J Popul Econ (2004) 17:83–116
DOI 10.1007/s00148-003-0141-6

Journal of Population Economics

The gender gap in labor market participation and employment: A cohort analysis for West Germany

Bernd Fitzenberger[1], **Reinhold Schnabel**[2], **Gaby Wunderlich**[3]

[1] University of Mannheim, Department of Economics, 68131 Mannheim, Germany (e-mail: bernd.fitzenberger@vwl.uni-mannheim.de) and ZEW, IFS
[2] University of Essen, Department of Economics, 45117 Essen, Germany (e-mail: reinhold.schnabel@uni-essen.de) and ZEW
[3] Centre for European Economic Research (ZEW), Department of Labour Economics, Human Resources, and Social Policy, 68161 Mannheim, Germany (e-mail: wunderlich@zew.de)

Received: 7 August 2001/Accepted: 11 September 2002

Abstract. Labor market participation rates of West German females have risen during the last decades, whereas participation rates of males have declined or remained stable. Nevertheless, differences in aggregate gender specific participation rates remain. The purpose of this paper is to compare life-cycle participation and employment profiles of West German males and females of different skill levels. Going beyond the descriptive cross tabulations of participation and employment rates by year, skill level, and sex, this paper uses a model which simultaneously takes into account the effects of time, age, and birth cohort membership. The estimation results allow for the construction and comparison of gender and skill specific life cycle participation and employment profiles. Even though the gap in average participation and employment rates has narrowed over time, the results confirm a persistent gender gap in the pattern of labor market participation and employment over the life-cycle.

JEL classification: J16, J2, J71

Key words: Gender gap in employment and participation, cohort analysis

---

We are grateful for the comments of three anonymous referees and of the participants at the workshop on "Gender Differences in Earnings and Labour Market Participation in the U.K. and Germany" in January 2001 at the ZEW. The paper is part of the research project "Holen die Frauen auf? Ein Vergleich von Erwerbsverhalten, Beschäftigung und Verdiensten deutscher und britischer Frauen im Zeitverlauf" at the Centre for European Economic Research (ZEW). We thank the Hans-Böckler-Stiftung for financial support and ZUMA in Mannheim for letting us use the German Microcensus. *Responsible editor:* Christoph M. Schmidt.

1. Introduction

During the last decades female labor force participation has been rising in all western countries, whereas male participation remained stable or even declined. As a result, the overall gender gap in labor market activity rates has been reduced (OECD 1997). In West Germany, the participation rate of the prime age population (age 20–64) rose in the 1950s, reached a maximum in the early 1960s at 70%, and has declined since then to a level of 62% by the end of the 1990s. The employment rate of males fell from 95% to 77% over the period from 1960–1994. The main driving force behind this was the fall in employment and participation rates of the young (15–25 years) and the old (55 years and older) due to expanded schooling and early retirement, respectively (see Börsch-Supan and Schnabel 1998a, b). The employment rate of females (full- and part-time) rose from 48 to 59% during the same period, which can be attributed mainly to the rise in part-time employment.[1] As a result of increasing participation of females and decreasing participation of males, the aggregate employment gap has more than halved, dropping from 47 to less than 20 percentage points between 1960 and 1994 in West Germany.

Labor force participation rates for men and women rise with increasing educational attainment (see OECD 1997). For women, however, the impact of education on participation is even stronger. "Although a gender gap in labor force participation remains among those with the highest levels of educational attainment, the gap is much narrower than among those with lower levels of educational attainment. (...) Since earnings tend to increase with educational attainment, incentives are greater for persons with a better educational background" (OECD 1997: 243). As participation (and employment) rates differ across education or skill levels, we will disaggregate the analysis by skill groups.

The literature explains the large shifts in employment by changes in labor demand and labor supply (e.g., Franz 1999; Goldin 1990; Jacobsen 1998). On the side of labor demand, changes took place in demands for goods and services, in the productivity of different groups of workers, in prices for non-labor inputs, and in the competitiveness of the economy. Frequently cited factors that explain an increase in labor demand for women are: a general rise in labor demand, which was difficult to satisfy by employing male workers; a shift in product demand towards goods of the service sector. At the same time, males were disproportionately affected by the decline in the traditional manufacturing sectors.

On the supply-side changes in household budget constraints, household production, and preference shifts took place. Female labor supply has probably reacted to time saving technologies of household production and to changes in family composition. The rising educational attainment of females has increased their opportunity costs of non-participation. On the other side, males have reacted to rising wages, increasing non-earned incomes, and early retirement incentives by reducing their labor supply. Jacobsen's (1998: 136) conclusion for the US is more or less applicable to all western societies:[2] "Women have, in general, increased their labor force participation, while men have reduced theirs. Both demand and supply curve shifts have led to these changes. In particular, the increase in available income during the late middle age has led men to retire earlier, and the increased demand for clerical and service labor has led to an increase in women's working, even during child raising years. Female and male work patterns over the life span have become more similar as well."

However, international comparisons uncover differences in employment patterns. This suggests that – in addition to demand and supply factors – social norms and institutional frameworks play an important role for female employment.[3] Particularly, the employment of mothers of small children depends on social institutions and norms (Rubery et al. 1999: 87). International differences in age related participation of females (and in fertility behavior) can be attributed to differences in social institutions, such as the availability of child care facilities or employment guarantees during maternity leave.

Different institutional settings together with demand and supply factors may result in very different age profiles of employment. Rubery et al. (1999: 84) distinguish three different age-specific employment patterns (see also OECD 1988: 49, 134):

- Plateau or inverted U-shaped curve: Labor market activity rises strongly up to an age of around 30 years, stays constant, and starts falling strongly at around 55 years. For females this represents an institutional setup under which child raising and employment are compatible.
- M-shaped curve or women returner curve: This curve exhibits a valley during the child raising ages of females. "Such a profile is usually generated when the presence of young children is the major barrier to participation" (OECD 1988: 49). After an interruption due to the family phase, women return to the labor force.
- Left hand peak curve or permanent labor market exit curve: The age related participation rate of females peaks early in the life-cycle and declines continuously. "This pattern is observed in societies where many women permanently withdraw from the labor force after marriage and/or children" (OECD 1988: 49).

These patterns are not constant over time (see OECD 1988: 132). Concerning cross-sections, it is necessary to differentiate between shifts and changes of their shape over time. Vertical parallel shifts of the age related cross section profile indicate intra cohort participation change over time whereas a change of shape of the cross-section profile exhibits inter cohort differences of participation in that successive cohorts move through their employment life-cycle and change age related participation rates. (For each younger cohort of women participation per se as well as timing and duration of job interruptions may have changed gradually.) If cohorts do not behave differently then age related patterns in participation rates are the same across cross-sections. By looking at differences in participation rates of synthetic cohorts, these processes can be analyzed (see for example OECD 1988: Chapts. 1 and 5, Shaw 1994: 351; Jacobsen 1998: 114).[4]

Empirical investigation of labor market participation, i.e., labor supply and female labor supply in particular, is usually carried out using structural models and individual data (see Blundell and MaCurdy 1999, for a comprehensive overview). The aim of this kind of analysis is to understand how behavior depends on individual or household characteristics, as well as on macro controls (to allow for demand side effects). In comparison to the wide variety and large number of studies in this field only few empirical studies investigate aggregate labor market participation.[5] These studies have mainly analyzed bivariate correlations, e.g., participation by education or by birth cohort (OECD 1988, 1997; Blundell and MaCurdy 1999; Jacobsen 1998; Kommission für Zukunftsfragen 1996). If, however, participation is affected by shifts in labor demand, by independent shifts in cohort behavior, and, at the same time, by life-cycle effects, it is not sufficient to investigate bivariate correlations.[6]

Thus, our strategy is to investigate the change of labor market activity over time, age, and birth cohort simultaneously and to separate the effects of these variables. We use the decomposition approach of MaCurdy and Mroz (1995) which additionally allows to test for separability of age, cohort, and time effects. The approach of investigating social change by using some kind of cohort analysis is not new (see Mason and Fienberg 1985). Although there has been various work based upon individual data, decompositions of aggregate data into age, time, and cohort effects are quite rare.[7] To our knowledge, this paper is the first application of cohort analysis to aggregate labor market activity rates in Germany. The MaCurdy and Mroz approach is also used by authors in other fields of research, e.g., in the analysis of savings behavior by Attanazio (1998).

The focus of our empirical analysis is the change of participation and employment rates across cohorts for men and women of different skill levels controlling for time and age effects. We investigate whether the hypothesis of a closing gender gap in labor market activity is true for West Germany. If the gender gap in participation (or employment) has declined, we could expect to find cohort effects due to a change in market relevant characteristics, after controlling for time trends, cyclical influences, and aging. Since aggregate part-time employment has expanded during the last decades, we also investigate part-time and full-time employment of females separately.

Our subsequent empirical analysis takes account of the issues discussed above. First, differences in participation across education groups should be visible in the estimated intercept and time trends. Second, economic restructuring, obsolescence of unskilled work, as well as rising educational attainment, i.e., smaller aggregates of the unskilled in comparison to larger aggregates of medium and high skilled, should result in different time trends across skill levels.[8] Low skilled male employees should exhibit a negative time trend, whereas for high skilled male employees we expect the time trend to be positive, which we would take as evidence for a fall in labor demand for low skilled and a rise in demand for high skilled male employees.

For females, we expect the time trends of participation rates and employment rates to be positive across all skill levels. The shift from traditional male sectors (agriculture, mining, manufacturing) to the service sector should increase the demand for female workers with medium and in particular with low skills. This demand shift is reinforced by the still existing gender wage gap. Moreover, a higher participation in education and training has decreased the numbers of low skilled women, both, relative to unskilled males and relative to the numbers of skilled women. Thus, low skilled women are both cheap to employ and scarce compared to men. In addition, we expect to find different profiles of participation for men and women across age, because age related participation of females is still very much influenced by the birth of children.

The remainder of the paper is organized as follows. Section 2 describes the data and discusses some basic trends. Section 3 develops the empirical model to distinguish cohort, age, and time effects. In Sect. 4 we first present the results on participation before turning to employment. Subsequently, we present the results for part-time and full-time employment. Section 5 concludes. The Appendix provides more details on the data (A.1) and the empirical model (A.2). Appendix 3 contains the empirical results in tables and figures.

2. Data description and basic trends

Since 1957, the Federal Statistical Office has conducted an annual population survey called the Micro-Census (Mikrozensus), which can be compared to the U.S. Current Population Survey (CPS). The Micro-Censuses are the main source of official population and labor market statistics in Germany. The surveys are one percent random samples of the residential population in Germany, stratified by some regional variables (state, size of city or county, etc.). Contrary to the CPS, the interviews are all conducted at the same time of the year so that no seasonal information is available. After the reunification of Germany, the East German population has been added. The primary sampling units are households. All household members of age 16 and older are personally interviewed. Before German unification, the sample size was approximately 250,000 households and 600,000 persons. The questionnaire is regulated by federal law and includes information on demographics, household structure, labor market status, and sources of income. Unfortunately, access to the raw data is limited because of restrictive data protection regulations. Upon submission of a research proposal to the Federal Statistical Office, the latest surveys can be obtained for scientific use. The older waves are still not available to the scientific community.

However, we could use the subsamples of the Micro-Census at the ZUMA Mannheim which contain a limited – and for our purpose sufficient – collection of variables for survey years from 1976–1995. The subsamples range from 70%–98% of the original samples.[9] We had to restrict the sample period due to a lack of consistent information on the skill level in the older censuses. Our working samples cover all West German residents in private homes (excluding institutionalized population). This also includes all nationalities living in Germany. For obvious reasons, we have to exclude the East German population from our analysis.

