most extensive mix of government and household investment in education, exhibits initial decrease in labour supply that consequently changes to an increase of up to 7.4% with respect to the reference scenario. Scenario SC1, where there is only household investment in education, exhibits no initial decrease in labour supply with respect to the reference scenario.

Figure 2: Labour supply of households in Slovenia, 2010-2060



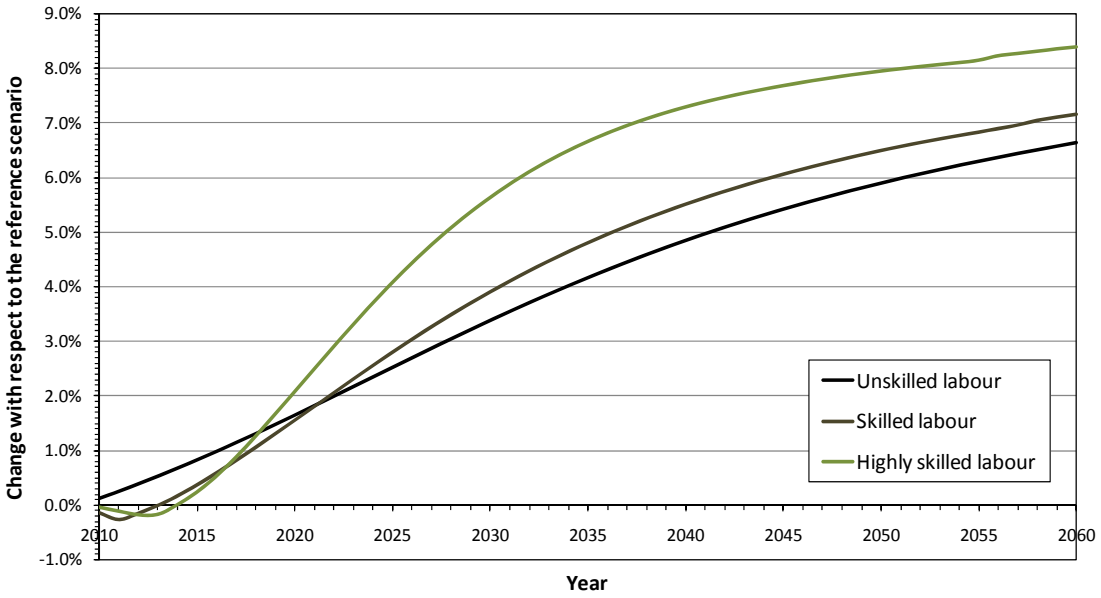
Source: Authors' simulations using SIDYN 2.0.

Let us examine this phenomenon is more detail in case of scenario SC5. Figure 3 reveals that the dynamic of labour supply depends on labour type, which in turn depends primarily on years of schooling. Investment in education of unskilled labour causes no initial decrease in labour supply with respect to the reference scenario, but leads to lowest long-term growth change. Conversely, investment in education of highly skilled labour pulls the (potential) labour force out of the production process for the longest period of time, but leads to highest long-term growth increase.

As seen from Figure 1, the policy measure of increasing government spending on education by 10% *per annum* is also accompanied by increasing household spending on education. Figure 4 presents the dynamic of this effect by labour type. It turns out that households with unskilled labour increase its spending on education the least, while households with highly skilled labour increase its spending on education the most. This follows naturally by observing the dynamic of household income (not shown, but follows closely the dynamic of GDP in Figure 5). Namely, by withdrawing labour from the production process the households lose income. Households with unskilled labour, which are on average also lower-income households, use higher share of their income for existential needs and are less able to invest its own funds in education. Consequently, one can observe an

