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Measuring growth of labour quality and the quality-adjusted unemployment rate in Switzerland*

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Abstract

This paper presents results on human capital accumulation for the Swiss economy. We find that the index of labour quality has grown at a rate of 0.5% per year from 1991 to 2006. The main sources are the growth in average levels of education and the passing of the baby boom cohort through the age structure of the workforce. Projections over the period 2006-2050 suggest that labour quality growth will slow down with time. We also calculate a quality-adjusted unemployment rate and find that the unemployment rate is reduced by about 0.3 pp when human capital accumulation is taken into account.

JEL Classification: E24, J24, J31

Key words: human capital, labour quality, unemployment rate

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1 Introduction

The labour effort in a given period is often measured by the total number of hours worked. This is acceptable if the workforce is homogenous, or nearly so. It is misleading, however, when the workforce is heterogenous as reflected in differences among workers in terms of productivity. In reality, the workforce is relatively heterogenous if we think of, for example, a young apprentice, on the one hand and an experienced engineer, on the other. Hence, it is useful for many purposes to have a measure of the quality-adjusted labour input which takes into account the fact that workers differ with respect to their abilities.¹

The productivity of individual workers cannot usually be observed. What can be observed, however, are the earnings individual workers obtain from their work. Under certain conditions, the two are related to one another. That is, with competitive labour markets and constant economies of scale in production, the wage rate equals the marginal product of labour. Starting with Jorgenson and Griliches (1967), various authors have exploited this relationship to construct an index of quality-adjusted labour input. This index can then be combined with the aggregate measure of raw hours worked to derive the index of labour quality.

In this paper, we address two issues. First, we construct an index of labour quality for Switzerland based on the method proposed by the Bureau of Labor Statistics (1993). The data are annual and cover the period from 1991 to 2006. The worker characteristics considered are education, gender and age, where age is regarded as a proxy for labour market experience. These three characteristics are widely used in the literature due to data availability and the large amount of empirical evidence supporting their relevance for productivity. Using population projections by the Federal Statistical Office (FSO), we also construct projections of labour quality over the period 2006-2050.

The second issue addressed in this paper is the quality-adjusted unemployment rate. This ratio relates the quality-adjusted number of unemployed workers to the quality-adjusted labour force. Following Greenwood and Kohli (2003), we calculate several variants of the quality-adjusted unemployment rate and assess the deviation from the unadjusted, conventional rate of unemployment. Depending on the issue at hand, the quality-adjusted rate may be more appropriate than the conventional rate. In particular, the quality-

¹In this paper, the terms labour quality and human capital are used interchangeably. Schwerdt and Turunen (2007) use the term labour composition to reflect the fact that changes in aggregate human capital are determined by changes in the composition of the workforce.

adjusted rate is bound to provide a more accurate measure of labour market slack, that is, the underutilisation of labour in the economy.

The paper is organised as follows. Section 2 presents the methodology for the calculation of growth in labour quality. The data is described in Section 3. Section 4 presents the results on growth in labour quality and on the contributions from the various sources (education, age, gender). In addition, projections are presented to highlight the effect of expected future changes in the age composition of the labour force. In Section 5, the sensitivity of the results is examined with respect to alternative methods and data sets. Among others, we recalculate the results based on the methodology proposed by Jorgenson, Gollop and Fraumeni (1987) which differs in the construction of the weights on changes in hours worked. Section 6 describes the method to compute the quality-adjusted unemployment rate and presents results. Section 7 concludes.

2 Methodology

The approach developed by the Bureau of Labor Statistics (1993) can be separated into two stages. In the first stage, using wages as a measure of productivity, wage rates are regressed on worker characteristics. In the second stage, the weights on changes in raw hours worked are constructed based on the predicted wages from the first stage, the index of quality-adjusted labour input is derived, and the index of labour quality is calculated as the ratio of quality-adjusted labour input to raw hours worked. Finally, as shown by Jorgenson et al. (1987), the index of labour quality can be decomposed into the contributions from the various worker characteristics.

2.1 Wages as a measure of worker productivity

To obtain estimates of the returns to worker characteristics, we estimate a version of the human capital earnings function proposed by Mincer (1974),

$$\ln q_i = \alpha + R_i \beta_R + \varepsilon_i. \quad (1)$$

This is done separately for each year the data are available. The subscript i indexes individuals, q_i is the real hourly wage rate, R_i is a vector of individual worker characteristics defined as binary dummies and β_R is a parameter vector.

Following the literature on growth of worker quality (see e.g. Bureau of Labor Statistics, 1993, Schwerdt and Turunen, 2007), R_i includes categorical

variables for education and age, where the latter acts as a proxy for experience.² We estimate (1) separately for men and women to allow the returns to characteristics to vary between the genders. There is substantial empirical evidence indicating that returns to characteristics are not the same for men and women. The Bureau of Labor Statistics (1993) argues that this may reflect differences in work histories as women tend to show interruptions due to the bearing and rearing of children.³

Given the parameter estimates $\hat{\alpha}$ and $\hat{\beta}_R$, we obtain predicted wages for a given year as

$$\hat{q}_i = \exp[\hat{\alpha} + R_i \hat{\beta}_R]. \quad (2)$$

These predicted wages are used in the second stage to construct weights for each worker group.

2.2 Aggregate labour input and aggregate labour quality

Let L_t be the aggregate quality-adjusted labour input defined by the aggregator function $g(l_{1,t}, \dots, l_{J,t})$, where $l_{j,t}$ is the quality-adjusted labour input of worker group j in period t . In our benchmark calculations, we consider five categories of education, five age categories and the two genders to create a total of $J = 50$ worker groups. Following Jorgenson et al. (1987) we assume the aggregator function $g(\cdot)$ to be a standard translog function homogeneous of degree one:

$$L_t = g(l_{1,t}, l_{2,t}, \dots, l_{J,t}) = \exp \left[a_t + \sum_{j=1}^J s_{j,t} \ln l_{j,t} + \frac{1}{2} \sum_{j=1}^J \sum_{k=1}^J s_{j,k,t} \ln l_{j,t} \ln l_{k,t} \right], \quad (3)$$

²It is possible that (1) suffers from an omitted variable bias (see e.g. Card, 1999). That is, the coefficients may pick up the impact of other variables like intelligence or motivation. In this case, the growth of labour quality that can be attributed to changes in the distribution of a characteristic is not necessarily caused by the characteristic itself, but may merely reflect the correlation between included and omitted variables.

³Another possible explanation for differences in returns to characteristics is discrimination. Discrimination implies that at least part of the wage differential between men and women is not caused by differences in productivity and consequently should not be included in our measure of human capital. In Section 5.4, we examine whether the interpretation of the wage differential affects our estimates of growth rates of labour quality in Switzerland.

where $\sum_{j=1}^J s_{j,t} = 1$, $s_{j,k,t} = s_{k,j,t}$, and $\sum_{j=1}^J s_{j,k,t} = 0$.⁴

The growth rate of the quality-adjusted labour input can then be calculated as a Törnqvist index:

$$\Delta \ln L_t = \ln\left(\frac{L_t}{L_{t-1}}\right) = \sum_{j=1}^J \left(\frac{s_{j,t} + s_{j,t-1}}{2}\right) \ln\left(\frac{h_{j,t}}{h_{j,t-1}}\right), \quad (4)$$

where $h_{j,t}$ denotes the number of total hours worked by group j , and $s_{j,t}$ is the share of labour compensation of group j . The hours worked by group j , $h_{j,t}$, are defined as

$$h_{j,t} = \sum_{\substack{i=1 \\ i \in j}}^I \omega_{i,t} h_{i,t}, \quad (5)$$

where $h_{i,t}$ denotes the total number of hours worked by individual i and $\omega_{i,t}$ is a correction factor that accounts for differences between sample and population.⁵ The share of labour compensation of group j , $s_{j,t}$, is defined as

$$s_{j,t} = \frac{\sum_{\substack{i=1 \\ i \in j}}^I (\omega_{i,t} h_{i,t} \hat{q}_{i,t})}{\sum_{j=1}^J \sum_{\substack{i=1 \\ i \in j}}^I (\omega_{i,j,t} h_{i,j,t} \hat{q}_{i,j,t})}, \quad (6)$$

where I is the number of workers in group j .