The employment status variable in the Micro-Census is defined according to the ILO-Standard. A worker is considered unemployed ("erwerbslos") if he or she did not work and was actively searching for a job. Similarly, a person is considered employed ("erwerbstätig") if he or she worked for money (either self- or dependently employed), and out-of-labor force ("nicht erwerbstätig") if neither of the former two conditions applied. Adding up the cases in the three categories yields the population.

The definition and measurement of labor market statuses in the Micro-Census differ from those that are used by the Federal Labor Office (Bundesanstalt für Arbeit). The labor market status variables in the Micro-Census are self-reported. The official rate of unemployment ("arbeitslos") is based on the entire population of persons who are officially registered as unemployed. The official unemployment rate is then calculated as the number of registered unemployed divided by the number of dependently employed (only civilian). The unemployment rates that we report are in general lower than the official rates due to (i) underreporting of unemployment in the survey, (ii) the ILO-requirement of active job search, and (iii) inclusion of the self-employed in the denominator.

Our analysis considers employment rates and participation rates. The employment rate (*ER*) is measured as the number of employed persons divided by the number of persons in a given age group for each year (age-year cell). The participation rate (*PR*) is calculated as the number of labor market participants (i.e., employed plus unemployed) divided by the total number of persons in a given age group for each year. We disaggregate further by gender and skill level. Participation and employment rates are thus calculated separately by gender and skill for each age-year cell.

We distinguish three skill levels which are defined by the highest degree of occupational training that a person has achieved. We use the degree as a proxy for the skill level of a person. The definition of skill groups is as follows:

Low skilled (*U*):	No vocational training degree
Medium skilled (*M*):	Vocational training degree, i.e., apprenticeship, period of practical instructions or training, master certificate or technical expert
High skilled (*H*):	Technical college or university degree ("Fachhochschule" or "Universität")

The sample sizes of the survey are large. The average size of the age-skill-gender cells is more than 3000 in each year. The cell sizes are never less than 2000. The employment and participation rates can thus be estimated with negligible standard errors.

Item non response in the skill variable may have two reasons. First, many persons have not yet finished their education. This is why non response is decreasing with age. Second, in some of the sample years the answer to this question has been voluntary. Apparently, some persons refused to answer this question. For those sample years, we corrected the employment and participation rates using also information from the years when the question was compulsory (see Appendix A for a description of the method of imputation).

In Fig. 1 in the Appendix A.3 we present a description of the relative sizes of the skill groups. Figure 1 is separated into females and males and displays how the three skill groups developed separately over time based on the raw data. We plot the relative size of a skill group (relative to the number of persons in the age group at time *t*) against time. The skills of the female labor force have increased dramatically over the 15 sample years. In 1976 over 50% of the women aged 40 and above did not have any formal training and only less than 5% of these age groups had a college degree. In the year 1995 the same age groups display much higher skill levels. The fraction of low skilled males halved over the sample period 1976–1995 for age groups above 30. However, due to the increasing duration of education, the relative number of low skilled has stayed constant for younger males (age group 25–29). In total, the labor supply of low skilled has dropped considerably. However, there is still a gender skill gap: in the year 1995 more than 20% of women report no formal training at all, while the numbers for men are much lower at 10–15%.

The relative size of the medium skilled male groups did not change at all, whereas the numbers of medium skilled women have increased and now almost reach the male level of about 70%. The relative sizes of the high skilled groups more than doubled during the sample period. Women, especially, increased their college participation. In the year 1995 17% of the males in the age group 30–34 and 12.5% of the women had a college degree. Again, since German students usually complete their college degree between the age of 25 and 30, the age group 25–29 does not display any significant change over the sample period. In total, the number of high skilled men and women has increased dramatically over the past 20 years, thus, leading ceteris paribus to an increased labor supply.

The charts in Fig. 2 in the Appendix A.3 show the employment trends based on the raw data for the age groups 25–29 (age 25), 35–39 (age 35), 45–49 (age 45), and 55–59 (age 55). (The shapes of the participation rates are very similar and are not shown here.) The employment trends differ greatly between males and females. The age-specific employment rates have declined across all skill groups for males. This is not the case for women: female age-specific employment rates have either risen (in the group of the medium skilled) or have stayed fairly constant (in the groups of the low skilled and the high skilled).

A very outstanding feature is the massive decline in the employment rates of low skilled males. At younger and older ages, employment rates were lower than 55% in the year 1995. Only about half the working capacities of these groups are used in Germany. For the middle age groups of the low skilled males, the decline was still considerable (from above 90% down to barely 80%) but not as steep. The employment rates of women in the group of the low skilled have no clear trend. Employment has increased slightly in the middle age groups.

The gender gaps in employment rates have narrowed considerably over the 20 sample years in the groups of low and medium skilled workers. The gender gap used to be around 40 percentage points in 1976 for the low and medium skilled but, depending on which skill group and age is studied, it has narrowed to between 13 and 25 percentage points in the mid 90's.

In the group of the high skilled the gender gap has not changed much. It hovers around 10 percentage points in the younger age group, and it has narrowed some 5 to 10 percentage points to around 18% in the higher age groups.

For females, we also distinguish part- and full-time employment. The age profiles of full-time employment differ from the age profiles of part-time employment profiles (see Tables 1 and 2). Full-time as well as part-time employment rates of low skilled females are low in comparison to medium and high skilled women across the whole age range from 25 to 60 years. The various cross sections exhibit some variation over time (see Tables 1 and 2). In particular, part-time employment rates from the youngest to the oldest age groups increased considerably in all skill groups. Comparing full-time employment rates of the several skill and age groups in the years 1976 and 1995 shows that full-time employment seems to be mostly decreasing, in particular for low skilled females.

3. Empirical model

We investigate the labor force participation rates (PR) and employment rates (ER)[10] over the years 1976 to 1995 for different cohorts stratified by gender and skill levels. A cohort is defined by the year of birth. We use the framework that was first developed in MaCurdy and Mroz (1995) to analyze wage trends in the United States. It has also been applied in Fitzenberger (1999), Fitzenberger and Wunderlich (2000), and Fitzenberger et al. (2001) in the context of estimating wage equations. This section outlines the basic empirical approach. Further methodological details can be found in the appendix.

Based on longitudinal data, we would like to separate the patterns of employment and participation in age, cohort, and time effects. The age effect describes how the labor market behavior of a given cohort changes as the cohort ages. The time effect describes how macro economic shocks shift the labor market outcomes for a given cohort. Cohort effects summarize the difference between cohorts. Of course, it is well known that the three effects cannot be separately identified. More specifically, the linear effects of time, cohort, and age are not separately identified without further prior assumptions. This is due to the fundamental identity that links birth year c, age α, and calendar time t

$$t = c + \alpha. \tag{1}$$

Let PER denote the variable PR or ER in the following. PER for a cohort c at age α is represented as

$$PER(c, \alpha) = g(c, \alpha) + u, \tag{2}$$

where u is a residual component.[11] PER can alternatively be represented as a function of α and t or equivalently as a function of c and t):

$$g(c, \alpha) \equiv g(t - \alpha, \alpha) \equiv f(t, \alpha). \tag{3}$$

$g(c, \alpha)$ specifies the longitudinal (cohort) profile for a given cohort c over age. $f(t, \alpha)$ specifies the cross-sectional age profile at a given t. Our empirical analysis uses a polynomial representation of $g(c, \alpha)$. We start with the following additively separable specification of cohort, time, and age effects (for more details, see Appendix A.2):

$$g(c, \alpha) = G + K(c) + A(\alpha) + B(t), \tag{4}$$

where $K(c)$, $A(\alpha)$, and $B(t)$ are polynomials in c, α and t respectively. We call $K(c)$ the "cohort effect", $A(\alpha)$ the "pure age effect" (or "life-cycle effect"), and $B(t)$ the "time effect". Due to the identity (1) $B(c + \alpha) \equiv B(t)$, the linear effects are not identified without further restrictions. However, the coefficients on the second, third, etc., powers in c, α, and t are identified.

As an identifying assumption, the linear cohort effect in the polynomial $K(c)$ is set to zero. This assumption is motivated by Eq. (4) – see also Eq. (12) in the Appendix – which for a given cohort allows a separation of changes over time into a pure age and a pure time effect; both are common to all cohorts in the labor market. In light of this condition, setting the linear cohort term to zero is quite natural based on the following argument. If $K(c) = 0$, i.e., only a linear cohort term exists, then the entire cross-section profile $f(\alpha, t)$ exhibits purely parallel shifts over time, a situation, one would not naturally characterize by "cohort effects".

Note that the sum of two effects can be identified without additional assumptions. For instance, the sum of age and time effects is identified and yields the longitudinal profile (cohort profile) $A(\alpha) + B(t)$ for each cohort as the change over time and age relative to the cohort specific level $K(c)$. The shape of these longitudinal profiles differs between cohorts since each cohort experiences the time (macroeconomic) effect at a different point of the life-cycle.

The specification of the cohort effect $K(c)$ differs between those cohorts born before 1951 (i.e., younger than 25 in the first sample year 1976) and younger cohorts born later. In the case of a third order polynomial for the older cohorts and a second order polynomial for the younger cohorts – with the linear effects set to zero – the cohort effect is:

$$K(c) = K_{b2} \cdot c_b^2 + K_{b3} \cdot c_b^3 + K_{a2} \cdot c_a^2, \tag{5}$$

where K_b and K_a are the coefficients to be estimated. For cohorts born before 1951 the variables are $c_a = 0$ and $c_b = c$; for cohorts born after 1951 $c_a = c$ and $c_b = 0$. We make this distinction since we do not observe the labor market entry of the older cohorts. The choice of polynomials is justified since the analysis does not intend to forecast *PER* outside of the observed sample. In the empirical analysis we actually center the variable α around age 25 and the variable t around year 1976. All variables are also divided by 10, with $\alpha = (age - 25)/10$, $t = (year - 1976)/10$, and $c = t - \alpha$. Thus, the cohort born in the year 1951 has $c = 0$.

An important issue is that of separability of the age, cohort, and time effects as assumed in Eq. (4). It is not clear from the outset that the labor market outcomes can be represented by such an additive function. We call this restriction the "hypothesis of a uniform insider trend" $\mathbf{H_{UI}}$ since Eq. (4) implies that the cohort profiles depend only upon age and time, relative to the cohort specific $K(c)$, defining the level at the entry into the labor market. Note that this hypothesis can be statistically tested without using the identifying restriction on the linear cohort terms. We use specific interaction terms of α and c for the statistical test (see Appendix A.2.3, Eq. 15).

In testing the separability restrictions, it may be important to use robust estimators for the variance-covariance matrix of the parameters. To this end, we use a block bootstrap procedure that controls for a fairly general pattern of correlation in the error term (see appendix). Only if the hypothesis of separability cannot be rejected, is it justified to speak of age, cohort, and time effects as being separate effects – conditional on our identifying assumption for the linear terms. Otherwise, the "age" effects depend also on cohort and calendar year and so on. A stronger restriction on the specification $g(c, \alpha)$ sets the entire cohort effect equal to zero, i.e., $K(c) = 0$. We denote this as uniform growth hypothesis $\mathbf{H_U}$ since under this hypothesis no level differences between cohorts exists. This hypothesis is tested separately for the cohorts born before 1951 and those born after 1951.