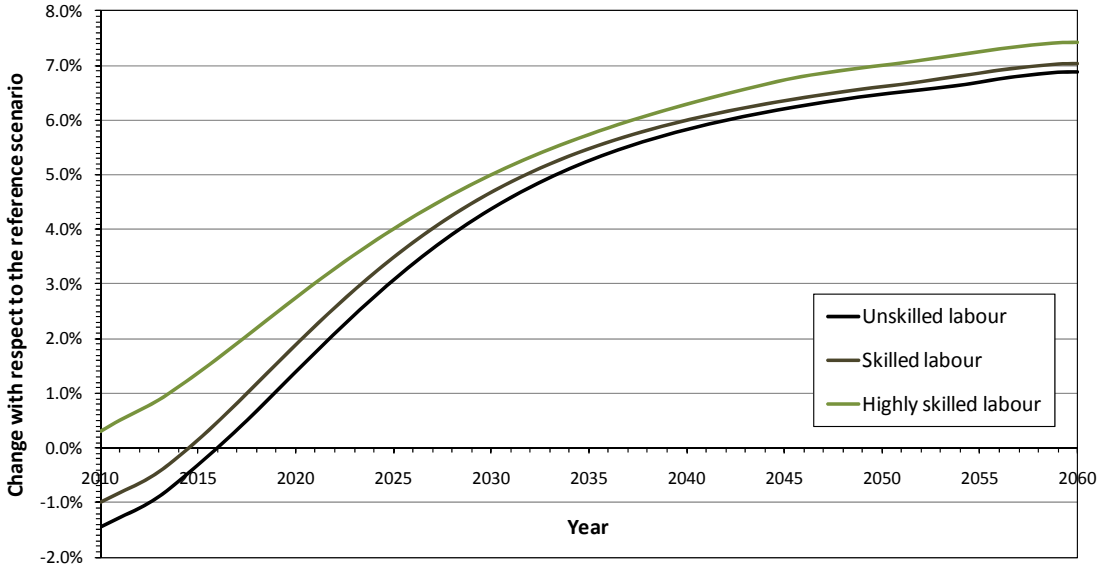
initial decrease in education expenditure of households with unskilled labour with respect to the reference scenario, and no such decrease for households with highly skilled labour[4].

Figure 3: Labour supply of households in Slovenia in case of increasing government spending on education by 10%, by labour type, 2010-2060



Source: Authors' simulations using SIDYN 2.0.

Figure 4: Education expenditure of households in Slovenia in case of increasing government spending on education by 10%, by labour type, 2010-2060



Source: Authors' simulations using SIDYN 2.0.

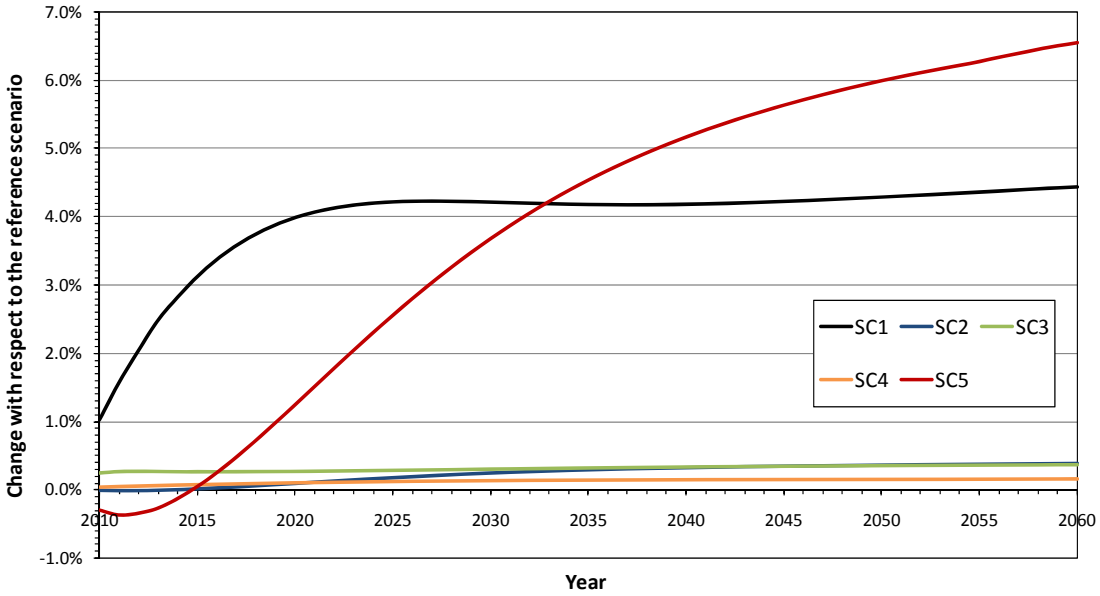
[4] The dynamics described herein is (to some extent) present in all the analyzed scenarios, but cannot be observed with the naked eye due to relatively smaller effects, except in part in scenario SC1.

