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ORIGINAL PAPER

PROJECTING A LIFE-CYCLE INCOME – A SIMULATION MODEL FOR THE SLOVAK PENSION BENEFIT STATEMENT

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Abstract

The introduction of a regulation requiring pension asset managers to provide savers with an estimation of pension benefits opened a wide range of scientific questions on the projection methods and estimation of input parameters. One of them is the estimation of life-cycle income for calculating expected contributions and the estimation of the benefit ratio at the moment of retirement. We present an estimation of life-cycle income functions for various age and educational cohorts influenced by temporary labor market shocks. By employing the resampling simulation method for incorporating macroeconomic shocks, we have shown that using longitudinal data on the income process from a large closed economy could bring valid results for a country with a small open economy as well where the longitudinal data on income processes of individuals are unavailable. Our findings could serve a practical use when pension or other social benefits tied to individual income should be modelled.

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PROGNOZOWANIE DOCHODU W CYKLU ŻYCIA – MODEL SYMULACYJNY DLA SŁOWACKICH ŚWIADCZEŃ EMERYTALNYCH

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Słowa kluczowe: mikrosymulacja, świadczenia emerytalne, dochód w cyklu życia, szoki na rynku pracy.

Abstrakt

Wprowadzenie regulacji nakładającej na zarządzających aktywami emerytalnymi obowiązek dostarczania oszczędzającym oszacowania świadczeń emerytalnych powoduje powstanie wielu pytań naukowych dotyczących metod prognozowania i szacowania parametrów wejściowych. Jedną z nich jest oszacowanie dochodu w całym cyklu życia do obliczenia oczekiwanych składek i oszacowanie wskaźnika świadczeń w momencie przejścia na emeryturę. W artykule przedstawiono oszacowanie funkcji dochodu w cyklu życia dla różnych grup wiekowych i edukacyjnych, na które wpływają przejściowe wstrząsy na rynku pracy. Z zastosowaniem metody symulacji resampling w celu uwzględnienia szoków makroekonomicznych pokazano, że wykorzystanie danych longitudinalnych dotyczących procesu dochodu z dużej gospodarki zamkniętej może przynieść ważne wyniki również dla kraju o małej otwartej gospodarce, w którym dane dotyczące procesów dochodowych osób w dłuższej perspektywie czasowej są niedostępne. Ustalenia autorów mogą posłużyć do praktycznego wykorzystania w modelowaniu emerytur lub innych świadczeń socjalnych powiązanych z indywidualnym dochodem.

Introduction and Relevant Literature Review

Understanding the life-cycle income process of individuals influenced by labor market shocks and permanent components like age and education has a significant impact on the amount of paid social insurance and pension contributions, and thus on the expected amount of paid benefits. Robust academic models are often beyond the ability of pension providers to apply such models for the estimation of expected benefits as required by regulation. However, the oversimplification of estimated life-cycle income parameters based on trivial fixed parameters and linearized assumptions could lead to misleading information for the savers. The aim of this paper is to present a stochastic model for the estimation of age and education specific life-cycle income with unemployment risk. The purpose of the model should serve for estimating the pension benefit statement, which should be implemented in the Slovak pension system.

Life-cycle income dynamics have been studied since Mincer´s (1958) seminal work and remains in the forefront for many researchers. The generally accepted hypothesis is that the life-cycle income function is hyperbolic rather than linear and has given rise to many empirical studies using longitudinal administrative data. Many influential economic studies have recognized that the use of current income as a proxy for long-run income can generate crucial errors-in-variables biases (Haider & Solon, 2006). In order to address the concavity of a life-cycle income function, the models should employ several key assumptions such as changing preferences towards employment positions with increasing age, diverging paths of the life-cycle income functions for different educational levels, or earnings inequality due to persistent and transitory components such as unemployment or maternity. Lagos *at al.* (2018) analyzed life-cycle wage growth in 18 countries using large-sample household survey data and their main finding is that experience-wage profiles are on average twice as steep in rich countries as in poor countries. In addition, more educated workers have steeper profiles than the less educated ones. Their findings are consistent with theories in which workers in poorer countries accumulate less human capital or face greater search frictions over their life cycle.