Next, the aggregate index of labour quality is derived based on the growth rates of total hours worked and of quality-adjusted labour. The total number of hours worked in the economy, H_t , is given by

$$H_t = \sum_{j=1}^J \sum_{\substack{i=1 \\ i \in j}}^I \omega_{i,j,t} h_{i,j,t}. \quad (7)$$

Growth of labour quality can then be calculated as

$$\Delta \ln Q_t = \Delta \ln L_t - \Delta \ln H_t. \quad (8)$$

⁴See e.g. Christensen, Jorgenson and Lau (1973), and Bell, Burriel-Llombart and Jones (2005).

⁵The correction factor $\omega_{i,t}$ is provided by the FSO (see Section 3 on data). It corrects for two aspects. First, the probability to be sampled is not the same for all individuals. Second, the sample is smaller than the statistical population. Notice that the latter does not affect our results on aggregate labour quality.

From (8), the index of labour quality is computed easily by adding the growth rates, taking anti-logs, and indexing the resulting series to a base year.

2.3 Decomposition of the index of labour quality

To examine the sources of growth of labour quality, we can calculate the partial indices of labour input proposed by Jorgenson et al. (1987).⁶ The basic idea behind the partial indices is to capture the effect of substitutions among a subset of components while ignoring other substitutions. Given the three characteristics, education (E), age (A) and gender (G), there are three orders of partial indices.

A first-order index captures the substitution between different categories of one characteristic. For example, the first-order index for education, L_t^E , captures the labour input effect of changes in the composition of education, keeping the age composition and the gender composition constant. The first-order contribution of education to the growth rate of labour quality can then be calculated as

$$\Delta \ln Q_t^E = \Delta \ln L_t^E - \Delta \ln H_t, \quad (9)$$

where $\Delta \ln L_t^E$ is calculated as in (4), except that j is restricted to the education groups. The first-order contributions of age, $\Delta \ln Q_t^A$, and gender, $\Delta \ln Q_t^G$, are defined correspondingly.

A second-order index captures the substitution between two characteristics. The second-order contribution of education and age, for example, measures the impact of shifts in the distribution of education and age on growth in labour quality, excluding the first-order effects of these two characteristics. That is,

$$\Delta \ln Q_t^{EA} = \Delta \ln L_t^{EA} - \Delta \ln H_t - \Delta \ln Q_t^E - \Delta \ln Q_t^A. \quad (10)$$

Similarly, a third-order index captures the substitution between three characteristics (excluding the first-order and second-order effects). For the third-order contribution of education, age and gender to the growth rate of labour quality, we obtain

$$\begin{aligned} \Delta \ln Q_t^{EAG} &= \Delta \ln L_t^{EAG} - \Delta \ln H_t - \Delta \ln Q_t^E \\ &- \Delta \ln Q_t^A - \Delta \ln Q_t^G - \Delta \ln Q_t^{EA} - \Delta \ln Q_t^{EG} - \Delta \ln Q_t^{AG}. \end{aligned} \quad (11)$$

The various contributions add up as

$$\begin{aligned} \Delta \ln Q_t &= \Delta \ln Q_t^E + \Delta \ln Q_t^A + \Delta \ln Q_t^G + \Delta \ln Q_t^{EA} \\ &+ \Delta \ln Q_t^{EG} + \Delta \ln Q_t^{AG} + \Delta \ln Q_t^{EAG}. \end{aligned} \quad (12)$$

⁶Also see: Jorgenson, Ho and Stiroh (2005) and Bureau of Labor Statistics (1993).

That is, the total of all first-order, second-order and third-order contributions equals growth of labour quality.

3 Data

The data are taken from three sources: the Swiss Earnings Structure Survey, the Swiss Labour Force Survey, and the Work Volume Statistics, all published by the FSO. The FSO kindly provided us the micro data from these three sets of statistics. They can be characterised as follows:

- The Swiss Earnings Structure Survey (SESS) is conducted once every two years in October since 1994. It is based on a written questionnaire sent to companies. In 2004, data was gathered from 43,800 companies and government offices with 1.4 million employees (for more information, see Federal Statistical Office, 2007a).
- The Swiss Labour Force Survey (SLFS) is a household survey conducted every year between April and June since 1991. The survey is representative of the permanent resident population aged 15 and older. It is based on a sampling of 33,000 households (16,000 before 2001) where each randomly selected household is interviewed over the phone five years in a row (for more information, see Federal Statistical Office, 2007b).
- The Work Volume Statistics (WV) are compiled from the SLFS and other sources. Data are annual, and available since 1991. The WV provide more accurate data on effective working hours than the SLFS because absences due to reduced work schedules, strikes or lock-outs are taken into account (for more information, see Federal Statistical Office, 2007c).

Although the SEES and the SLFS/WV differ in focus, both data sets provide information on earnings as well as on education, age and gender. Thus, both data sets can be used, in principle, to cross-classify individual earnings with the individual characteristics going into (1). This said, each data set has specific strengths. The SEES data have the advantage that the sample is considerably larger (3 millions versus 300,000), and measurement errors are likely to be smaller in an establishment survey (SEES) than in a household survey (SLFS/WV). The SLFS/WV data, in turn, have the advantage that they are annual rather than biannual and that they allow us to calculate not only normal hours worked but also effective hours worked. In

addition, the SLFS/WV data are representative of the permanent population in Switzerland. That is, unlike the SEES, the SLFS/WS data include family workers, self-employed persons and apprentices, but exclude cross-boarder commuters and workers with short-term permits. Considering the relative strengths of the two data sets, we use the SEES data to estimate the returns to characteristics in (1), and the SLFS/WF data to calculate the number of hours worked in (5) to (7).⁷

Real wage rates are computed by deflating nominal hourly wages with the consumer price index. Nominal wage rates, in turn, are computed by dividing nominal earnings by hours worked. Observations of real hourly wage rates above CHF 100 are excluded from the sample because they appear to be more prone to measurement errors. Missing values are replaced by the average value of the group.

In the benchmark calculations of labour quality, three worker characteristics are considered: education, age and gender. There are five categories of education (“minimal school level”, “apprentice”, “university entrance certificate”, “higher vocational training”, “university degree”), five age groups (“15-24”, “25-39”, “40-54”, “55-64”, “65 and more”) and two gender categories (“male”, “female”). For some calculations presented in Section 5.3, the number of categories is expanded to include three sectors (“primary”, “secondary”, “tertiary”) and a more refined set of age categories (“15-19”, “20-24”, “25-29”, “30-34”, “35-39”, “40-44”, “45-49”, “50-54”, “55-59”, “65 and more”).

The long-term forecasts (2006-2050) of the index of labour quality are based on population scenarios by the FSO. The FSO provides projections of the working-age population stratified by age and gender, and projections of the educational attainment of the working-age population with Swiss citizenship stratified by gender.⁸ The number of categories of educational attainment is three (“primary”, “secondary”, and “tertiary”).⁹ From these data, we construct projections of the labour force (stratified by education, age and gender) based on two assumptions. First, the distribution of education is the same for the working-age population with Swiss citizenship and the labour force. Second, educational attainment is identical for different age groups.

⁷The exception is the robustness check described in Section 5.2, where the weights on hours worked are based on the approach by Jorgenson et al. (1987) and SLFS/WF data.

⁸The scenarios by the FSO cover the period 2004-2050 (first projected value: 2005); for more information, see Federal Statistical Office (2006) and [http : //www.bfs.admin.ch/bfs/portal/de/index/themen/01/03/blank/key_kant/01.html](http://www.bfs.admin.ch/bfs/portal/de/index/themen/01/03/blank/key_kant/01.html).

⁹Primary education corresponds to “minimal school level”, secondary education includes “apprentice” and “university entrance certificate”, and tertiary education includes “higher vocational training” and “university degree”.

Because we are interested in the total number of hours worked rather than the labour force, we additionally assume that the unemployment rate of a given worker group corresponds to its average for 1991-2006, and that the number of hours worked per employee of a given worker group is constant at its 2006 value. Whether these assumptions are critical to the results will be examined in Section 5.5.

4 Results

This section presents the results for the index of labour quality over the period 1991 to 2006. We first give the results for the full economy and for economic sectors (Section 4.1). Then, the contributions to the growth of labour quality from the various sources are considered (Section 4.2). Finally, long-term forecasts based on the population scenarios by the FSO are provided.

4.1 Growth of labour quality

Growth of labour quality is calculated based on (1) to (8). Equation (1) is estimated separately for men and women with SEES data for 1994, 1996, 1998, 2000, 2002 and 2004. The explanatory variables are five categories each of education and age. Given the estimates of $\hat{\alpha}$ and $\hat{\beta}_R$, the rest of the calculation is based on data for hours worked, $h_{i,t}$, and for the correction factor, $\omega_{i,t}$, from SLFS/WV. These data are annual for 1991 to 2006.¹⁰

We find that the index of labour quality rose by 7.9% from 1991 to 2006. This corresponds to an average increase of 0.51% per year. The annual rates displayed in the bottom part of Figure 1 suggest that growth of labour quality has been reasonably stable. This is confirmed by results for sub-samples. Splitting up the full period into three intervals of roughly equal length gives average growth rates of 0.70% for 1991-1996, 0.34% for 1995-2001 and 0.48% for 2001-2006.