In the empirical analysis, we also estimate cyclical movements of participation or employment around its trend (see appendix) thus effectively estimating a year dummy for all available years. We start the estimation with the most general specification of $PER(c, \alpha)$, including an interaction term of age and cohort:

$$G + K(c) + A_1\alpha + A_2\alpha^2 + A_3\alpha^3 + A_4\alpha^4 + B_1 t + \sum_{\tau} k_\tau D_{YJ(\tau)}(t) + \rho R(\alpha, t), \tag{6}$$

where $K(c)$ is specified as in Eq. (5), $R(\alpha, t)$ denotes the interaction term to test for $\mathbf{H_{UI}}$, and $\sum_\tau \kappa_\tau D_{YJ(\tau)}(t)$ represent the cyclical year effects which are estimated as being uncorrelated with the linear trend $B_1 t$, see appendix for further details. We then search for the most parsimonious specification (e.g., order of the polynomials in age and cohort, interaction term) that is compatible with our data. The empirical estimates and graphical illustrations are presented in the following section.

4. Results and graphical illustrations

Based on the empirical framework introduced in the previous section, this section presents the empirical results. We investigate participation rates, total employment rates as well as full- and part-time employment rates separately. Various graphical illustrations are used to describe the findings of this paper. The detailed estimation results of our final preferred specifications can be found in the appendix. In Tables 3 and 4 we present the estimates of participation rates and employment rates for males and females of the different skill levels. In Table 5 we present the estimates of part-time and full-time employment rates for females. The final specifications are the outcome of testing for uniformity of time trends and age profiles across cohorts. The Tables 3 to 5 only contain the remaining significant regressors. Significance, respectively joint significance of the coefficients, is given at conventional levels. Standard error estimates are obtained by using a block bootstrap procedure to take into account dependencies of cells across time and cohorts (see Appendix for details). Because separability of age and time is not rejected for males and females of all skill groups, it is possible to construct time trends as well as age profiles in all cases.

The main findings of the empirical analysis are as follows: The final specifications do not differ between total employment and participation rates (implying similarity of both measures, as far as model specification is concerned, even though participation rates take unemployment into account) but between males and females. In the female category they differ across skill groups (see Tables 3 and 4). For males, the most restrictive model specification $\mathbf{H}_{\mathrm{U}}$ is always justified and exhibits a linear time trend and a quadratic age profile. This applies both to participation rates and employment rates. During the observation period employment and participation rates of males change less than those of females. In particular, employment and participation rates of males exhibit no cohort effects, and they do not swing across age groups – in contrast to the case of females involving a significant third order age polynomial and cohort effects for all skill groups. Distinguishing between full- and part-time employment rates for females, we investigate the hypothesis that the rise in female employment rates can be attributed mainly to a rise in part-time employment. The findings show a positive trend in full-time rates for medium skilled and a negative trend in full-time rates for low skilled females. Part-time rates exhibit a positive trend only for low skilled females. The life-cycle profiles differ strongly between full- and part-time employment. While full-time employment rates decline strongly with age part-time employment rates increase strongly.

4.1. Participation rates

The participation rate in a cohort-year cell is defined as the sum of employed and unemployed among the total number of persons within the cell (see Sect. 2). Table 3 and Figs. 3–4 in the Appendix contain the empirical results for participation rates. The most important aspect of the results is that male and female participation rates follow different models. In the case of males, the same model specification applies to all skill groups, such that a linear time trend and a second order age profile describe the data sufficiently. Descriptive evidence shows that average participation rates are lower for low skilled men compared to men with higher skill levels (see Sect. 3). In addition, the time trend is significantly negative for all skill groups but most negative for the low skilled. The time trend for low skilled workers may mingle a discouraged worker effect, declining demand for low skilled workers (because of skill-biased technological change), or substitution of female for male work. Comparing the age profiles, low skilled men differ again very strongly from medium and high skilled men. Their age profile is very steep, corresponding to their participation starting from a lower level. This finding of a low labor market attachment for low skilled men in their late twenties and early thirties is puzzling at first glance. However, this group includes persons in higher education (university, technical college) who have not finished their degree. In contrast, high skilled men exhibit the flattest age profile, declining only little after the age of 45. This observation reflects high labor market attachment, even at the end of the career. A marginally steeper decline after the age of 45 years can be detected for medium skilled workers. Taken together, male participation rates declined over time, steepest for the unskilled (−7 percentage points) and only little for the other skill groups (−1 percentage points). Age profiles show the traditional male plateau pattern, which is modelled best by a second order age polynomial.

The final specifications for females differ very much from the male specifications, and there are differences across skill levels as well. Descriptive evidence shows that the ranking of participation rates by skill level is even more pronounced than is the case for men. Only for high skilled women is average participation nearly as high as for medium and high skilled men. Concerning the linear time trend, we find a rise in participation for low skilled (13 percentage points) and medium skilled (17 percentage points) women, in contrast to high skilled women, who do not expand their participation over time. An explanation for an increasing labor market attachment at lower skill levels is that demand for female labor, caused by an expanding service sector or by the gender wage gap, has risen. This, along with a changing attitude towards work, might motivate employers to substitute female for male workers. A non-existent time trend for high skilled women might indicate that a further extension of labor supply is impossible for this skill group (higher education might always have been a commitment for a high degree of labor market attachment) or that demand for high skilled females is already saturated. Furthermore, a constant gender wage gap for this group (see Fitzenberger and Wunderlich 2000) might prevent some high skilled females from participating in the labor market in light of the difficulty to coordinate family and (full time) employment.

A third order age polynomial (which corresponds to our hypothesis stated in the beginning of the paper) fits the data for females best. Very interesting is the fact that the age patterns differ very much across skill levels, see Fig. 3: Participation rates of low skilled women do not change very much until age 45 and then begin to fall by a total of 16 percentage points until age 55. Medium skilled women reduce their participation rate by 14 percent between age 25 and 35. Their participation recovers a little until age 45 but then declines further. The participation rate of medium skilled females declines by 24 percentage points between age 25 and 55 with a comparatively stable period around age 40. Participation of high skilled women falls by 10 percentage points until age 35, climbs back to its starting point until age 50, and then falls again until age 55. Compared to men, it seems to be the case that the comparatively few low skilled females who would like to work, do so until they are 45 years old. We have, perhaps, left out important parts of the family phase of the low skilled women by restricting the data to cover only individuals who are at least 25 years old or the family phase is more spread out. Medium and high skilled females' participation rates show clearly the family phase valley, and high skilled females tend to return to the labor market, in contrast to medium skilled females, who rather exhibit a pattern of permanent exit from the labor market. In contrast, the younger cohorts of low skilled females exhibit both an age profile and a cross-section participation pattern almost without a valley. Figure 4 displays differences in age profiles of various birth cohorts caused by the time trend which applies to all cohorts. A possible interpretation of this finding is that low skilled females are split into a group of family oriented females who do not supply any labor and a group of females who would like to work. Maybe the latter can not afford to stay at home very long.

One could suspect, in general, that low skilled low paid females have, if married to a partner with high earnings, the strongest incentives, caused by the tax system, to stay out of the labor market. This possible splitting of low skilled females may reflect a selection process caused by tax splitting. In contrast to low skilled females, it might be the case that medium and high skilled females are reconciling family and employment to a much larger extent (maybe through part-time employment), in that incentives caused by tax splitting are weaker for these skill groups and these females use their higher human capital more effectively.

The empirical model makes a distinction between cohort effects before and cohort effects after 1976. Cohort effects for the year 1976 are normalized to zero. The time axis of the cohort-profile representation in Fig. 3 depicts the labor market entry of the various birth cohorts, which we assume to occur at age 25. The relevant part of the picture starts in entry year 1950 when the West German economy started recovering from the war. It becomes apparent that successive cohorts of high skilled females have expanded their participation, starting with birth cohort 1925, who entered the labor market in 1950. Medium skilled females also expanded their participation rate but to a lesser extent than high skilled females. This is in contrast to low skilled females, whose participation rate fell nearly continuously for all successive cohorts, staying constant for birth cohorts 1925–1950. We do not find cohort effects for birth cohorts of medium and high skilled females entering the labor market after 1975.

The hypothesis that male and female participation patterns have become more similar between 1976 and 1995 is evaluated in Fig. 4. Figure 4 depicts how the actually experienced profiles differ across cohorts, i.e., how the estimated cohort specific age profiles change over time. We use the cross-section profile in the year 1985 as reference. The curve represents the cross-section age profile for all cohorts present in the labor market in the respective year. The other curves represent the age profiles for three birth cohorts. These cohorts are 30, 40, and 50 years old in 1985.

Age related participation rates have increased over time (across cohorts) for low and medium skilled females and have decreased for males – particularly for low skilled males. As a result, the gender gap in labor market participation has decreased for all skill groups. The profile of female participation still exhibits the family valley. The valley is very weak for the low skilled females. The age related profile of the medium skilled females appears to have changed from a permanent labor market exit pattern to a women returner pattern. However, as indicated by the non-rejection of the separability hypothesis H_{UI}, the pure age profile – or life-cycle profile – of medium skilled women is uniform across cohorts and, thus, has not (!) changed. The returner pattern in the data is actually a pure time effect which applies to all cohorts.

4.2. Total employment rates

The employment rate in a cohort-year cell is defined as the share of employed among the total number of persons within the cell. Table 4 and Fig. 5 in the Appendix show that male and female employment rates follow different models, which are very similar to the structure found for participation rates in the previous subsection.

The time trend is again negative for all skill groups and steepest for the low skilled. For those, the negative time trend of employment is considerably stronger than the negative time trend of participation (8 percentage points). It amounts to a 16 percentage point employment loss over 20 years. The negative time trends in employment of medium and high skilled males are only a little more pronounced than their negative trends in participation. Our results for the period of observation confirm the conventional wisdom that unemployment among the low skilled is much higher than among the skilled males. Because participation rates do not follow such a marked downward trend, this suggests a skill-biased decline of labor demand. Later, we will show that within skill groups a considerable substitution from male to female work did not occur.

Comparing the male age profiles in employment rates, we observe no considerable differences to participation rates. This finding and the non-existence of cohort effects in both cases show that macro economic circumstances are probably most decisive for changes in male employment rates.

The final specifications for female employment rates differ very much from the male specifications and across skill levels. Concerning the time trend, we find a rise of 4 percentage points in employment rates for low skilled women, which is 10 points less than the rise in participation rates. Like males, unemployment among low skilled females increased. Thus, one could suspect that no or little substitution of female for male labor took place.

However, this finding could also be attributable to sectoral change. What has to be recorded here is the fact that labor supply of low skilled females has risen but that a considerable amount of it translated into unemployment.

Medium skilled females expand their labor supply the most in comparison to the other skill groups. Interestingly, this labor supply has almost completely met its demand on the market, which can be seen by comparing the time trends in participation and employment rates for medium skilled females in Figs. 3 and 5. Employment rates of medium skilled females rise by

15 percentage points over time, whereas their participation rates rise by 17 percentage points. This is in stark contrast to both low *and* high skilled females. The latter exhibit neither a rise in participation nor in employment rates, and the former show a large increase in labor supply (see above). Altogether we may suspect that medium skilled – maybe part-time employed – females have partly replaced low skilled males. To examine this hypothesis more deeply, a distinction between sectoral employment rates as well as full and part-time employment is necessary.

The age patterns of female employment rates differ very much across skill levels (see Fig. 5). Age profiles of participation and employment differ only marginally for medium and high skilled women. Medium and high skilled females' employment rates mirror clearly the family phase. Whereas high skilled females completely return to employment, medium skilled females tend to follow the pattern of permanent exit. In contrast to the other skill groups, the age related employment profile of low skilled women differs from the participation profile. The curve exhibits an early family valley and rises considerably between the ages of 25 and 45. The cohort profiles in employment rates are very similar to the cohort profiles in participation rates, with the exception that the cohort effect for low skilled women, who entered the labor market before 1976, is smaller than the respective cohort effect in their participation rates.