Guvenen (2009) pointed to the long-term effects of unemployment on the future income of an economic agent. Indeed, the long-term effects of unemployment as one of the temporary labor market shocks have led to the study of this shock in the context of the lifetime of an individual's life-expectancy hypothesis. The dynamics of the development of idiosyncratic risks are examined through stochastic models of lifetime income, with the modeling of the likelihood of temporary shocks (Guvenen & Smith, 2014). The influence of the variable associated with years of experience, which essentially increases labor productivity, was also confirmed by Katz and Murphy (1992). We work with the main assumption that the education of economic agents is a permanent determinant of their income and has a significant impact on the course of the life-long income function (Balco *et al.*, 2018).

Faber (1998) examined the length of employment for age and educational cohorts using empirical data from the Current Population Survey from 1973 to 1993. In his research, Faber confirmed that the duration of the employment relationship, i.e. the length of staying in the same position, is strongly dependent on the age of an individual. He has shown that younger cohorts (the cohorts of 25-34 and 35-44 years of age) frequently change position while, an individual tends to prefer job stability with increased age (the educated cohorts 45-54 and 55-64 years). At the same time, he rejected the hypothesis that the length of stay in one job is the same across educated cohorts. Raymo *et al.* (2010), based on data from the Wisconsin Longitudinal Study, examined the impact of work experience at an earlier age on individual preferences for the nature and type of work performed at an older age. They showed that, at a higher age (53+), individuals prefer stable and less demanding work or even part-time work. These findings should be incorporated into the estimation of the lifecycle function parameters in the form of time preferences.

Low *et al.* (2010) distinguish two types of risks in the labor market: exogenous risks such as job disruption that directly affects unemployment, and endogenous risks such as greater variability in labor productivity. Unlike the fall in labor productivity, which is reflected in wage rigidity, job cuts are a transient shock to the individual's income. These risks have a considerable impact on an individual's lifecycle income.

Research objective and methodology

The objective of the paper is to present estimations for the age and education specific life-cycle income under the unemployment risk for the purpose of pension benefit projections under various scenarios. The model should serve the Ministry of Finance of the Slovak republic and pension providers, which are required to regularly provide their clients (savers) with pension projections, where the contributions are tied to the agent´s wage (insurable income).

When constructing the model, the main constraint is the reliable long-term series of data for relatively young democracies such as the Central and Eastern European countries. Lack of long-term longitudinal data for individual wages combined with the transitory period of economies do not allow modeling of stable scenarios for long-term projections. Therefore, we decided to combine long-term data from developed economies and short-term administrative data from analyzed country. Combining longitudinal data on wage profiles with the long-term data series of the macroeconomic variables from the United States and linking them to the Slovak short-term administrative data on wage profiles allowed us to estimate the life-cycle income even for countries where reliable longitudinal data are still unavailable.

First, we present the longitudinal data from the American Community Survey presented by Julian and Kominski (2011). However, these data present the life-cycle income for 9 educational cohorts. In order to compare the Julian and Kominski data to the 2004–2018 administrative data for Slovakia (Fodor & Cenker, 2019), obtained from the Ministry of Finance of Slovakia, we needed to combine the American educational cohorts into the 3 educational cohorts for which the data are available in Slovakia. Then, we transformed the values into the coefficients of the average wage. Comparing the transformed values allowed us to inspect whether the data from Julian and Kominski would fit the administrative data for Slovakia. Based on the results of the data comparison, we used the curve fitting technique to estimate the regressors of age (x) for 3 educational specific (j) income functions that should follow the polynomial function:

$$y_{j;x} = a + b_j x + c_j x^2 + \varepsilon \tag{1}$$

Further, we applied the estimated income functions on the Slovak working population and calculated labor productivity using the simulation method described below. The results were then compared to the projected labor productivity growth from the Ageing Report 2018 (EC, 2018). Differences in the projected labor productivity and estimated labor productivity from our model were then recursively incorporated into the fitted life-cycle income functions.