The upper part of Figure 1 displays the raw hours worked published by FSO and the quality-adjusted labour input, both as indices.¹¹ The index of quality-adjusted labour input is computed based on the two indices of raw hours worked and labour quality. We can see that raw hours worked declined temporarily in the first half of the 1990s. By 2006, they exceeded their 1991 level by merely 3.2%. This corresponds to an annual average growth rate of

¹⁰In the calculation of $s_{j,t}$, the bi-annual estimates of $\hat{\alpha}$ and $\hat{\beta}_R$ are used as follows: parameter estimates from 1994 to calculate $s_{j,t}$ for the years 1991 to 1994; 1996 for 1995-1996; 1998 for 1997-1998; 2000 for 1999-2000; 2002 for 2001-2002; and 2004 for 2003-2006.

¹¹The number of hours worked in 2006 is our own estimate.

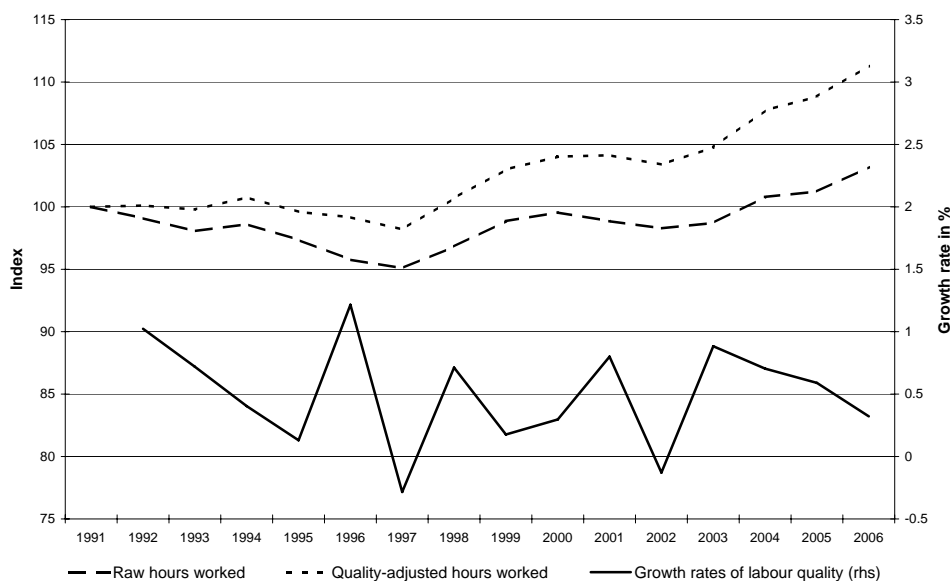


Figure 1: *Indices of raw hours worked, quality-adjusted hours worked, and labour quality*

0.21%. The quality-adjusted labour input, in contrast, rose by 11.3% over the full period, amounting to an average annual growth rate of 0.72%. These figures highlight the importance of changes in labour quality for measures of labour input during the period 1991-2006.

The results presented so far apply to the economy as a whole. But growth of labour quality can also be calculated for economic sectors. Figure 2 shows the results for the secondary sector (construction and manufacturing industries) and the tertiary sector (service industry). We find that worker quality has grown more rapidly in the tertiary than in the secondary sector. The average annual growth rates are 0.55% and 0.33%, respectively.

Results for a more detailed subdivision of the two main sectors of the economy show that low growth of labour quality in “construction” acted as a drag on the growth rate for the secondary sector. Whereas labour quality virtually stagnated in “construction” (-0.05% per year), it grew at about the same rate in the “manufacturing industries” (0.46%) as in the total economy (0.51%). Large differences among growth rates are found in the tertiary sector too. At the top of the list are “banking and insurance” (0.83%), “other social activities” (0.68%), and “public administration” (0.65%). These groups are followed by “transport and communication”, “real estate, renting and R&D” and “health and social work” with growth rates close to that in the total

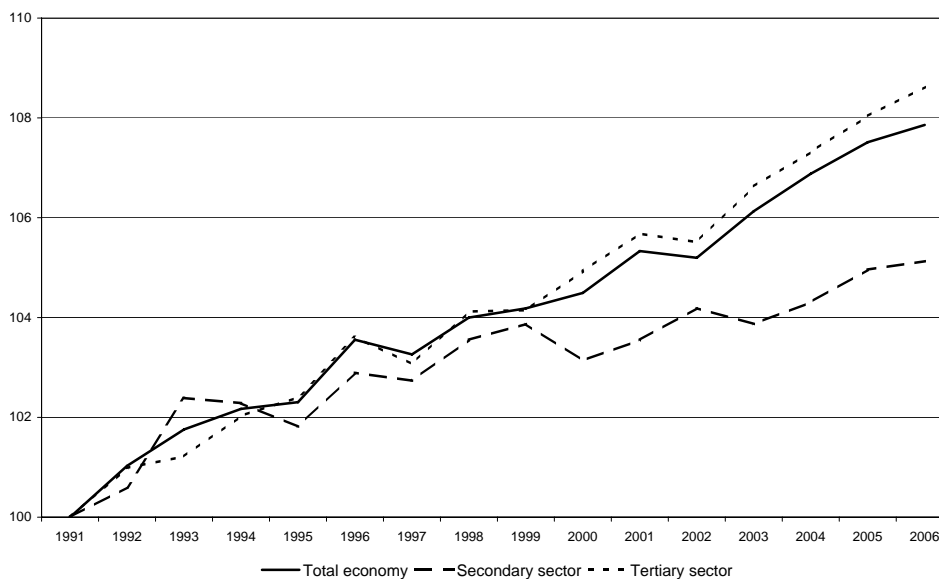


Figure 2: *Indices of labour quality for total economy, secondary sector and tertiary sector*

economy. At the bottom end, we have “sale and repair” (0.29%), “hotels and restaurants” (0.30%), and “education” (0.33%). Results for subsamples are given in the Appendix, Table 1.

Comparison of these findings with those from studies on other industrialised countries suggests that Switzerland’s growth in labour quality was about average. For the euro area, Schwerdt and Turunen (2007) find an average growth rate of 0.52% over the period 1989 to 2005. Growth in labour quality is reported to be higher in France (0.67%), but lower in Italy (0.48%) and Germany (0.38%). In a study on the UK, Bell et al. (2005) find an average annual rate of labour quality of 0.70% for 1990-2002. Working with US data, Aaronson and Sullivan (2001) estimated average annual growth in labour quality at 0.42% (for 1987-2000). This is roughly in line with results reported by Jorgenson et al. (2005) for the same period (0.48%).

4.2 Sources of growth in labour quality

To examine the sources of growth in labour quality, we calculate the partial indices defined in Section 2.3. These indices express the growth of labour quality that can be attributed to a subset of characteristics. For example, the partial index of education captures the contribution to human capital

accumulation that can be attributed to increasing educational levels.

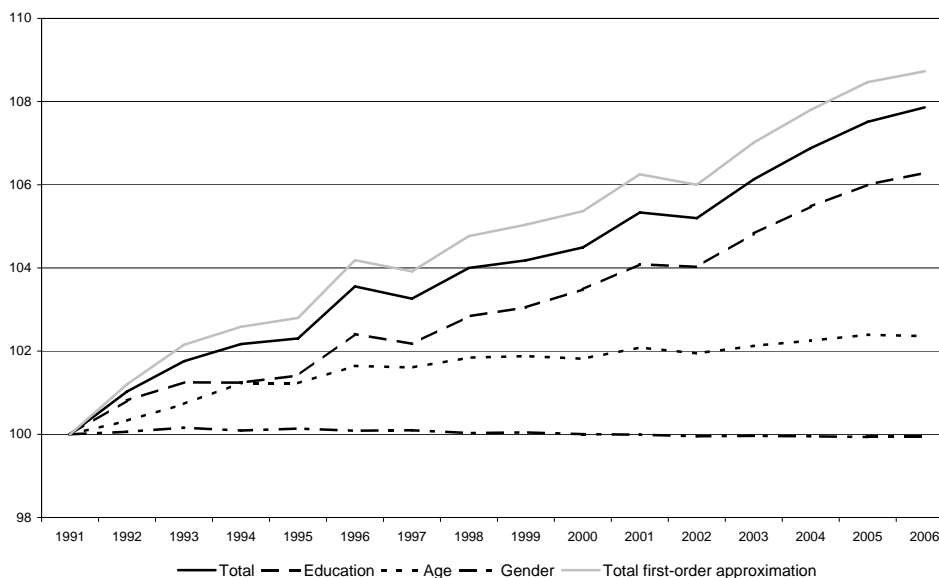


Figure 3: *First-order partial indices for education, age and gender*

The first-order indices for education, experience and gender are shown in Figure 3. The results indicate two things. First, the three first-order indices explain most of the change in the index of labour quality. Their total increase (see “Total first-order approximation”) exceeds that of the index of labour quality, implying that the contributions from the various interactions (second-order and third-order indices) are negative.¹² Second, the main driving force of growth in labour quality is improvement in educational attainment. Labour market experience represented by age is a distant second, and the contribution from gender is close to zero, suggesting that the substitution between men and women has been largely irrelevant for the growth of labour quality.