Figure 6 displays differences in life-cycle employment profiles of various cohorts in relation to a reference cross-section (of all cohorts) in 1985. In comparison to Fig. 4, it becomes clear that the time trend shifted male employment rates more than male participation rates. Concerning the increasing similarity of male and female employment patterns, employment rates have increased for low and medium skilled females and decreased for males in general, especially for low skilled males; i.e., the gender gap in employment rates has decreased for all skill groups (see Fig. 6). This is much like the gender gap in participation rates, which shrank as well. Although the case is weak for low skilled females, all female age profiles of employment rates exhibit the family valley, even for the younger cohorts. However, despite the positive trends and the presence of cohort effects, the life-cycle profiles ($\equiv$ pure age effects) of females with different skill levels have not changed between 1976 and 1995. It is the time trend which causes differences in the location of cohort specific life-cycle employment profiles, being visible where the profiles of the various cohorts overlap.

4.3. Full-time and part-time employment among females

It is well known that a major part of the aggregate decline of the gender gap in participation and employment can be attributed to the rise in part-time employment among females. For a more precise picture of the shifts in female employment, we also distinguish full- and part-time employment. Since the part-time employment of males is negligible, we only consider female full- and part-time employment. Moreover, since it is not feasible to distinguish "part-time" from "full-time" unemployment, the analysis cannot be done for participation rates.

We apply our empirical approach separately to full-time and part-time employment rates among females. As in the previous analysis of total employment, the separability hypothesis is not rejected for both, the full-time and the part-time employment, in either skill group. Table 5 provides the preferred specifications as the result of the statistical tests. We find significant cohort effects before 1976 but no cohort effects after 1976. Figure 7 displays the graphical illustrations of the estimated models.

The employment trends differ across skill groups and by type of employment. The part-time employment rates exhibit a positive trend only for the low skilled females. The negative trend of full-time employment in this group contrasts to their positive trend of part-time employment. This indicates a substitution from full- to part-time employment in the group of the low skilled females. Among medium skilled females, there is no significant trend in part-time employment. However, this skill group displays an upward sloping trend in full-time employment. Finally, there is no significant trend in any type of employment of high skilled females.

The life-cycle profiles differ strongly between full- and part-time employment. While the full-time employment rates decline strongly with age, the part-time employment rates increase strongly. The decline in full-time employment over the life-cycle and the corresponding increase in part-time employment are quite strong for all skill groups with the largest effect for medium skilled females. The clear pattern of exit from full-time employment and the strong move towards part-time employment over the life-cycle can be attributed to family formation. In comparison, the total exits to non-employment are small.

There are significant cohort effects before 1976 in all groups. Compared to younger cohorts, older cohorts tend to exhibit slightly higher part-time and slightly lower full-time employment rates (except for older cohorts of low skilled females who also exhibit slightly higher full-time employment rates). The cohort effects contribute to the declining employment rates among low skilled females (thus compensating the small positive time trend in part-time employment rates for this group) and they reflect a slight shift from full-time to part-time employment for younger cohorts.

Overall, the strong increase in part-time employment can mainly be attributed to cohort effects among medium and high skilled women and to demographic changes resulting in a higher share of older women with particularly high part-time employment rates.

5. Conclusions

Based on data from the German Microcensus, we investigate life-cycle participation and employment profiles of West German males and females of different skill levels over a time period of 20 years. The empirical model simultaneously takes into account the effects of time, age, and birth cohort membership. Since the hypothesis that age profiles are separable from the time trend is not rejected, it is possible to construct and compare gender and skill specific life-cycle participation profiles. Even though the gap in average participation and employment patterns has narrowed over time, the overall results confirm a persistent gender gap in life-cycle profiles. The estimated participation and employment patterns are quite similar. Therefore, we will focus here on the differences.

The male life-cycle employment pattern, irrespective of skill level, exhibits an inverted U-shape. There is no indication that participation and employment patterns of males are affected by labor supply reductions due to the family phase. In contrast, the data for females are best represented by an age profile of third order, consistent with the presumption that life-cycle participation and employment profiles of women are still very much influenced by family formation processes; this is still the case for the younger cohorts as well. An exception are low skilled females whose participation and employment rates are much lower in comparison. The remarkably flat and low level profile of low skilled females could indicate that participation incentives are weak for this group. This may partly be due to tax splitting. An additional explanation may be that timing and distribution of the family phase differs across the various skill levels and that by restricting the sample to persons aged 25 to 55, important parts of the family phase are cut off.

In contrast to males, and with the exception of high skilled females, participation and employment of women increase significantly over time. However, employment rates of low skilled German women have not increased to the same extent as participation rates. In addition to the considerable negative time trend found for low skilled males, this finding supports the hypothesis of a decreasing demand for low skilled individuals.

Although the age profiles within the respective groups are common for all cohorts observed within the time frame, the actual participation and employment rates experienced over the life-cycle change across subsequent cohorts. This is due to the time trend but also reflects a change of cohort specific starting points of the actual life-cycle profile experienced. We actually do not observe a "permanent exit pattern" for the youngest cohorts of females. This finding can probably be attributed to part-time employment of females after the family phase.

When distinguishing between full- and part-time employment for females, we find that the life-cycle profiles differ strongly. While the full-time employment rates decline strongly with age, the part-time employment rates increase strongly. Overall, the strong increase in part-time employment can mainly be attributed to cohort effects among medium and high skilled women and to demographic changes resulting in a higher share of older women with particularly high part-time employment rates.

Appendix A

A.1. Data

The empirical analysis in this study is based on data from the Microcensus ("Mikrozensus", an annual population survey) for West Germany. We construct gender, skill, and age specific employment and participation rates for various years from 1976 to 1995 (see Sect. 3).

We define:
- UN number of unemployed persons,
- EMP number of employed persons, and
- NP number of non-participants.

The size of an age-skill group (population) is the sum $POP = EMP + UN + NP$. The employment rate is the ratio EMP/POP, and the participation rate is given by the ratio $(EMP + UN)/POP$.

Correction for missing skill information

In the years 1980, 1982, 1985, 1987, and 1989, the Microcensus required the respondents to provide the information about their formal education and vocational training. This data was used to infer the skill groups, based on our above mentioned definitions, of the respondents. Hence, for these years, the share of missing observations in the skill variable is fairly small (it is close to zero among the employed and the unemployed persons). However, in the years 1976, 1991, 1993, and 1995, answering the skill question was optional resulting in a high frequency of missing answers. Since the response behavior seems related to the skill level of the person and the labor market status, we develop the following correction procedure.

The correction is applied separately for the three labor market states (*EMP*, *UN*, *NP*). We define cells *cl* of persons with a given age, year, sex, and labor market status. The share of persons in this cell who have provided the skill information (U, M, H) in the interview is denoted by $s_U(cl)$, $s_M(cl)$, and $s_H(cl)$ and the corresponding share of persons with missing skill information by $s_{mi}(cl)$.

We assume that the share of persons with missing skill information among the persons in a certain cell $s_{mi}(cl)$ affects the shares of persons with reported skill information $(j \in \{U, M, H\})$ in a linear way as follows

$$s_j(cl) = \beta_{j,0} - \beta_j^{mi} \cdot s_{mi}(cl) + \beta_j^t \cdot t + \beta_j^c \cdot c \qquad (7)$$

where t is a linear time trend and c denotes the cohort ($\equiv$ year of birth of the center in the respective age group in a year). Since $s_U(cl) + s_M(cl) + s_H(cl) + s_{mi}(cl) = 1$, it follows that $\beta_U^{mi} + \beta_M^{mi} + \beta_H^{mi} = 1$. Provided suitable estimates $\hat{\beta}_j^{mi}$ are available, we argue that we could reasonably predict the true shares $\hat{s}_j(cl)$ of the three skill groups within the cell *cl* by

$$\hat{s}_j(cl) = s_j(cl) + \hat{\beta}_j^{mi} \cdot s_{mi}(cl)$$

and thus correct the reported skill specific numbers of persons for the three labor market states by

$$N_j(cl) = \hat{s}_j(cl) \cdot N(cl)$$

where $N(cl)$ is the total number of persons in the cell (defined by age group, year, gender, and labor market status) and $N_j(cl)$ the number of persons in the cell with skill level j.

Without loss of generality, we obtain $\hat{\beta}_j^{mi}$ by estimating jointly Eq. (7) just for $s_U(cl)$ and $s_M(cl)$ using the SURE Method. Based upon a logit transformation of the coefficients, we impose the restriction that $\hat{\beta}_U^{mi} + \hat{\beta}_M^{mi} + \hat{\beta}_H^{mi} = 1$ and that all estimated $\hat{\beta}_j^{mi}$ lie within the interval $[0, 1]$. Since $s_U(cl) + s_M(cl) + s_H(cl) = 1 - s_{mi}(cl)$, the following restrictions hold in addition: $\beta_{U,0} + \beta_{M,0} + \beta_{H,0} = 1$ and $\beta_U^z + \beta_M^z + \beta_H^z = 0$ for $z \in \{t, c\}$. Therefore, the coefficients of Eq. (7) for $s_H(cl)$ are implied by the estimates for $s_U(cl)$ and $s_M(cl)$.

A.2. Methodological details of the empirical approach

The goal of the empirical analysis is to analyze trends both in the participation rate and the employment rate by skill group and gender. Let *PER* denote the participation or the employment rate. We investigate movements in *PER* for synthetic cohorts over time. Testing for uniformity across cohorts allows to investigate whether *PER* moves uniformly over time. Alternatively, it could be the case that *PER* trends differ across cohorts, which would then indicate the presence of "cohort effects". Under certain conditions, which will be discussed later, a cohort effect designates a movement of the entire life-cycle *PER* profile for a given cohort relative to other cohorts. In providing a parsimonious representation, we are able to pin down precisely the differences in *PER* trends across groups of workers defined by gender and skill level. We also explicitly take into account the possibility that *PER* is sensitive to cyclical effects.

A.2.1. Characterizing profiles in participation or employment rates

We denote the age of a person by α and the calendar time by t. A cohort c can be defined by the year of birth. The variables age, cohort, and calendar year are linked by the relation $t = c + \alpha$. Often researchers investigate empirically the cross-sectional relation between age and *PER* in a given year and trends in this relationship over time:

$$PER(t,\alpha) = f(t,\alpha) + u. \tag{8}$$

The deterministic function f measures the systematic variation in *PER*, and u reflects cyclical or transitory phenomena. Movements of f as a function of t describe how cross-section age profiles in *PER* shift over time. The cross-sectional relation f as a function of age does not describe the "life-cycle" profile for any cohort, or, put differently, the cross-section relation may very well be the result of "cohort effects". Profiles in *PER* can also be expressed as a function of cohort and age

$$g(c,\alpha) \equiv g(t-\alpha,\alpha) \equiv f(t,\alpha) \tag{9}$$

where the deterministic function g describes how age-*PER* profiles differ across cohorts. Holding age constant, $g(c,\alpha)$ describes *PER* for different cohorts over time. Holding the cohort constant yields the profile experienced by a specific cohort over time and age. The latter can be interpreted as the actual *PER* profile, because it reflects the movements of *PER* over the actual life-cycle for a given cohort.

The different parameterizations $g(c,\alpha)$ and $f(t,\alpha)$ are equivalent representations of the same relationship. Without further assumptions, "pure life-cycle effects" due to aging or "pure cohort effects" cannot be identified. Because of our focusing on *PER* trends for a given cohort over time, we use the cohort representation in Eq. (9) as the perspective of our analysis.