However, the income function should also be influenced by the temporary labor market risks. According to Cooper (2014) and Guvenen *et al.* (2015), if an economic agent drops out of the labor market for a certain period, his wage departs from a full uninterrupted income function, since the skills, working habits, and experience during the period of unemployment do not improve. Thus, we can create the scenarios, where the unemployment risk is incorporated. In order to estimate the nominal values of projected income, we also incorporated projected inflation from the macro scenarios. Given the existence of unemployment risk and inflation, the nominal wage (w) could be expressed as:

$$w_{j;t} = \begin{cases} w_{j;t};\ t = 1 \\ w_{j;t-1} \times (1 + \tau_t); \quad U_t = 1, t \in < 1, T > \\ w_{j;t-1} \times \omega^*_{j,t} \times (1 + \tau_t); U_t = 0, t \in < 1, T > \end{cases} \tag{2}$$

Where $\omega^*_{j,t}$ represents monthly changes in the real wage based on the estimated life-cycle income functions; τ_t represents the inflation in time t. $U_t = 1$ means that the economic agent is unemployed at time t, while $U_t = 0$ means that the economic agent is employed at time t. If an economic agent is employed ($U_t = 0$), his income function depends on the development of inflation and the increased labor productivity over time. In the case that the economic agent is unemployed ($U_t = 1$), his lifetime income function changes over time only by the impact of inflation and the labor capital remains constant.

Secondly, in order to get a different labor income process under the unemployment risk that reflects the impact of age and education (Skrętowicz & Wójcik, 2016), we developed a transition matrix, that transforms general unemployment rates into age and specific rates. The probability of unemployment is reviewed every year by the rate of change in total unemployment from the macroeconomic block. In modeling the probability of changes in the employment of an economic agent at age x, education j at time t, the transition matrix has the following form:

$$\mathbf{M}_{x,j,t} = \begin{pmatrix} p_{U_t=1 \to U_t=1\ x,j,t} & p_{U_t=1 \to U_t=0\ x,j,t} \\ p_{U_t=0 \to U_t=1\ x,j,t} & p_{U_t=0 \to U_t=0\ x,j,t} \end{pmatrix} \tag{3}$$

For each element of matrix **M**, the probability of status change (p) applies, where:

$$0 \leq p \leq 1$$

The initial transition matrix with probabilities (odds ratios) has been created using cross-sectional data on age and education specific unemployment from the Ministry of Finance of Slovakia for the reference period of 2004 until 2018.

Thirdly, we have created a stochastic model that generates macroeconomic scenarios, which in turn influence the individual attributes of age and educational cohorts, mainly wage and employment status. We use the moving-block bootstrap (resampling) method, which allows an increased number of simulations by pseudo-randomly generated macroeconomic scenarios while preserving correlations among macroeconomic indicators (k_k). Data on monthly macroeconomic indicators for the period of 1,919 until 2017 include unemployment, inflation, GDP change, labor productivity, DJIA30 total returns and 3-7-year bonds with constant maturity returns. The empirical time series of macroeconomic variables (k_k) contain 1,164 monthly values. Since we want to obtain monthly changes for each macroeconomic variable, in total we have 1,163 monthly changes ($\Delta k_{j;t}$), where $t \in 1; 2; \ldots; 1{,}163$.

Next, we cut the empirical time-series into up-trending (Up^i) and down--trending periods (Down^i) using data from the NBER (2018) on economic cycles and marked each period with the appropriate index value (i). Altogether, we have 18 up-trending and 18 down-trending periods. Figure 1 illustrates up-trending and down-trending economic periods between 1919 and 2017.