The first-order contribution of education amounts to 0.41 pp per year. Figure 4 shows the shares of the various educational groups. The picture is unambiguous. Whereas the shares of worker groups with relatively high qualifications (“university degree”, “higher vocational training”, “university entrance certificate”) have increased, the shares of worker groups with medium or low qualifications (“apprentice”, “minimal school level”) have declined.

¹²Table 2 in the Appendix below gives detailed results for all partial indices including the higher order indices calculated with (10) and (11).

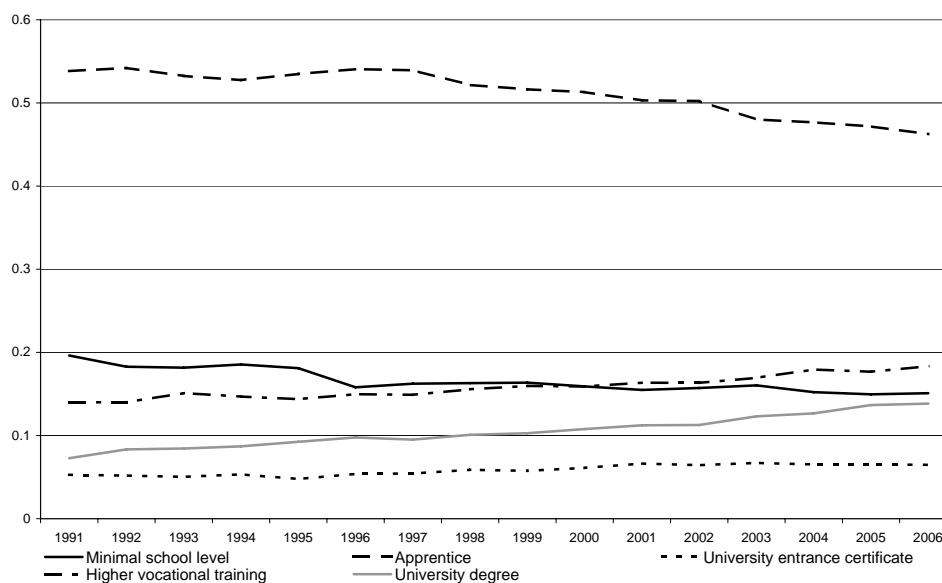


Figure 4: Shares of hours worked by educational attainment

Thus, the educational level of the employed workers has improved and contributes positively to the index of labour quality.

The first-order contribution of age is estimated at 0.16 pp per year. Figure 5 shows how the shares of the five age groups evolved during the period 1991-2006. The most striking changes reflect the movement of the baby boomer cohort through the age structure. The baby boomers, as conventionally defined, are the generation born between 1946 and 1964. In the late 1990s, the share in total hours worked by those aged 25 to 39 begins to fall as the peak of the baby boom cohort moves to the next higher age group (40 to 54 years). Moreover, we can see that the share of age group 55-64 rises over the period 1991-2006, whereas the shares of age groups 15-24 and 65+ declines. In the medium to longer term, we expect the contribution of age to human capital growth to fall as the baby boomers increasingly retire.

The results presented by Schwerdt and Turunen (2007) for the euro area (1989-2005) and by Bell et al. (2005) for the UK (1990-2002) indicate that the contributions of education and age to the index of labour quality have been slightly higher in these countries than in Switzerland. As in Switzerland, the largest contribution by far has come from education, while the contribution from gender is negligible (or slightly negative). The same broad picture is provided by Aaronson and Sullivan (2001) for the US (1987 to 2000).

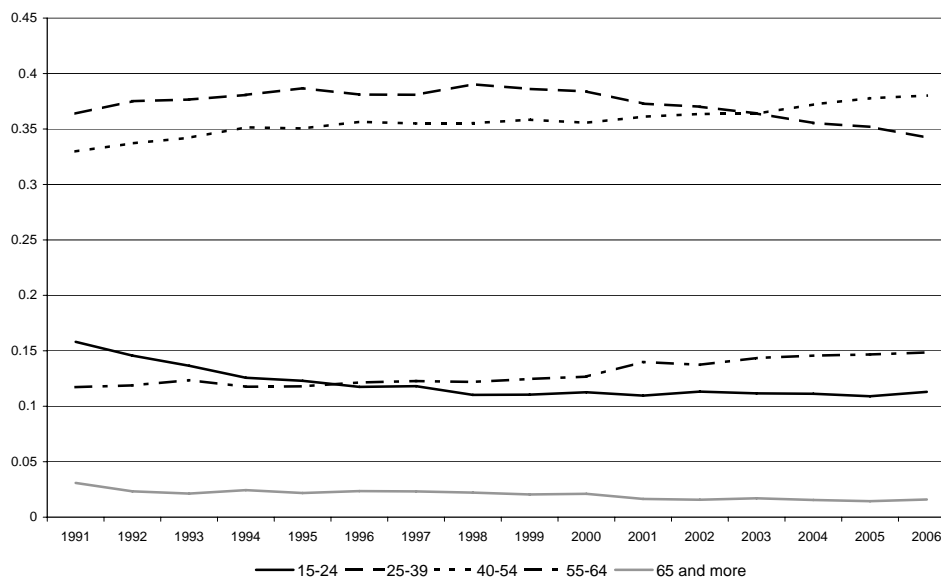


Figure 5: Shares of hours worked by age

4.3 Forecast of growth in labour quality 2006-2050

In this section, we present forecasts of growth in labour quality between 2006 and 2050. The projections of effective hours worked per worker group has been described in Section 3. The estimation of (1) differs in two respects from the one underlying the results presented in Section 4.1. First, the number of education classes is three rather than five. Second, the returns to characteristics are estimated as a pooled regression over observations from 1994 to 2006.¹³ The functional form of the index remains the same.

Figure 6 displays the predicted growth rates of labour quality for three projections of effective hours worked: “Reference”, “High” and “Low”. “Reference” is derived from the FSO population scenario “Middle”, while “High” and “Low” are derived from FSO population scenarios of the same name. The growth rates decline over the forecasting period in all three scenarios. There are substantial differences, however, between “High” on the one hand and “Reference” and “Low” on the other. In the latter two cases, the growth rate in labour quality diminishes continuously and approaches zero at the end of the period. In the “High” scenario, however, the growth rate declines

¹³Time dummies for each year (except 1994) are added to the equation, as real hourly wages are not stationary.

more slowly and stabilises at around 0.1% after the year 2040.¹⁴

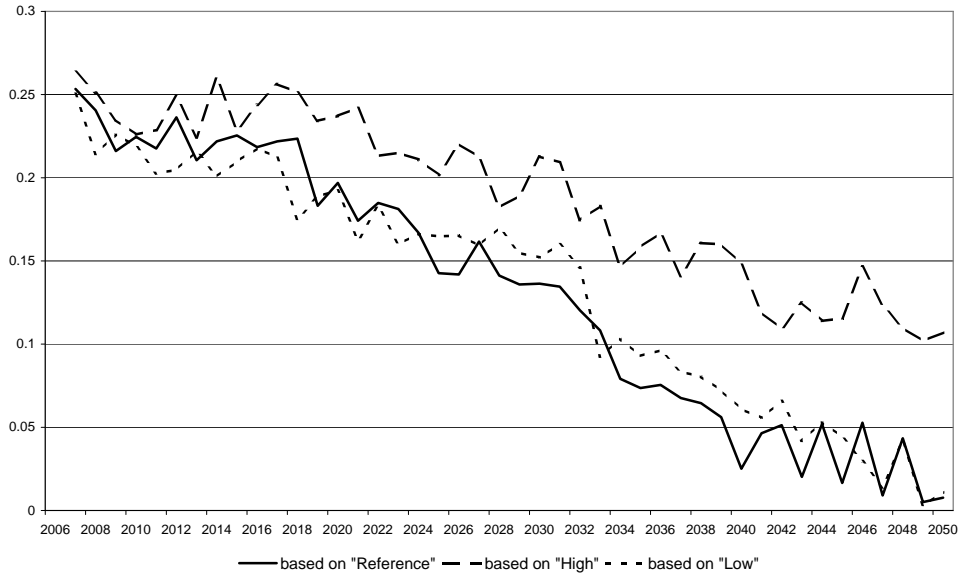


Figure 6: Forecasts of labour quality growth for three scenarios (“Reference”, “High” and “Low”)