Investment in labour that is achieved through investment in education (see Figures 1 and 4) is followed also by additional capital input (not shown). This is most evident in scenario SC1, where capital input increases with respect to the reference scenario by 4.2% in the long run, and in scenario SC5, where we observe an increase of up to 6.2%. Capital input change is even more manifest in the education services sector, where it amounts up to 8.5% in scenario SC5 with respect to the reference scenario.

Diverse policy measures obviously affect different incomes in a different way, which is most distinct in the case of real dividends (not shown). Namely, while they exhibit the already observed dynamic in scenarios SC1 and SC4, the real dividends increase with respect to the reference scenario on average by 4.6% in scenario SC3 and decrease on average by 2.3% in scenario SC4. This was expected, as decreasing the CIT rate (scenario SC3) not only provides more funds in the profit optimization process for investment, but also leaves the firm with more profit for sharing. On the other hand, by increasing the share of sectoral investment in human capital stock that is deductible from the CIT (scenario SC4), it becomes rational for the firm to redistribute profit from sharing to investing in order to increase future profits.

As already indicated, the dynamics of real household income change (not shown) and real GDP change (Figure 5) are similar, but with different levels. Real household income increases noticeably with respect to the reference scenario in scenario SC3 (by 0.5% on average), scenario SC1 (by 3.5% in the long run) and scenario SC5 (by 4.6% in the long run). Real consumption (not shown) and real saving (also not shown) increase accordingly in the same three scenarios. Real GDP increases markedly in scenario SC1 (by 4.4% in the long run) and scenario SC5 (by 6.5% in the long run). This would indicate that increasing the PIT rate and government spending on education provide the most efficient policy measures with respect to the long-term economic growth. However, even if one neglects the problem of comparability of the analyzed policy measures, it is necessary to compare other measures of well-being as well.