A.2.2. Testing for uniform changes over time

Our analysis investigates whether time trends in *PER* are uniform across cohorts, in the sense, that every cohort experiences the same time trend and the same age related change. The latter is interpreted here as the life-cycle effect (≡ "pure age effect"). Despite the identification issues discussed above, the existence of a uniform time trend across cohorts is a testable implication in the framework presented here. If such a uniform time trend is found, it is designated as the macroeconomic trend for the group considered.[12] However, as can be seen from the empirical results, the uniform time trends found differ by skill level, gender, and employment status.

Two notions of changes over time prove useful: First, changes for a given cohort in the labor market over time ("Insider trend"), and second, changes over time experienced by successive cohorts when entering the labor market ("Entry trend"). The Insider trend is given by

$$\left.\frac{\partial g}{\partial t}\right|_c = \left.\frac{\partial g}{\partial \alpha}\right|_c \equiv g_\alpha(c,\alpha) \equiv g_\alpha, \tag{10}$$

resulting from the simultaneous change of time and age. Alternatively, holding age constant yields the change observed over different cohorts at a given age. For the age at labor market entry, α_e, the Entry trend is given by

$$\left.\frac{\partial g}{\partial t}\right|_{\alpha=\alpha_e} = \left.\frac{\partial g}{\partial c}\right|_{\alpha=\alpha_e} \equiv g_c(c,\alpha_e) = g_c(t-\alpha_e,\alpha_e) \equiv e(t). \tag{11}$$

Again, this results from two effects, a change of cohort and time. Now, two testable separability conditions arise. If the changes over time can be characterized as the sum of a pure aging effect and a pure time effect in the following way

$$g_\alpha = a(\alpha) + b(t) = a(\alpha) + b(c+\alpha), \tag{12}$$

then the life-cycle effect is independent of the calendar year t. This condition is designated as the "uniform Insider trend hypothesis", which we denote by H_{UI}. It implies that each cohort faces the same change in *PER* over the life-cycle due to aging $a(\alpha)$ and that economy wide shifts $b(t)$ are common to all cohorts in the same year but they occur at different points during the life-cycle of each cohort. If the separability condition (12) holds, we can construct a "life-cycle profile" independent of the calendar year and a macroeconomic time trend independent of age. Condition (12) is violated if interaction terms of α and t enter the specification of g_α.

Integrating back the derivative condition (12), with respect to α, yields an additive form for the systematic component of the *PER* function $g(c,\alpha)$:

$$g(c,\alpha) = G + K(c) + A(\alpha) + B(c+\alpha) \tag{13}$$

where $G + K(c)$ is the cohort specific constant of integration. H_{UI} can be tested by investigating whether "interaction terms" $R(\alpha, t)$ enter specification (13), which are constructed as integrals of interaction terms of α and t in g_α.

If, in addition to H_{UI}, the Entry trend equals the macroeconomic time trend

$$e(t) = b(t), \tag{14}$$

a stronger hypothesis can be formulated. We designate this hypothesis as the "Hypothesis of uniformity in the Insider trend and the Entry trend" and denote it as H_U. Under this hypothesis the life-cycle profile of each new labor market cohort is a parallel shift of the profile of the previous cohort corresponding to the uniform time trend $b(t)$ for all cohorts already in the labor market. Again, this is a testable implication. Given specification (13), condition (14) implies that $K(c)$ is equal to zero for the cohorts entering the labor market during the period of observation.

A.2.3. Implementation of the tests

The hypothesis H_{UI} requires Eq. (13) to hold against a more general alternative, whereas the (stronger) hypothesis H_U additionally requires $K_{a2} = 0$ (no cohort effect after 1976). Formally, it is also possible to test the hypothesis that $K_{b2} = 0$ and $K_{b3} = 0$. This test of Eq. (14) for older cohorts is not directly based on the entry age, because these cohorts are only observed in the data during a later phase of their life-cycle.

In order to formulate a test of H_{UI}, we consider in the derivative g_α the interaction term αt. The implied non-separable variant of $g(c, \alpha)$ expands (13) by incorporating the integral of this interaction term

$$R = \int \alpha(c + \alpha)\, d\alpha = c\alpha^2/2 + \alpha^3/3. \tag{15}$$

Consequently, the most general formulation of Eq. (13) also involves R and the orthogonalized year dummies. The formal test of H_{UI} is a test in order to indicate whether or not R is significant. Note that the test relies on the interaction term $c\alpha^2/2$ and not on the term $\alpha^3/3$. The test of the stronger hypothesis H_U is a test of whether or not both R and c^2_{after} are significant.

Only if the separability condition H_{UI} holds, is it meaningful to construct an index of a life-cycle profile, as a function of pure aging $A(\alpha)$, and a linear macroeconomic trend index $B(t)$. Otherwise, a different PER profile would apply for each cohort. As pointed out above, it is important to recognize that neither the level nor the coefficient on the linear term are identified for these indices in a strict econometric sense.

A.2.4. Cyclical year effects

The estimated specifications effectively use year dummies for each available year. The year effects are decomposed in a linear time trend and the remaining cyclical year effects are orthogonalized with respect to the linear time trend. Concretely, we estimate

$$B(t) = B_1 \cdot t + \sum_\tau k_\tau D_{YJ(\tau)}(t) \tag{16}$$

where $t, \tau = 0, .4, .6, .9, 1.1, \ldots, 1.9$. $J(\tau) = 76, 80, 82, 85, \ldots, 95$ denotes the respective year with $\tau = (J(\tau) - 76)/10$ and $D_{YJ(\tau)}$ are year dummies. We impose the following restrictions on the estimated coefficients κ_t

$$\sum_{\tau} \kappa_\tau = 0 \quad \text{and} \quad \sum_{\tau} \kappa_\tau \cdot \tau = 0. \tag{17}$$

Thus, κ_τ can be interpreted as the cyclical deviation from the linear trend and the estimated linear trend (B_1) is not affected by the presence of the year dummies.

A.2.5. Block bootstrap procedure for inference

In the context of this study, we allow for the error terms being dependent across individuals within cohort-year-cells and across adjacent cohort-year-cells. The dependence is assumed to take the form of rectangular m-dependence across time and across cohorts. Temporary shocks (e.g., to labor demand) affecting employment of a particular group of workers may generate autocorrelation of the error term over time because of lagged adjustment. Similarly, it is likely that adjacent cohorts (being close substitutes) are affected by the same shocks. Given our empirical approach, it would be very difficult to model such shocks. However, by estimating robust standard errors, we consider the possible presence of the implied correlation pattern in the error term.

We use a flexible Block Bootstrap approach allowing for standard error estimates which are robust against fairly arbitrary heteroskedasticity and autocorrelation of the error term, see Fitzenberger (1999), Fitzenberger and Wunderlich (2000), and Fitzenberger et al. (2001) for applications in the context of estimating wage equations. The Block Bootstrap approach employed here extends the standard bootstrap procedure in that it draws blocks of observations to form the resamples. For each observation in a block, the entire vector comprising the endogenous variable and the regressors is used (Design-Matrix-Bootstrap), i.e., we do not draw from the estimated residuals. When resampling, we draw two-dimensional blocks of observations of block length 10 in the cohort and 10 in the time dimension with replacement. Accordingly, standard error estimation takes account of error correlation both within a cohort-year-cell and across pairs of cohorts and time periods which are at most nine years in the cohort dimension and the time dimension apart. To build up a resample, we draw as many blocks as necessary until the total number of observations (size of resample) is at least as large as the number of observations in the sample.

When the design matrix for a resample becomes rank deficient (this happens frequently with dummy specifications) the resample is dismissed. Contrasting the results presented in Sect. 4 with conventional standard error estimates (the latter are not reported here) indicates that allowing for correlation between the error terms within and across cohort-year-cells (when forming the blocks) changes the estimated standard errors considerably. Thus, it is very likely that such correlation is present and important for inference. In the absence of a clear cut decision rule about the choice of block size, we experimented somewhat with slightly smaller or larger blocks without changes in the substance of the results.