A closer look at the results of the “Reference” scenario reveals that the average growth rate of labour quality between 2006 and 2050 is predicted at 0.13%. This is substantially lower than the 0.51% found in the period 1991-2006. Within the forecasting period, the annual growth rates decline fairly steadily from 0.25% in 2007 to 0.01% in 2050. Declining growth rates of human capital accumulation have been forecast for other countries too. For the US, Aaronson and Sullivan (2001) predict growth of labour quality to slow down to 0.07% in 2010. This implies an even faster decrease in the growth rate of human capital than we obtain for Switzerland.

To examine the sources of labour quality growth in the forecasting period, we calculate the first-order partial indices for education, age and gender for the “Reference” scenario. The resulting indices are depicted in Figure 7. They show that most of the expected growth in human capital can be attributed to shifts in the distribution of educational attainment. The contribution from shifts in the age distribution is considerably smaller while that of shifts in the gender composition is negligible.

¹⁴Detailed results for the full period and for various subperiods are given in Table 3 in the Appendix.

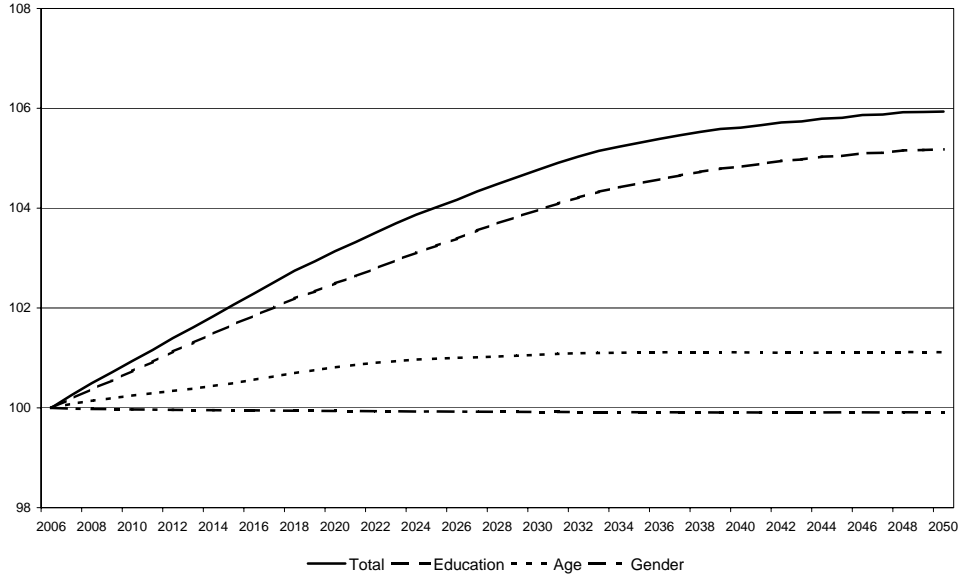


Figure 7: First-order partial indices for education, age and gender (‘Reference’ scenario)

The shift in the educational distribution reflects the trend towards higher skills. The share of workers with a primary education is expected to decrease from 9% to 5%, whereas the share of workers with a tertiary education is expected to rise from 34% to 46%. The shifts in age distribution, in turn, reflect the expected ageing of the workforce. The contribution from this source is strongest at the beginning of the forecasting period and becomes weaker over time, reflecting the passing of the baby boom cohort through the age structure of the workforce. After 2020, the effect is barely noticeable.

To analyse the reasons why growth of labour quality is faster in the ‘High’ scenario than in the other two scenarios, we compute first-order partial indices for all three scenarios. We find that differences in results between the ‘High’ scenario and the rest are primarily caused by the assumptions about the educational composition of the workforce. More specifically, the share of workers with a tertiary education begins to level off after the year 2020 in the ‘Reference’ and ‘Low’ scenarios, but continues to grow at nearly the same rate in the ‘High’ scenario. The growth of labour quality due to shifts in the age distribution is about the same in all three scenarios.

5 Robustness of results

In this section, we examine the sensitivity of our results with respect to alternative methods and data sets. Five alternatives are considered. First, the weights applied to changes in hours worked are calculated without reference to predicted wages. Second, the wage equation is estimated based on SLFS data instead of SEES data. Third, the number of categories of age and education is expanded to allow for greater heterogeneity. Fourth, the wage differential between the genders is allowed to result from discrimination. Fifth, we analyse the sensitivity of the methodology used for the prediction of labour quality growth up to 2050.

5.1 Weights on hours worked based on group averages: Jorgenson et al. (1987)

The main difference between the approaches of the Bureau of Labor Statistics (1993) and Jorgenson et al. (1987) is that the former constructs the weights for the aggregation based on predicted wage rates, whereas the latter uses the actual wage rates calculated as averages on the data for each worker group. Thus, following Jorgenson et al. (1987), we calculate the index of labour quality based on actual wage rates taken from the SLFS. Since the data for apprentices, family workers and self-employed are likely to be distorted, these three groups are excluded from the data set. The benchmark index is recalculated accordingly.

The results displayed in Figure 8 show that the two methods give similar answers. Differences are not negligible in individual years, but they are nonetheless relatively minor for the period 1991-2006 as a whole.

5.2 Estimation of earnings equation based on SLFS data

As described in Section 3, the SEES and the SLFS data can both be used to cross-classify wage rates with the education-age-gender characteristics of workers considered in this paper. The SEES data have been used in Section 4 to estimate (1). Estimating (1) based on SLFS data (for each year from 1991 to 2006) and calculating the index of labour quality gives the results presented Figure 9.¹⁵

¹⁵Since the wages of apprentices, family workers and self-employed may be distorted, we exclude them for the estimation of (1).

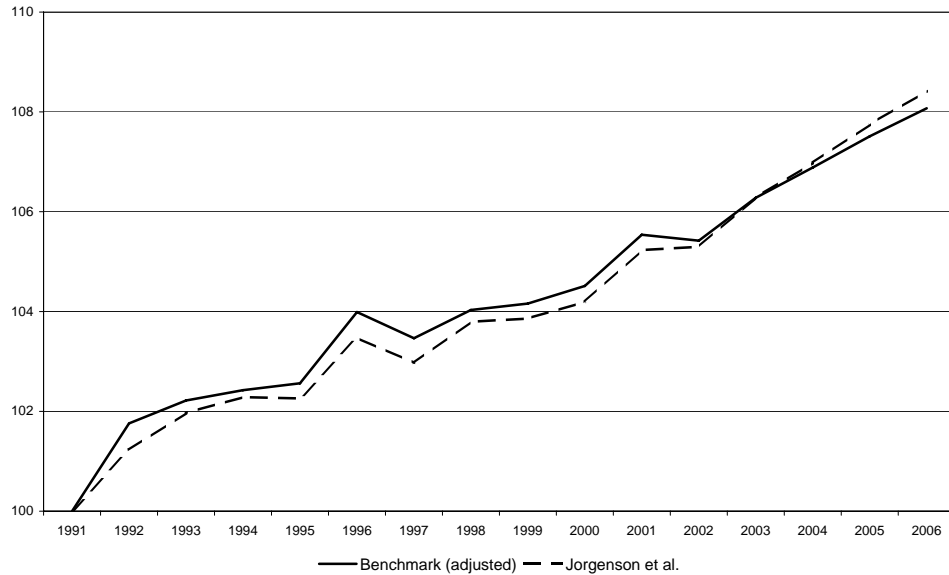


Figure 8: Index of labour quality: method by Jorgenson et al. (1987)

The differences are moderate over the period 1991-2006 as a whole. In 2006, after 15 years, the benchmark index exceeds the SLFS-based index by just 1.2 pp. However, the bulk of this difference is attributable to the years from 2002 to 2006. The start of the process may be related to the introduction of the free movement of persons as part of the Swiss/EU bilateral agreements concluded in June 2002. Since 2002, the share of immigrants from neighbouring countries has increased considerably. The knowledge of these immigrants is likely to be easier to transfer to Switzerland than that of immigrants from other countries. As described above, the SEES includes cross-boarder commuters and workers with short-term permits while the SLFS/WV does not. So we expect the SEES-based estimates of growth in labour quality to exceed those based on SLFS/WV data.