Figure 5: Real gross domestic product in Slovenia, 2010-2060

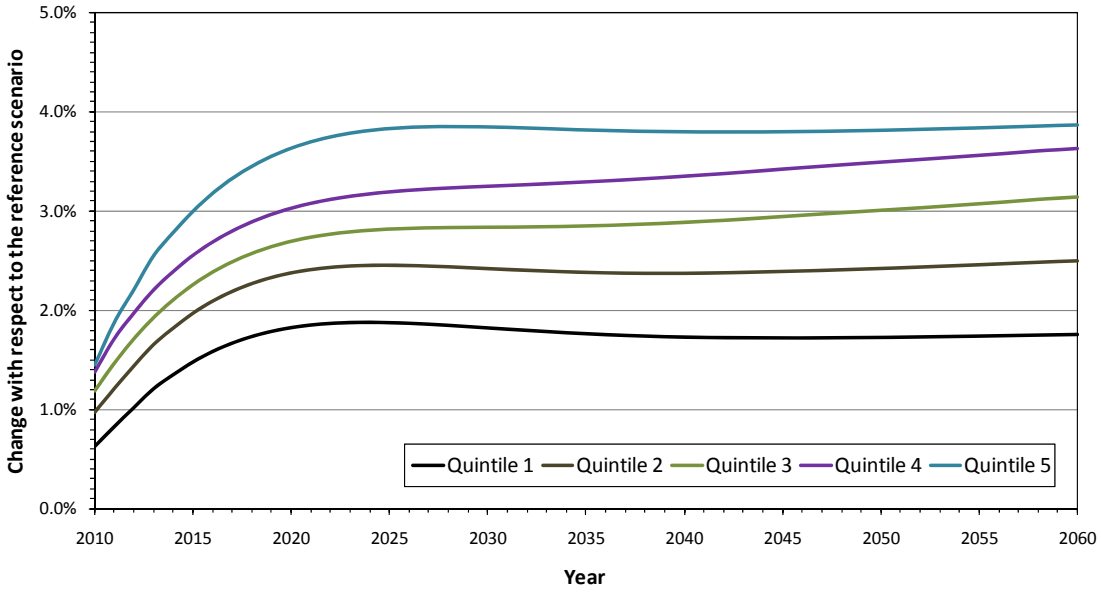


Source: Authors' simulations using SIDYN 2.0.

One such measure is the household welfare, which comprises the consumption of material goods and services and consumption of leisure[5]. It turns out that the dynamic of aggregate welfare change (not shown) follows closely the dynamic of real GDP change. Namely, welfare increases noticeably with respect to the reference scenario in scenario SC3 (by 0.5% on average), scenario SC1 (by 3.0% in the long run) and scenario SC5 (by 3.7% in the long run). Figure 6 illustrates the dynamic of welfare changes by household type in case of scenario SC1. One can observe that this dynamic is very similar irrespective of the income quintile, with some divergence in levels in the course of time. Detailed analysis of other scenarios leads to the same conclusion; households with more skilled labour and thus higher income level would gain more utility in case of implementing the analyzed policy scenarios.

[5] Household welfare in the model is defined in the form of its equivalent variation as a share of income. The equivalent variation represents the amount of income needed to achieve the same utility level as in the reference scenario at present prices.

Figure 6: Welfare change in Slovenia in case of decreasing the personal income tax rate by 10%, by household type, 2010-2060



Source: Authors' simulations using SIDYN 2.0.

6. Concluding Remarks

The debate whether long-run economic growth patterns can be best explained by traditional or endogenous growth is far from settled, but the notion that education and innovations can contribute to economic growth is nowadays widely accepted. This provided us with the motivation to develop a dynamic general equilibrium model with endogenous growth, driven by investment in education and R&D. In the present article, we demonstrate how education and human capital can be modelled as major endogenous growth elements in a small open economy general equilibrium framework, and consider several education and human capital policy scenarios for Slovenia, with primary focus on macroeconomic and welfare aspects.

Human capital in the economy is modelled as country-level human capital that is differentiated by skill (education) level, and sector-specific human capital. On one hand, the households decide how much time and money to invest through education into a particular type of human capital. The human capital stock owned by the households is freely traded on the labour market and mobile between the sectors. On the other hand, the firms choose investments into their human capital, which is not mobile between the sectors and thus not traded. It represents sector-specific knowledge accumulated within the company, such as experience, reputation and contacts. The human capital stock is accumulated over time through new investments made by households, firms and the government. The economic growth is subsequently endogenously determined by the joint development of all production factors and the total factor productivity.

In the simulations, we analyzed several policy scenarios that directly or indirectly increase the education expenditure. Decrease of the PIT rate and increase of government spending on education turned out to be the most effective policy measures. It is important, though, to understand the transitory dynamic behind such policy scenarios. Namely, as education expenditure is increased and more education services are consumed in the economy, certain amount of labour is temporarily withdrawn from its productive use and put into the educational system to increase the yield and productivity of labour. Higher skill upgrade of labour requires longer and higher short-term labour force decrease, but also provides us with higher long-term growth. The households that would gain more utility in case of implementing the analyzed policy scenarios are those with more skilled labour and thus higher income level.

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