A.3. Figures and tables

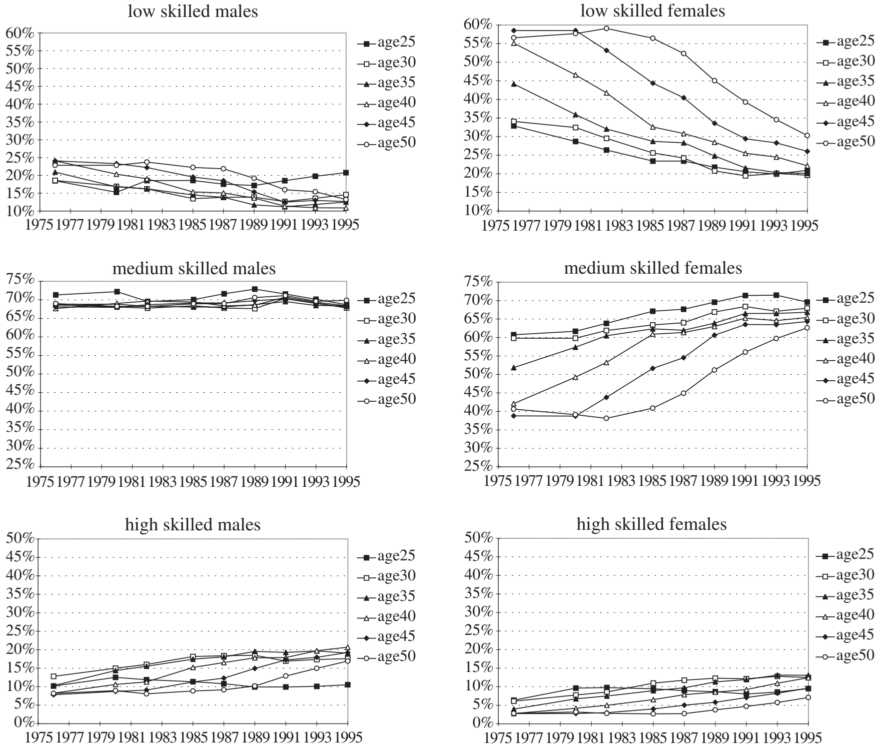

Fig. 1. Relative size of skill groups by age from 1976–1995

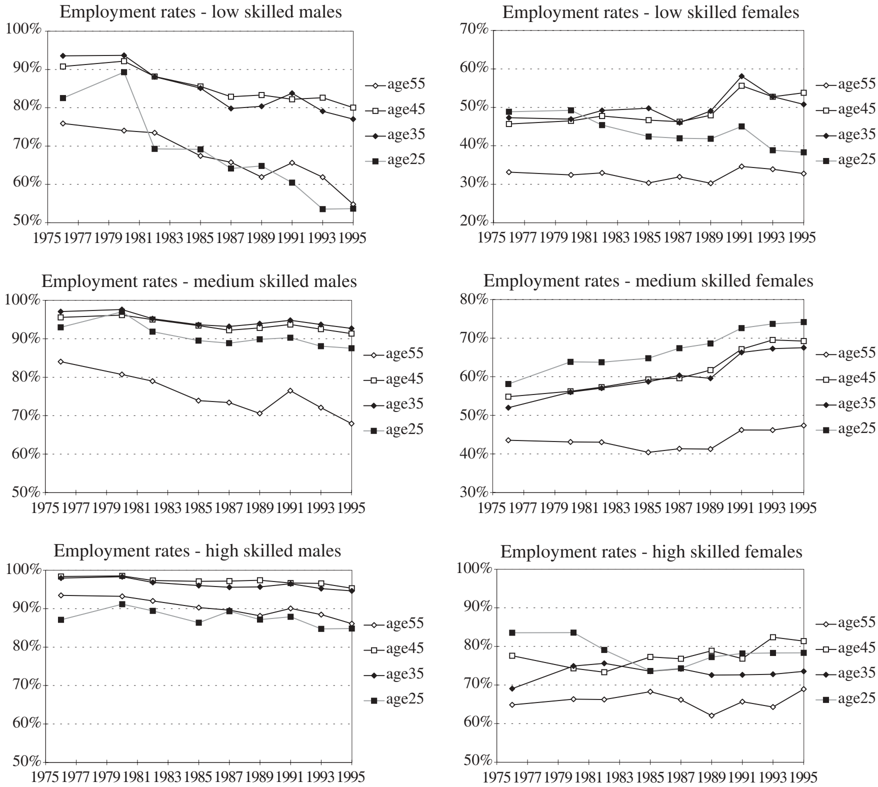

Fig. 2. Employment rates of skill groups by age from 1976–1995

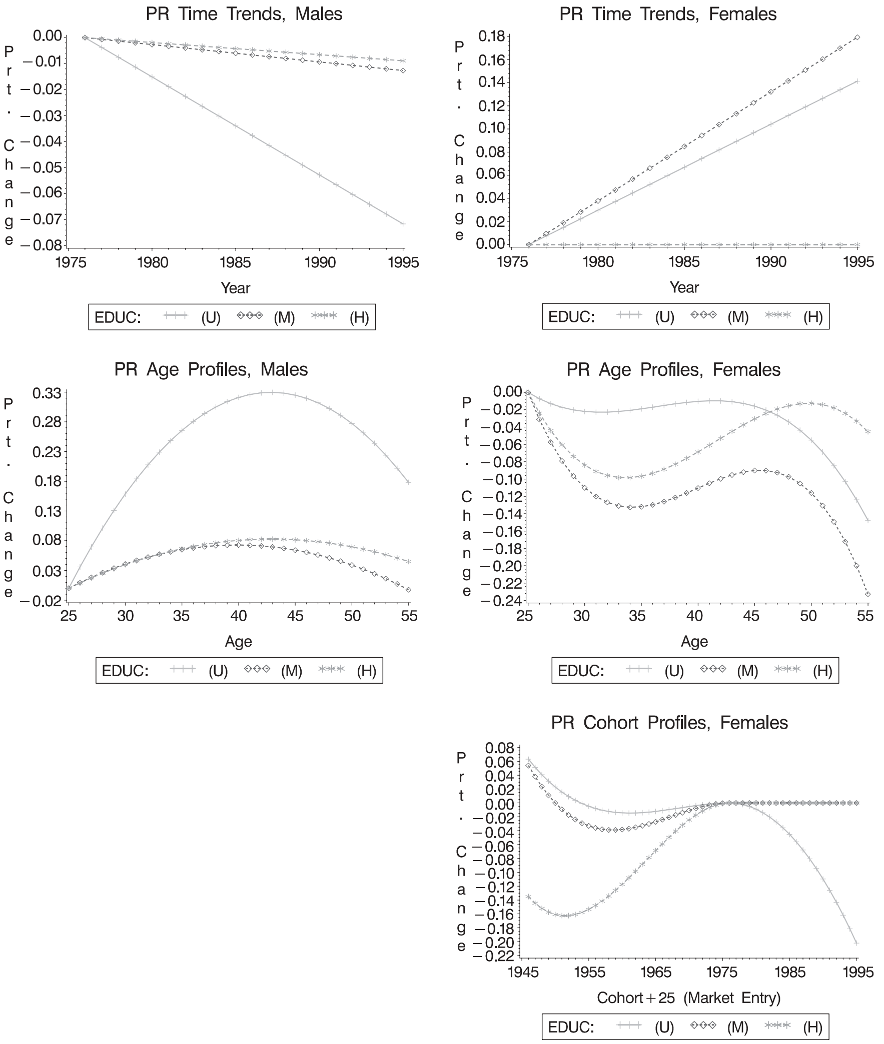

Fig. 3. Participation rates – time trends, age and cohort profiles for males and females for skill groups *U* (Low skilled), *M* (Medium skilled), and *H* (High skilled). Based on preferred final specifications

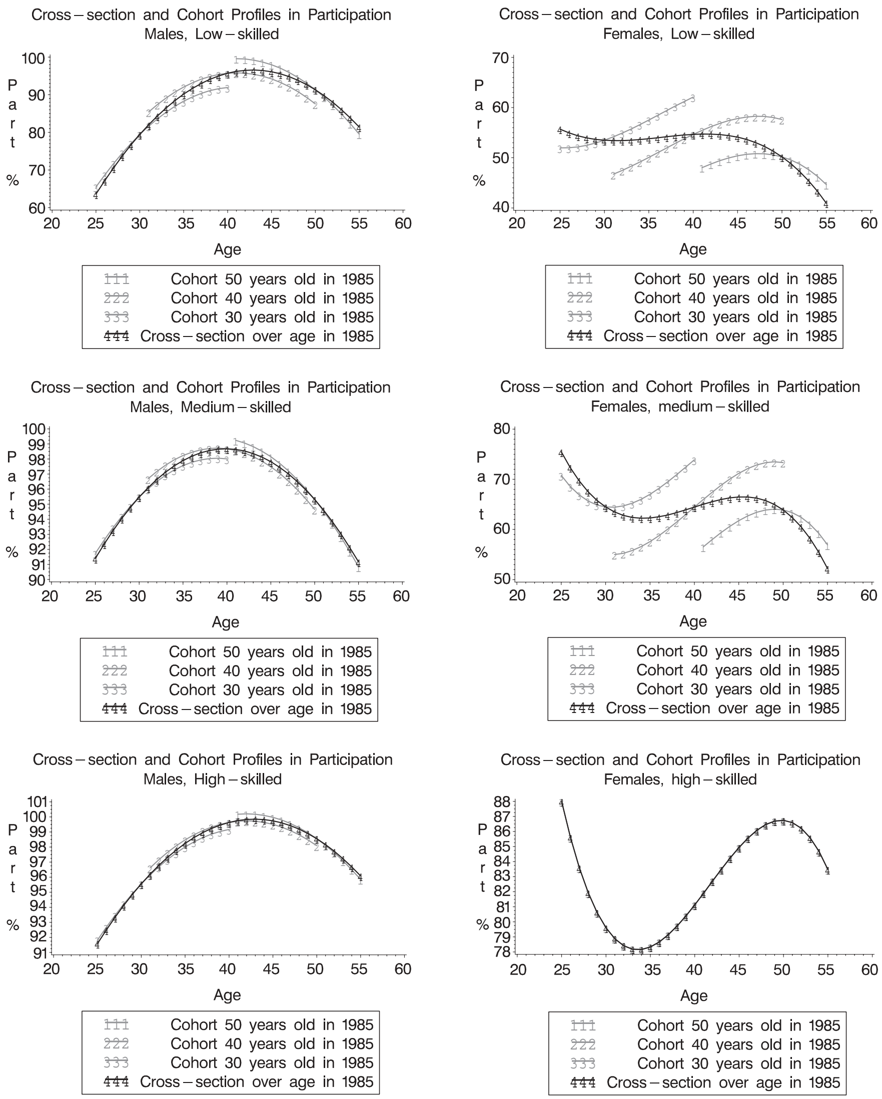

Fig. 4. Cross-sections of predicted participation rates 1985 and cohort profiles of males and females for skill groups *U* (Low skilled), *M* (Medium skilled), and *H* (High skilled). Based on preferred final specifications

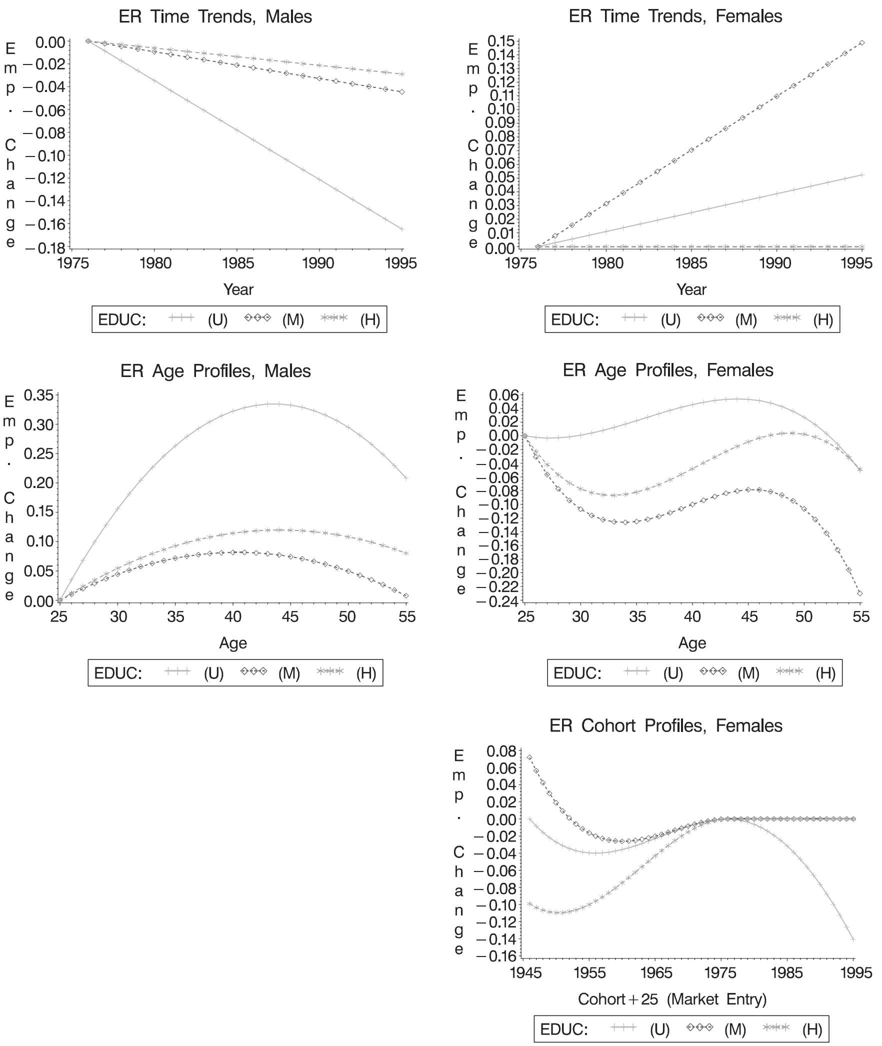

Fig. 5. Employment rates – time trends, age and cohort profiles for males and females for skill groups U (Low skilled), M (Medium skilled), and H (High skilled). Based on preferred final specifications