5.3 Estimation of earnings equation with expanded set of categories

The results presented so far are based on 50 worker groups. In this section, two expansions are considered. First, the number of age categories is increased from five to ten. As a result, the number of worker groups doubles from 50 to 100. Second, the three economic sectors are included as additional

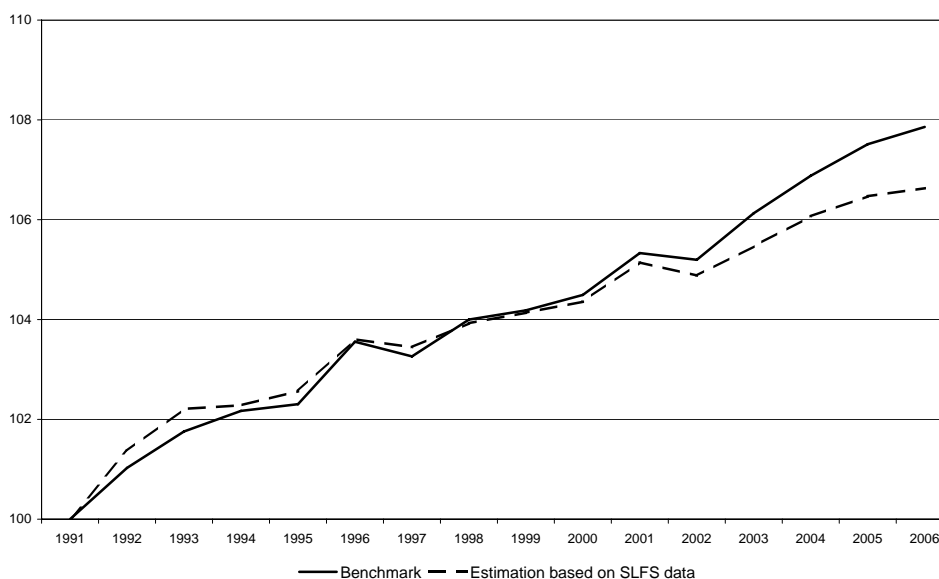


Figure 9: Index of labour quality: estimation of earnings equation with SLFS data

explanatory variables in (1), thus raising the number of worker groups from 50 to 150. As pointed out by Abowd, Kramarz and Magnolis (1999), wage differentials between sectors may reflect differences in average human capital that cannot be explained by variables that can be observed. Hence, substitutions between economic sectors can be used to capture changes in aggregate labour quality caused by shifts in the distribution of characteristics of the workforce that cannot be observed.

Figure 10 summarises the results. Overall, the increase in the number of categories causes the index of labour quality to rise more rapidly, suggesting that the growth of the benchmark index should be interpreted as the lower bound of the true growth rate. Differences are fairly small, however, in relation to the total size of the increase in labour quality over the period 1991-2006.

5.4 Interpretation of the differences in returns between men and women as discrimination

By estimating (1) separately for men and women, we have assumed that the wage differential between the two genders reflects differences in productivity. This assumption is questionable, given the evidence of labour market discrim-

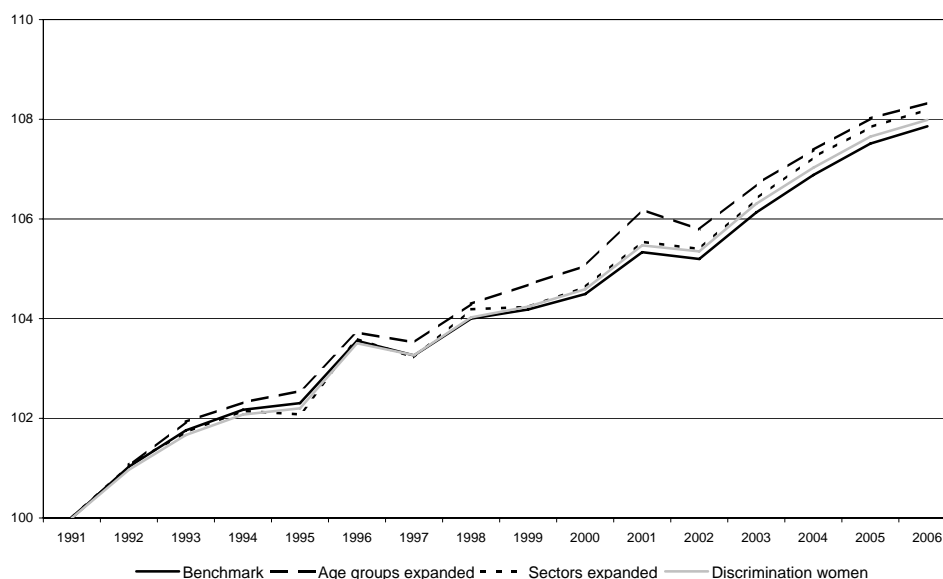


Figure 10: Index of labour quality: set of worker characteristics expanded

ination against women (see e.g. Bonjour and Gerfin, 2001, and Sousa-Poza, 2001). In order to test whether the interpretation of the wage gap affects our results for the index of labour quality, we recalculate the index based on the alternative assumption that discrimination is the only cause of the observed wage gap between men and women. We do this by adding a binary dummy variable for gender to (1); estimating the equation for all observations; and setting the coefficient on the gender dummy to zero when the predicted wage rates, $\hat{q}_{i,t}$, are calculated.

The resulting index of labour quality is shown in Figure 10, together with the benchmark index. The index is marginally shifted upwards, leading us to the conclusion that it is irrelevant for our results whether discrimination or productivity is seen as the source of the wage differential between men and women.

5.5 Examining the assumptions underlying the 2006-2050 projections of growth in labour quality

The projections of the index of labour quality over the period 2006-2050 are based on a number of auxiliary assumptions which may prove to be incorrect. These assumptions concern the construction of the series of hours worked and

the estimation of the earnings equations.¹⁶ To assess the potential impact of the assumptions on the forecasts, we apply them to the calculation of the index of labour quality in 1991-2006 and compare the results with the benchmark results from Section 4.1. Figure 11 shows the effect of the assumptions in cumulative form. The benchmark results are given for comparison.

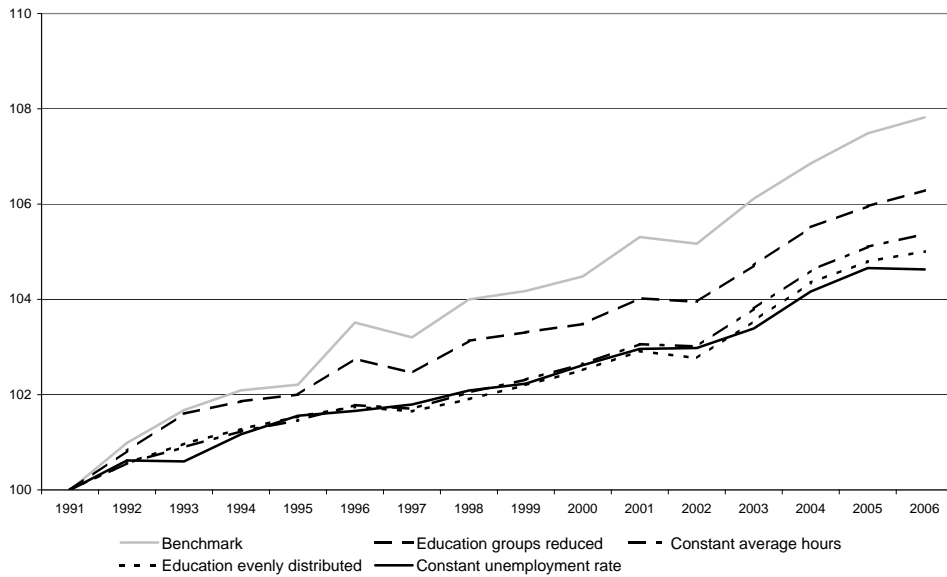


Figure 11: Labour quality indices over 1991-2006 based on the auxiliary assumptions underlying the 2006-2050 forecasts

The first assumption is that three (instead of five) categories of education capture the relevant substitutions. The resulting index is labelled “Education groups reduced”. The gap between this line and the line depicting the benchmark results in Figure 11 represents the effect of reducing the categories of education from five to three. The results show that growth in labour quality over the period 1991-2006 is adjusted downwards by 1.5 pp overall, or 0.1 pp per year.