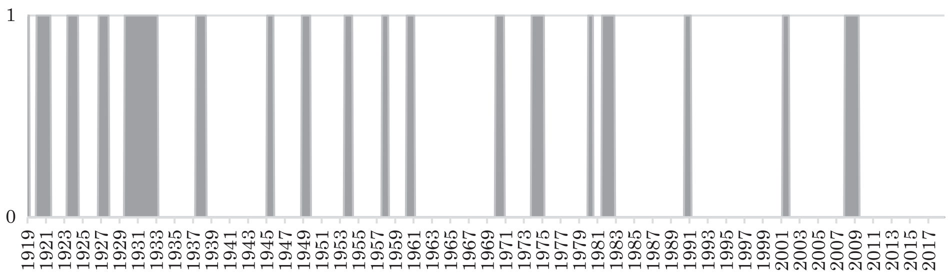

Fig. 1. Up-trending and down-trending macroeconomic periods in the US (1919–2017)
*Remark: Dark-colored columns represent the periods of economic downturn (recession).
Source: *US Business Cycle Expansions and Contractions.* (2018).

Each period (i) has a precisely identified time series of macroeconomic variables (Δk). Let us define a vector of the time series of monthly changes in macroeconomic variables ($\Delta k_{k;t}$) where the lower index k represents the observed macroeconomic variable (in the range 1 to K variables). Let us call the generated vector a simulation block ($\boldsymbol{r_N}$). The first simulation block ($\boldsymbol{r_1}$), which consists of empirically measured values of monthly changes in observed macroeconomic variables ($\Delta k_{k;t}$), and contains all up-trending and down-trending periods in a sequential order from 1 up to 18, has the following form:

$$\boldsymbol{r_1} = \begin{bmatrix} \Delta k_{1;1} & \cdots & \Delta k_{1;1163} \\ \vdots & \ddots & \vdots \\ \Delta k_{K;1} & \dots & \Delta k_{K;1163} \end{bmatrix} \tag{4}$$

In order to increase the number of simulations, we have created new simulation blocks using a resampling procedure. We combined up-trending and down-trending periods without repetition while maintaining the rule that each period (i) can only occur once. Applying the resampling technique, we obtained a total of 150 simulation blocks ($\boldsymbol{r_N}$, where $N \in 1; \dots; 150$).

Finally, we can expose our age and education cohorts to the randomness of external macroeconomic development. The simulation at the level of a specific age and educational cohort is performed as follows. For each simulation block ($\boldsymbol{r_N}$), we start from the first month ($t = 0$) with the empirically gathered data on wages and respective unemployment rates for each age and educational cohort from the Statistical Office of the Slovak Republic for the year 2016. Each month the values of the macroeconomic indicators change, which affects the individual status parameters of an economic agent, where the employment status is affected by formula (3) and wage change by formula (2). We continue with simulations of each age and educational cohort until age (x) of the cohort reaches the statutory retirement age (R) set at 69 years. For each cohort, we perform simulations of the length from 1 year (age cohort of 68) to the remaining length of the working career (D, where $D = R - x_{j;t}$). If, for example, the age of the youngest cohort with a professional degree (PhD. degree) is 27 years, then the remaining working career (D) equals 42 years. This means, that within each simulation block, we can move this cohort 55 times. The total number of simulations for the cohort at age x and education j, which remains in the labor market for D years is given by the product of the number of blocks, the length of the block, the remaining length of the working career and number of status possibilities (employed/unemployed). For example, for an economic agent with a high-school degree who enters the labor market at the age of 19, we perform simulations ranging from 1 year (12 months) to 50 years (600 months) as we anticipate that he will retire at 69 years of age. In total, for this age and educational cohort, we get 3,330,600 simulations that form the scenarios for the life-cycle income and employment probabilities during the entire working career.