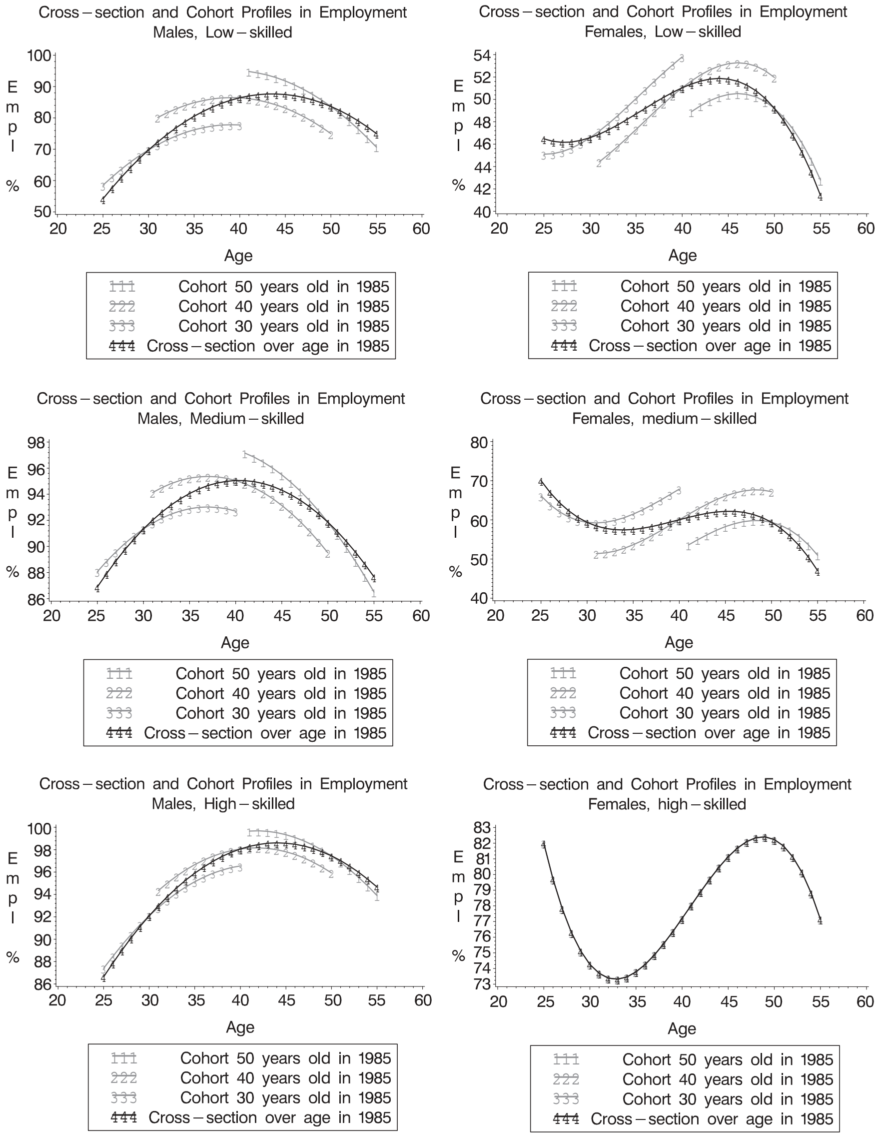

Fig. 6. Cross-sections of predicted employment rates 1985 and cohort profiles of males and females for skill groups *U* (Low skilled), *M* (Medium skilled), and *H* (High skilled). Based on preferred final specifications

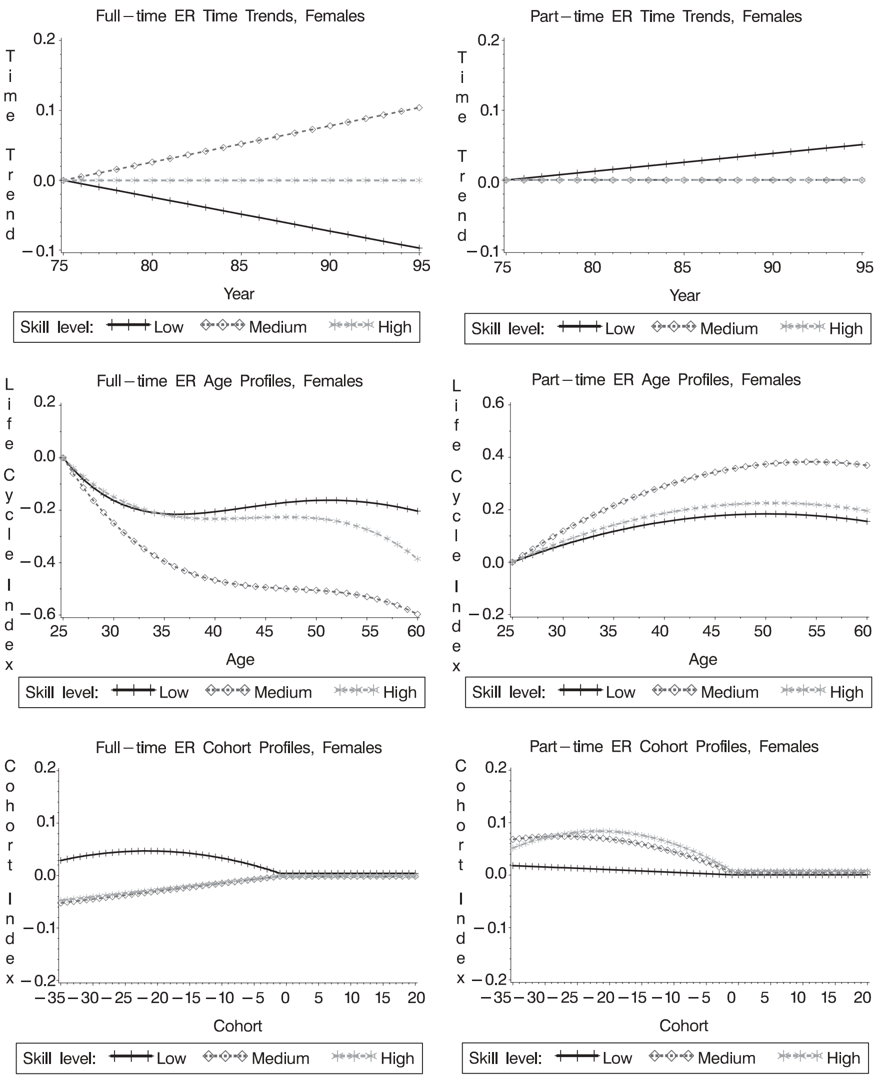

Fig. 7. Employment rates – time trends, age and cohort profiles for full-time and part-time employed females for skill groups *U* (Low skilled), *M* (Medium skilled), and *H* (High skilled). Based on preferred final specifications

Table 1. Full-time employment rates for skill groups *U* (Low skilled), *M* (Medium skilled), and *H* (High skilled)

Skill group	Age	1976	1980	1985	1991	1995
Low	25–29	0.3637	0.3768	0.3063	0.2818	0.2369
	35–39	0.2811	0.2846	0.3183	0.3223	0.2456
	45–49	0.2879	0.2778	0.2601	0.2890	0.2806
	55–60	0.2192	0.2084	0.1796	0.1688	0.1357
Medium	25–29	0.4261	0.4833	0.5017	0.5618	0.5806
	35–39	0.2938	0.3032	0.3364	0.3369	0.3149
	45–49	0.3650	0.3494	0.3301	0.3395	0.3477
	55–60	0.3166	0.2964	0.2532	0.2588	0.2288
High	25–29	0.5539	0.6689	0.5399	0.6293	0.6097
	35–39	0.4110	0.5095	0.4426	0.3968	0.4176
	45–49	0.5222	0.5490	0.4994	0.4418	0.4376
	55–60	0.4899	0.5369	0.4857	0.4353	0.3846

Table 2. Part-time employment rates for skill groups *U* (Low skilled), *M* (Medium skilled), and *H* (High skilled)

Skill group	Age	1976	1980	1985	1991	1995
Low	25–29	0.1250	0.1155	0.1178	0.1687	0.1462
	35–39	0.1921	0.1846	0.1796	0.2589	0.2620
	45–49	0.1690	0.1872	0.2068	0.2672	0.2574
	55–60	0.1123	0.1158	0.1240	0.1775	0.1919
Medium	25–29	0.1550	0.1554	0.1461	0.1642	0.1612
	35–39	0.2259	0.2569	0.2508	0.3260	0.3604
	45–49	0.1833	0.2130	0.2630	0.3320	0.3449
	55–60	0.1187	0.1347	0.1508	0.2032	0.2450
High	25–29	0.2815	0.1669	0.1965	0.1525	0.1738
	35–39	0.2796	0.2397	0.2931	0.3296	0.3179
	45–49	0.2537	0.1941	0.2733	0.3266	0.3763
	55–60	0.1588	0.1264	0.1971	0.2216	0.3048

Table 3. Parameter estimates of participation rates for males and females in skill groups U (Low skilled), M (Medium skilled), and H (High skilled)

	Females			Males		
Skill level	U	M	H	U	M	H
Intercept	0.490	0.667	0.884	0.670	0.921	0.918
	(0.010)	(0.012)	(0.007)	(0.030)	(0.006)	(0.006)
t	0.074	0.094	–	−0.038	−0.007	−0.005
	(0.011)	(0.006)	–	(0.012)	(0.002)	(0.002)
α	−0.082	−0.338	−0.260	0.369	0.098	0.092
	(0.026)	(0.028)	(0.027)	(0.041)	(0.008)	(0.008)
α^2	0.090	0.266	0.203	−0.103	−0.033	−0.026
	(0.019)	(0.024)	(0.024)	(0.013)	(0.002)	(0.003)
α^3	−0.026	−0.060	−0.041	–	–	–
	(0.004)	(0.005)	(0.006)	–	–	–
c_b^2	−0.020	−0.039	−0.081	–	–	–
	(0.012)	(0.011)	(0.017)	–	–	–
c_b^3	−0.009	−0.015	−0.022	–	–	–
	(0.004)	(0.004)	(0.008)	–	–	–
c_a^2	−0.056	–	–	–	–	–
	(0.018)	–	–	–	–	–
D_{Y76}	0.012	0.000	−0.002	−0.002	−0.001	−0.000
	(0.003)	(0.005)	(0.006)	(0.011)	(0.002)	(0.002)
D_{Y80}	−0.003	0.002	0.010	0.001	0.002	−0.000
	(0.003)	(0.004)	(0.005)	(0.009)	(0.002)	(0.002)
D_{Y82}	0.005	0.001	0.003	−0.003	0.000	0.001
	(0.003)	(0.003)	(0.006)	(0.008)	(0.001)	(0.002)
D_{Y85}	−0.004	0.002	−0.001	0.003	0.000	−0.000
	(0.003)	(0.003)	(0.007)	(0.008)	(0.001)	(0.002)
D_{Y87}	−0.026	0.005	−0.007	0.003	0.000	−0.003
	(0.003)	(0.004)	(0.004)	(0.008)	(0.002)	(0.002)
D_{Y89}	−0.015	−0.011	−0.008	0.005	0.001	0.000
	(0.003)	(0.004)	(0.006)	(0.010)	(0.002)	(0.003)
D_{Y91}	0.015	0.004	−0.008	−0.006	0.000	0.001
	(0.003)	(0.003)	(0.004)	(0.010)	(0.001)	(0.001)

Remarks: Participation rates are defined as $pr = (emp + unp)/pop$. $D_{Y76}, \ldots, D_{Y91}$ are year dummies controlling for cyclical effects. They are orthogonalized with respect to the linear time trend. $\alpha, \ldots, \alpha^3$ are the coefficients of the age polynomial; t depicts the coefficient of the linear time trend; c_b^2, c_b^3 depict the effects of birth cohort membership for cohorts entering the labor market before 1976, and c_a^2 after 1976. Age at labor market entry is 25 years. The covariance matrix is obtained using a Block Bootstrap Procedure with 1000 resamples for skill groups (U), (M), and (H). Standard errors are in parentheses.