The second assumption is that the number of hours worked per employee of a given worker group is constant at the level of 2006. In Figure 11, the effect of this assumption on the results is represented by the difference between “Constant average hours” and “Education groups reduced”. The results suggest that growth in labour quality over the period 1991-2006 is reduced by 1.3 pp overall, or less than 0.1 pp per year.

¹⁶See Section 3 on data and 4.3 on forecasts.



Figure 12: Forecasts of labour quality growth with and without correction for methodology bias

There are three other assumptions which appear to have very little effect on the results. The third assumption is that the distribution of education in a given year is the same for all age categories. The fourth assumption is that the unemployment rate for a given worker group does not vary over time and corresponds to the 1991-2006 average. The fifth assumption is that the returns to characteristics can be estimated with a pooled regression (instead of being estimated separately for each year). The effect of the third and fourth assumptions are represented by the gap between “Education evenly distributed” and “Constant average hours”, and between “Constant average hours” and “Constant unemployment rate”, respectively. The effect of estimating the wage equations with a pooled regression is negligible and therefore is not reported in Figure 11.

Overall, we find that applying the auxiliary assumptions from the forecasts to the calculation of the index of labour quality over 1991-2005 causes growth rates of labour quality to fall significantly. The average ratio between the growth rates of the benchmark index and the alternative index is 1.66. We do not know how this ratio will change over time. Therefore, we set it constant at 1.66 and recalculate the forecasts of the index of labour over 2006-2050 accordingly. The results are shown in Figure 12, together with the predicted growth rates of the labour quality index presented in Section 4.3

(“Reference” scenario). The growth rates are higher than in the benchmark forecast, but are still projected to approach zero at the end of the forecasting period.

6 The quality-adjusted unemployment rate

This section examines the impact of constant quality measures on the rate of unemployment. As pointed out by Greenwood and Kohli (2003), quality-adjusted unemployment rates are more appropriate than unadjusted (conventional) rates when the focus is on the output loss caused by the underutilisation of the labour force. The method is presented in Section 6.1 followed by the results in Section 6.2.

6.1 Methodology

To calculate a quality-adjusted measure of unemployment, we need constant-quality measures of the labour force and the unemployed workers. This brings two notational changes. First, the workers considered now include employed and unemployed persons. Second, because hours worked do not exist for the unemployed, the focus is shifted from the effective hours worked per worker group to the number of persons per worker group.

Let the observations in each worker group j be indexed as

$$i \in j = \{1, 2, \dots, I, I + 1, \dots, F\}, \quad (13)$$

where F denotes the number of all workers, employed and unemployed. Then, the labour force of worker group j is calculated as

$$f_{j,t} = \sum_{\substack{i=1 \\ i \in j}}^F \omega_{i,t}, \quad (14)$$

and the employed workers of group j is calculated as

$$e_{j,t} = \sum_{\substack{i=1 \\ i \in j}}^I \omega_{i,t}. \quad (15)$$

In principle, the constant-quality measures of the labour force can be obtained based on estimation of the translog aggregator function with econometric methods. In this paper, we adopt a Cobb-Douglas aggregator function

and take the index-number approach. Greenwood and Kohli (2003) apply the econometric approach as well as the index approach to US data. They find that the translog measure of the rate of unemployment comes quite close to the Cobb-Douglas measure.

Based on the Cobb-Douglas aggregator,

$$g(\cdot) = \prod_j^J (e_{j,t})^{c_{j,t}}, \quad (16)$$

with $c_{j,t} \geq 0$, the quality-adjusted unemployment rate is calculated as

$$u_t^{CD} = 1 - \frac{\prod_j^J (e_{j,t})^{s_{j,t}}}{\prod_j^J (f_{j,t})^{s_{j,t}}}, \quad (17)$$

where

$$s_{j,t} = \frac{\hat{q}_{j,t} e_{j,t}}{\sum_j^J \hat{q}_{j,t} e_{j,t}}. \quad (18)$$

To examine the deviation of the conventional unemployment rate from a quality-adjusted rate in further detail, Greenwood and Kohli (2003) assume two alternative aggregator functions which represent extreme poles of substitution among worker groups. The linear aggregator function assumes the different worker groups to be perfect substitutes for each other. In contrast, the Leontief form of the aggregator function does not allow for any substitution among worker groups. The unemployment rate resulting from these two extreme assumptions can thus be viewed as the lower bound (Leontief function) and the upper bound (linear function) of the true unemployment rate.

Using the linear aggregator function

$$g(\cdot) = \sum_{j=1}^J a_{j,t} e_{j,t}, \quad (19)$$

with $a_{j,t} \geq 0$, the quality-adjusted unemployment rate is calculated as

$$u_t^{LN} = 1 - \frac{\sum_{j=1}^J \hat{q}_{j,t} e_{j,t}}{\sum_{j=1}^J \hat{q}_{j,t} f_{j,t}}. \quad (20)$$

Based on the Leontief aggregator function

$$g(\cdot) = \min \left\{ \frac{e_{1,t}}{b_1}, \frac{e_{2,t}}{b_2}, \dots, \frac{e_{J,t}}{b_J} \right\}, \quad (21)$$

with $b_j \geq 0$, the unemployment rate is calculated as

$$u_t^{LF} = 1 - \min\{u_1, u_2, \dots, u_J\}, \quad (22)$$

where the unemployment rate of worker group j is given by $u_{j,t} = 1 - \frac{e_{j,t}}{f_{j,t}}$.

6.2 Results

Figure 13 shows the Cobb-Douglas measure, the linear measure and the Leontief measure of the quality-adjusted rate of unemployment over the period 1991-2006.¹⁷ The conventional rate displayed in the same figure corresponds to the official rate published by the FSO. It can be computed based on (20) with all weights set equal to one, $\hat{q}_{j,t} = 1$.

We find that the conventional unemployment rate is always outside the boundaries of the quality-adjusted rate determined by the Leontief and the linear aggregator functions. The average discrepancy between the conventional rate and the upper bound is 0.29 pp. This corresponds to an average upward bias of about 9% of the number of unemployed persons. Assuming that the Cobb-Douglas rate represents the true quality-adjusted unemployment rate gives about the same upward bias. The bias appears to be smaller than in US data. Greenwood and Kohli (2003) report an upward bias of 14%.

The results displayed in Figure 13 imply that the average human capital of employed workers exceeds that of unemployed workers. To make this point explicit, we can calculate the labour-quality ratio between employed and unemployed workers. Aaronson and Sullivan (2001) have done this for the US based on the linear aggregator function. They find that the ratio was bouncing between 1.15 and 1.20 during most of the period 1964-2000. Figure 14 shows the corresponding results for Switzerland.

Three points can be made. First, the quality ratio is 1.10 on average during the period 1991-2006, implying that the human capital of an employed worker was 10% higher than that of an unemployed worker. Second, the trend

¹⁷Also see Table 4 in the Appendix below. To calculate the Leontief measure, education is used as the only worker group characteristic. This is necessary to reduce the number of worker groups. If we utilise the same amount of worker groups as before (50), the resulting unemployment rate is 0% in all years. This is due the fact that distributing the relatively small number of unemployed workers among the large number of worker groups always results in at least one empty cell.