The generated scenarios allow us to inspect what was the estimated development of individualized (cohort) variables under the various macroeconomic scenarios. The scenarios represent percentiles, where the higher percentile corresponds to better macroeconomic conditions.

Results and discussion

The initial phase of the research was to compare the US longitudinal data on income from the ACS survey obtained from Julian and Kominski (2011) and compare them to the relatively short-term data on income for Slovakia obtained from Fodor and Cenker (2019).

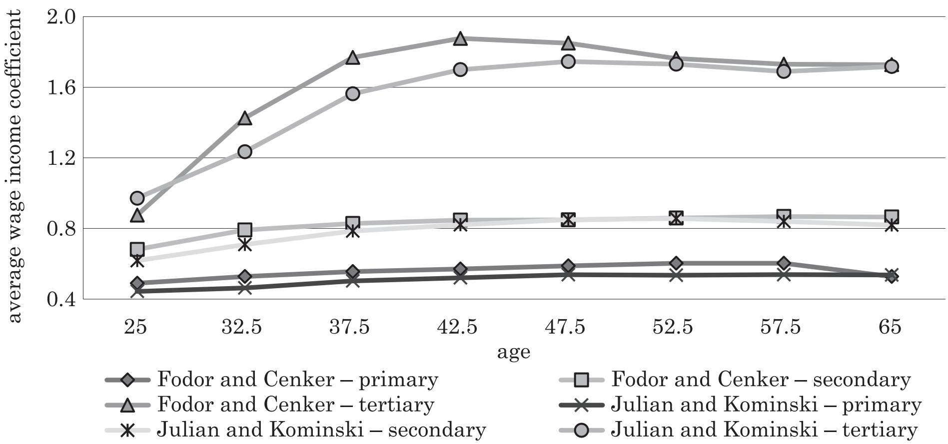

Fig. 2. Comparison of educational specific income coefficients for US and Slovakia
Source: authors´ estimations using Julian and Kominski (2011) and Fodor and Cenker (2019).

The presented data for 3 educational cohorts suggests the possibility to estimate the income functions using more reliable longitudinal data from Julian and Kominski (2011). However, we can observe higher income growths for younger tertiary education cohorts suggesting higher labor productivity for younger university educated individuals in Slovakia.

Estimated regression parameters for all educational cohorts including statistics are presented in the table below.

Comparing US longitudinal data to the Slovak short-term administrative data shows that the model fits the US longitudinal data better, where all key statistics perform better including Standard Error, the parameters´ standard deviations and the coefficient of determination.

Secondly, understanding the importance of labor productivity on income path (Jarmołowicz & Kuźmar, 2017), we applied estimated life-cycle income functions on the Slovak working population and performed microsimulations using the resampling method that allowed us to get the expected development of labor productivity and average wage over the next 50 years. Then we compared the labor productivity growth rate projections in the 50th percentile with the European Commission projected labor productivity (Fig. 3).

Table 1

Estimation of regression parameters for educational cohorts using Julian and Kominski (ACS) data vs. Fodor and Cenker (Ministry of Finance of Slovakia) data

Regressors	Fodor and Cenker – Ministry of Finance			Julian and Kominski – ACS		
	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary
a	0.1293	0.2825	-1.7447	0.2242	0.0006	-0.9978
b	0.0016	0.0018	0.0119	0.0009	0.0027	0.0085
c	-0.0000013	-0.0000014	-0.0000097	-0.0000006	-0.0000021	-0.0000065
Standard Error	0.01724	0.0159	0.1172	0.0086	0.0095	0.0702
R^2	0.87	0.95	0.91	0.96	0.993	0.96
Correlation	0.93	0.98	0.95	0.98	0.99	0.98
Parameter Standard Deviations:						
*a*_stddev	0.0786	0.0724	0.5342	0.0392	0.0431	0.32
*b*_stddev	0.0003	0.0003	0.0021	0.0002	0.0002	0.0012
*c*_stddev	0.0000003	0.0000003	0.000002	0.00000014	0.00000015	0.00000114
Parameter Uncertainties, 95%						
*a*_unc	0.2021	0.1862	1.3732	0.1009	0.1109	0.8226
*b*_unc	0.0008	0.0007	0.0053	0.0004	0.0004	0.0032
*c*_unc	0.0000007	0.0000007	0.000005	0.0000004	0.0000004	0.000003

Source: authors' calculations.