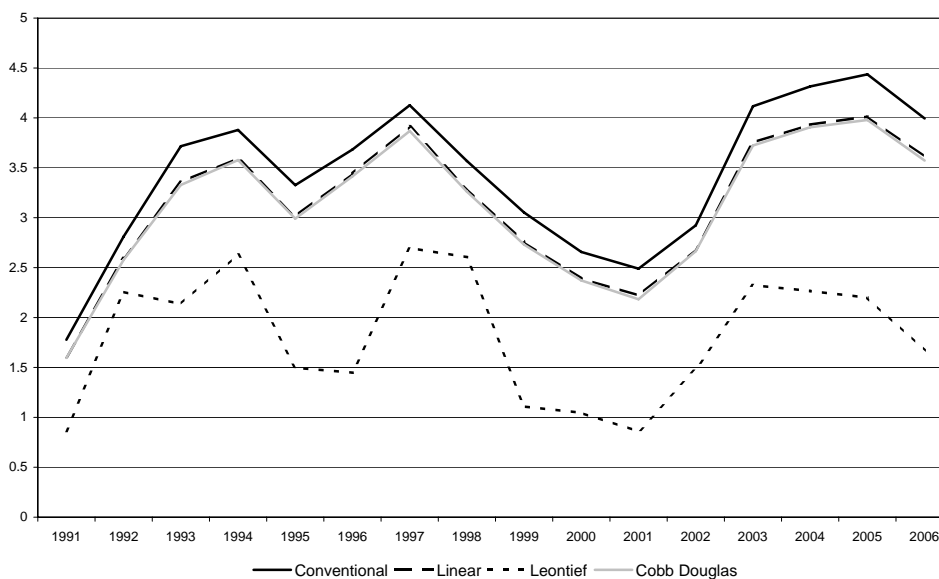


Figure 13: Various measures of labour market slack

of the quality ratio appears to be flat, which implies that human capital per employed and per unemployed have grown at about the same rate. Third, there are some variations over the period with a high of 1.12 in 2001 and a low of 1.05 in 1997. Because the unemployment rate was low in 2001 and high in 1997, this suggests that the swings in the quality ratio are related to the business cycle. That is, the gap between the human capital of the employed and the unemployed tends to shrink in a recession and to widen in a boom.

7 Conclusions

In this paper we have applied the methodology developed by the Bureau of Labor Statistics (1993) to measure the growth of labour quality in Switzerland between 1991 and 2006. We find that human capital has grown at an average annual rate of 0.51%. The results are robust to changes in the specification of the earnings equation and the underlying data set. The method proposed by Jorgenson et al. (1987) also gives quite similar results.

The increase in the index of labour quality is mainly caused by growth in the average levels of education. Changes in the age distribution reflecting the passage of baby boomers through the age structure of the workforce have also contributed to growth in human capital. Changes in the gender

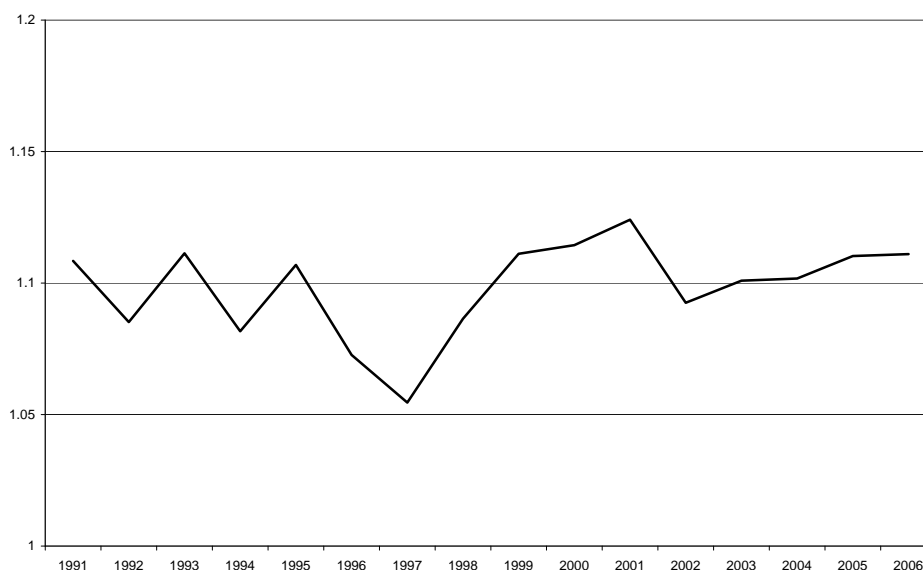


Figure 14: Ratio of labour quality of employed workers to unemployed workers

distribution of the workforce, however, have not affected the index of labour quality significantly.

Growth of labour quality has been highest for services and lowest for agriculture. A more detailed analysis reveals that growth of human capital in the service sector is driven by the finance and insurance sectors. We further find that, even though growth of human capital is rather sluggish for the industrial sector as a whole, it is only slightly below average for the manufacturing sector.

The forecasts of labour quality over the period 2006-2050 suggest that growth rates will decline with time. During the last decade of the forecasting period, they are close to zero. This decline can be traced back to lower contributions to human capital growth from both the educational and the age composition of the workforce.

Aggregate measures of labour quality can be used for various purposes. First and foremost, they can be used to calculate more accurate measures of labour input in calculations of productivity growth. As the share of labour compensation (adjusted for mixed income) amounts to about 0.7 during the period 1991-2006, measures of multi-factor productivity growth are about 0.3 pp to 0.4 pp smaller when the increase in labour quality is taken into account.

Finally, following Greenwood and Kohli (2003), we have calculated a set

of quality-adjusted rates of unemployment. We find that the conventional unemployment rate has always been higher than these quality-adjusted rates, implying that the human capital of the average employed worker has been higher than that of the average unemployed worker.

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Appendix: Tables

Table 1: Indices of labour quality for total economy and sectors, average growth rates in percent

	1991-2006	1991-1996	1996-2001	2001-2006
Total Economy	0.51	0.70	0.34	0.48
<i>Agriculture</i>	0.40	1.48	0.46	-0.75
<i>Industry</i>	0.33	0.57	0.13	0.30
Manufacturing industries	0.46	0.83	0.15	0.41
Construction	-0.05	-0.20	-0.08	-0.12
<i>Services</i>	0.55	0.71	0.40	0.55
Sale, repair	0.29	0.52	0.06	0.29
Hotels and restaurants	0.30	2.34	-0.91	-0.50
Transport, communication	0.48	0.28	0.71	0.45
Banking, insurance	0.83	1.35	0.28	0.84
Real estate, renting, R&D	0.60	1.32	0.03	0.46
Public Administration	0.65	0.27	0.86	0.84
Education	0.33	0.86	0.00	0.13
Health and social work	0.59	0.96	0.85	-0.03
Other social activities	0.68	0.50	1.25	0.29

Table 2: *Partial indices for education, age and gender, 1991=100*

	Total	Education	Age	Gender	E-A	E-G	A-G	E-A-G
1991	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1992	101.03	100.81	100.33	100.06	99.86	99.96	99.99	100.03
1993	101.76	101.25	100.73	100.16	99.74	99.91	99.95	100.02
1994	102.17	101.24	101.23	100.09	99.66	99.91	100.01	100.02
1995	102.30	101.41	101.23	100.14	99.62	99.86	99.96	100.07
1996	103.56	102.41	101.64	100.09	99.51	99.87	99.91	100.10
1997	103.26	102.17	101.61	100.10	99.52	99.88	99.86	100.11
1998	104.00	102.84	101.84	100.03	99.40	99.85	99.88	100.14
1999	104.18	103.05	101.88	100.05	99.37	99.84	99.83	100.14
2000	104.49	103.48	101.82	100.00	99.36	99.86	99.83	100.12
2001	105.33	104.09	102.09	99.99	99.36	99.82	99.83	100.12
2002	105.20	104.03	101.94	99.95	99.45	99.84	99.84	100.12
2003	106.13	104.83	102.13	99.96	99.40	99.82	99.81	100.14
2004	106.88	105.48	102.25	99.95	99.33	99.82	99.83	100.16
2005	107.51	106.00	102.39	99.94	99.28	99.84	99.84	100.16
2006	107.86	106.29	102.36	99.94	99.36	99.83	99.83	100.18

Table 3: *Projections of index of labour quality for three scenarios, average growth rates in percent*

	2006-2050	2006-2010	2010-2020	2020-2030	2030-2040	2040-2050
High	0.19	0.24	0.24	0.21	0.16	0.12
Reference	0.13	0.23	0.22	0.16	0.08	0.03
Low	0.13	0.23	0.20	0.16	0.10	0.04

Table 4: *Conventional and quality-adjusted unemployment rates*

	Conventional	Linear	Leontief	Cobb Douglas
1991	1.78	1.61	0.86	1.60
1992	2.81	2.60	2.26	2.58
1993	3.72	3.36	2.13	3.33
1994	3.88	3.60	2.64	3.58
1995	3.33	3.02	1.50	2.99
1996	3.68	3.44	1.45	3.41
1997	4.13	3.92	2.70	3.87
1998	3.57	3.29	2.60	3.26
1999	3.05	2.76	1.11	2.73
2000	2.66	2.39	1.05	2.37
2001	2.49	2.22	0.86	2.18
2002	2.92	2.68	1.48	2.66
2003	4.12	3.75	2.32	3.72
2004	4.32	3.93	2.27	3.91
2005	4.44	4.01	2.20	3.98
2006	3.99	3.61	1.67	3.57

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