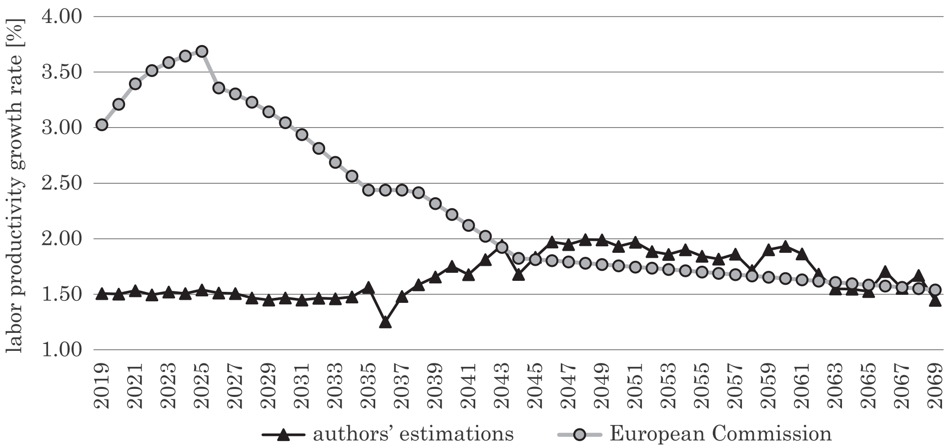

Fig. 3. Labor productivity growth rates – authors´ vs. European Commission projections
Source: own calculations.

Our model with estimated life-cycle income functions keeps the labor productivity growth rates relatively stable around 1.5% annually for the next 25 years and underestimates expected labor productivity growth rates compared to the European Commission projections. However, the second projected period provides similar projections with labor productivity growth rates. In order to prepare the model for practical usage, we incorporated the labor productivity convergence factor and adjusted the income function regression parameters in a way that redistributes the necessary increase in labor productivity into individual life-cycle income functions evenly. The projected life-cycle income functions for 3 education cohorts including unemployment risk under various economic conditions (scenarios) presented as a percentile of all simulations are presented in the appendix.

First, the estimation of life-cycle income using our approach brings more realistic outcomes compared to the simplified assumptions of linear growth tied to the general total factor productivity growth that is often used when estimating future wage growths. Decreasing coefficients over the life-cycle clearly emphasize other research findings that echo the concept of economic agents preferring wage growth during the early stages of their careers whereas later stages are associated with preferences for job stability. An economic agent is willing to accept lower wage growth compared to the rest of the working population in exchange for job stability and work-hour flexibility at the end of their career.

Our approach also incorporates recent findings, that regardless of a previous career, employers do apply similar wage increase mechanisms for older workers. In other words, later in their career, the age of a worker is a more dominant factor than the years of working experience and human capital. For the same age and educational cohort, the coefficients of wage growth during the last 10 years of work in all scenarios are quite similar with relatively low variability.

At the same time, we can observe, that the model predicts lower changes of a significant up-tick for mid and older cohorts with lower education, where the wage growth coefficients suggest optimistic scenarios (higher percentiles) for relatively modest wage growths.

Conclusions

The objective of the paper was to estimate life-cycle income functions for educational cohorts in Slovakia in order to provide pension benefit projections for the Slovak pension system. At the same time, the model generates respective employment coefficients that are tied to the life-cycle income functions and together are able to assess the number of working career years which is a significant input for the projection of pension benefits. Based on the inherent risk of unemployment in the lifetime income function, it is possible to identify how much the economic agent transfers to public finances, as well as the volume of benefits received from the social insurance system.

The model serves the Ministry of Finance of Slovakia for the estimation of the fiscal and welfare impact of various policy settings where individual economic agents should be considered. On the other hand, the weaker point of the model could be that it employs empirical data from the economy with a constantly growing population, which in the conditions of the Slovak Republic may not prove to be an acceptable assumption. However, we have shown that it is possible to adopt longitudinal data from a different country if combined with a robust simulation technique that allows for generating macroeconomic scenarios.

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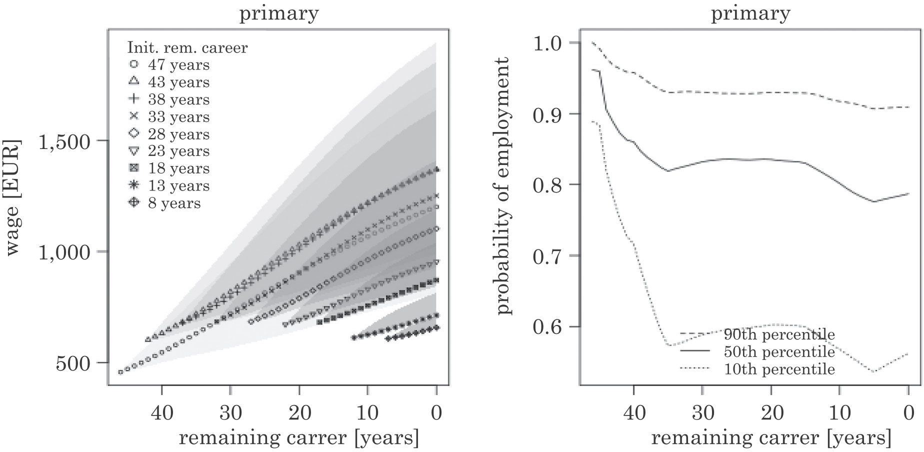
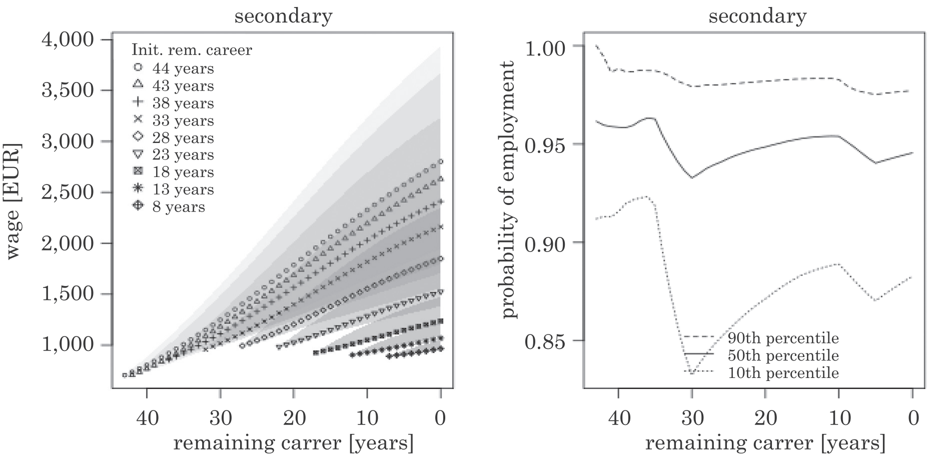
Appendix

The charts below present education specific life-cycle income projections for different remaining career/working years (left chart) complemented with the estimation of probability of being employed until achieving the standard retirement age (right chart) presented as percentiles of all simulations. Grey shaded areas around the 50th percentile within the charts on the left represent 10th and 90th percentile of all simulations.

Primary education level



Secondary education level



Tertiary education level