Table 4. Parameter estimates of employment rates for males and females in skill groups U (Low skilled), M (Medium skilled), and H (High skilled)

	Females			Males		
Skill level	U	M	H	U	M	H
Intercept	0.437	0.633	0.817	0.623	0.893	0.875
	(0.017)	(0.012)	(0.015)	(0.028)	(0.006)	(0.006)
t	0.028	0.078	–	−0.087	−0.023	−0.015
	(0.013)	(0.006)	–	(0.011)	(0.002)	(0.003)
α	−0.031	−0.334	−0.250	0.360	0.106	0.126
	(0.035)	(0.030)	(0.042)	(0.033)	(0.007)	(0.008)
α^2	0.077	0.270	0.213	−0.097	−0.035	−0.033
	(0.023)	(0.025)	(0.032)	(0.011)	(0.002)	(0.003)
α^3	−0.024	−0.062	−0.045	–	–	–
	(0.005)	(0.006)	(0.007)	–	–	–
c_b^2	−0.030	−0.031	−0.050	–	–	–
	(0.015)	(0.010)	(0.015)	–	–	–
c_b^3	−0.010	−0.013	−0.013	–	–	–
	(0.005)	(0.004)	(0.006)	–	–	–
c_a^2	−0.039	–	–	–	–	–
	(0.021)	–	–	–	–	–
D_{Y76}	0.013	0.004	0.000	−0.002	−0.002	−0.001
	(0.005)	(0.005)	(0.009)	(0.011)	(0.002)	(0.003)
D_{Y80}	0.009	0.014	0.023	0.028	0.015	0.007
	(0.004)	(0.004)	(0.009)	(0.009)	(0.002)	(0.003)
D_{Y82}	0.005	0.002	0.004	−0.005	−0.000	0.000
	(0.004)	(0.003)	(0.009)	(0.009)	(0.002)	(0.002)
D_{Y85}	−0.021	−0.016	−0.019	−0.016	−0.012	−0.010
	(0.005)	(0.003)	(0.018)	(0.007)	(0.002)	(0.004)
D_{Y87}	−0.034	−0.017	−0.018	−0.029	−0.013	−0.002
	(0.004)	(0.004)	(0.007)	(0.009)	(0.002)	(0.002)
D_{Y89}	−0.023	−0.018	−0.019	0.006	−0.000	−0.002
	(0.003)	(0.004)	(0.010)	(0.009)	(0.002)	(0.002)
D_{Y91}	0.031	0.015	0.000	0.018	0.013	0.010
	(0.005)	(0.004)	(0.005)	(0.009)	(0.001)	(0.002)

Remarks: Employment rates are defined as $er = emp/pop$. $D_{Y76}, \ldots, D_{Y91}$ are year dummies controlling for cyclical effects. They are orthogonalized with respect to the linear time trend. $\alpha, \ldots, \alpha^3$ are the coefficients of the age polynomial; t depicts the coefficient of the linear time trend; c_b^2, c_b^3 depict the effects of birth cohort membership for cohorts entering the labor market before 1976, and c_a^2 after 1976. Age at labor market entry is 25 years. The covariance matrix is obtained using a Block Bootstrap Procedure with 1000 resamples for skill groups (U), (M), and (H). Standard errors are in parentheses.

Table 5. Parameter estimates of full-time and part-time employment rates for females in skill groups U (Low skilled), M (Medium skilled), and H (High skilled)

	Full-time			Part-time		
Skill level	*U*	*M*	*H*	*U*	*M*	*H*
Intercept	0.566	0.847	0.665	0.004	−0.002	0.125
	(0.042)	(0.020)	(0.025)	(0.009)	(0.012)	(0.014)
t	−0.048	0.060	–	0.024	–	–
	(0.015)	(0.009)	–	(0.005)	–	–
α	−0.479	−0.826	−0.400	0.161	0.259	0.175
	(0.093)	(0.037)	(0.048)	(0.008)	(0.013)	(0.016)
α^2	0.353	0.361	−0.224	−0.031	−0.044	−0.034
	(0.076)	(0.022)	(0.028)	(0.002)	(0.003)	(0.005)
α^3	0.096	−0.052	0.040	–	–	–
	(0.025)	(0.003)	(0.005)	–	–	–
α^4	−0.009	–	–	–	–	–
	(0.003)	–	–	–	–	–
c_b^2	−0.043	0.017	−0.013	−0.005	−0.054	−0.077
	(0.017)	(0.003)	(0.003)	(0.001)	(0.007)	(0.012)
c_b^3	–	–	–	–	−0.009	−0.017
	–	–	–	–	(0.002)	(0.005)
D_{Y76}	−0.020	−0.020	−0.056	0.011	0.016	0.030
	(0.005)	(0.005)	(0.011)	(0.002)	(0.012)	(0.013)
D_{Y80}	−0.011	0.011	0.058	0.001	0.009	−0.019
	(0.004)	(0.004)	(0.011)	(0.002)	(0.012)	(0.013)
D_{Y82}	0.006	0.006	0.047	0.005	0.000	−0.029
	(0.003)	(0.003)	(0.013)	(0.002)	(0.015)	(0.015)
D_{Y85}	0.002	0.002	−0.024	−0.012	−0.020	0.007
	(0.004)	(0.004)	(0.021)	(0.002)	(0.037)	(0.023)
D_{Y87}	0.007	0.007	−0.004	−0.021	−0.023	−0.002
	(0.005)	(0.005)	(0.041)	(0.003)	(0.037)	(0.058)
D_{Y89}	0.009	0.009	−0.022	−0.017	−0.024	0.018
	(0.005)	(0.005)	(0.014)	(0.003)	(0.009)	(0.016)
D_{Y91}	−0.002	−0.002	−0.004	0.018	0.010	−0.010
	(0.006)	(0.006)	(0.010)	(0.003)	(0.016)	(0.014)

Remarks: Employment rates are defined as $er = emp/pop$. $D_{Y76}, \ldots, D_{Y91}$ are year dummies controlling for cyclical effects. They are orthogonalized with respect to the linear time trend. $\alpha, \ldots, \alpha^4$ are the coefficients of the age polynomial; t depicts the coefficient of the linear time trend; c_b^2, c_b^3 depict the effects of birth cohort membership for cohorts entering the labor market before 1976. Age at labor market entry is 25 years. The covariance matrix is obtained using a Block Bootstrap Procedure with 1000 resamples for skill groups (U), (M), and (H). Standard errors are in parentheses.

Endnotes

1 Only the US exhibited a steady growth in female employment since the beginning of the last century. European countries experienced increases in female (part-time) participation beginning with the 70s (see various Chapts. in Blossfeld and Hakim 1997; for the US see Goldin 1990; Jacobsen 1998).

2 For Europe, see OECD (1988, 1997), Blossfeld and Hakim (1997), Rubery et al. (1999).

3 See Antecol (2000) for evidence on the influence of social norms on female participation. See Dingeldey (2000) for a comparison of European tax systems and household employment patterns.

[4] The approach of synthetic cohorts in aggregate data examines labor force behavior of demographic groups as they age. The differentiation of cohorts matters a lot, especially for married women: "... cohorts acquire varying amounts of education, have different numbers of children, accumulate different types of labor market experience, and mature in different social climates" (Goldin 1990: 138).

[5] Examples are Goldin (1990), Killingsworth and Heckman (1986), and Pencavel (1986) for the U.S.

[6] E.g., Shorrocks (1975) discusses the importance of using both age and cohort in analyzing life-cycle behavior.

[7] Müller (1983) investigates the determinants of the individual employment probability, defining cohorts by the year of the first marriage. However, year and cyclical effects are not modelled.

[8] This argument refers to "skill biased technological change", see Blau and Kahn (1997) and Berman et al. (1998).

[9] The subsamples are: 1976, 1980, 1982, 1985, 98%, 1987, 1989, 1991, 1993, 1995, 70%.

[10] Either total employment rates or distinguishing full-time and part-time employment rates.

[11] We have also experimented with a logistic transformation in *PER*. The specification applied here uses the level of *PER* as the left-hand-side variable in the regression, i.e., a linear probability model based on grouped data.

[12] If no uniform trend is found, the average across age groups combines age, time, and cohort effects.

References

Antecol H (2000) An Examination of Cross-Country Differences in the Gender Gap in Labor Force Participation Rates. *Labour Economics*: 409–426

Attanasio O (1998) A Cohort Analysis of Saving Behavior by U.S. Households. *Journal of Human Resources* 33(3):575–609

Berman E, Bound J, Machin S (1998) Implications of Skill-Biased Technological Change: International Evidence. *The Quarterly Journal of Economics* 113:1245–1279

Blau F, Kahn L (1997) Swimming Upstream: Trends in the Gender Wage Differential in the 1980s. *Journal of Labor Economics* 15:1–42

Blossfeld H-P, Rohwer G (1997) Part-Time Work in West Germany. In: Blossfeld H-P, Hakim C (eds) *Between Equalization and Marginalization. Women Working Part-Time in Europe and the United States of America*. Oxford University Press, Oxford, pp 164–190

Blossfeld H-P, Hakim C (eds) (1997) *Between Equalization and Marginalization. Women Working Part-Time in Europe and the United States of America*. Oxford University Press, Oxford

Blundell R, MaCurdy T (1999) Labour Supply: A Review of Alternative Approaches. In: Ashenfelter O (ed) *Handbook of Labor Economics*, vol. 3A

Börsch-Supan A, Schnabel R (1998a) *Social Security and Declining Labor Force Participation in Germany*. American Economic Review, Papers and Proceedings, May 1998

Börsch-Supan A, Schnabel R (1998b) Social Security and Retirement in Germany. In: Gruber J, Wise D (eds) *Social Security and Retirement around the World*. University of Chicago Press, Chicago

Dingeldey I (2000) Einkommensteuersysteme und familiale Erwerbsmuster im europäischen Vergleich. In: Dingeldey I (ed) *Erwerbstätigkeit und Familie in Steuer- und Sozialversicherungssystemen. Begünstigungen und Belastungen verschiedener familialer Erwerbsmuster im Ländervergleich*. Leske + Budrich. Opladen, Chapt. 1, 11–47

Esping-Andersen G (1993) *The Three Worlds of Welfare Capitalism*, 2nd reprint. Princeton University Press, Princeton

Fitzenberger B (1999) *Wages and Employment Across Skill Groups: An Analysis for West Germany*. Physica, Heidelberg

Fitzenberger B, Wunderlich G (2000) Gender Wage Differences in West Germany: A Cohort Analysis. Discussion Paper 00-48, Centre for European Economic Research (ZEW), Mannheim

Fitzenberger B, Hujer R, MaCurdy TE, Schnabel R (2001) Testing for Uniform Wage Trends in West Germany: A Cohort Analysis using Quantile Regressions for Censored Data. *Empirical Economics*: 41–87

Franz W (1999) *Arbeitsmarktökonomik*, 4th ed. Springer, Berlin Heidelberg New York

Goldin C (1990) Understanding the Gender Gap. An Economic History of American Women. Oxford University Press, New York, Oxford, Chapt. 5: *The Changing Economic Role of Married Women*, 119–158

Hakim C (1993) The Myth of Rising Female Employment. *Work, Employment and Society* 7:97–120

Jacobsen JP (1998) Labor Force Participation: Analysis of Trends. In: Jacobsen JP (ed) *The Economics of Gender*, 2nd ed. Blackwell, Oxford, Chapt. 4, 106–153

Killingsworth M, Heckman JJ (1986) Female Labour Supply: A Survey. In: Ashenfelter O, Layard R (eds) *Handbook of Labour Economics*, vol. I, Chapt. 2

Kommission für Zukunftsfragen der Freistaaten Bayern und Sachsen (1996) Erwerbstätigkeit und Arbeitslosigkeit in Deutschland. Entwicklung von Erwerbstaetigkeit und Arbeitslosigkeit in Deutschland und anderen frühindustrialisierten Laendern. Bonn, Germany

MaCurdy TE, Mroz T (1995) Measuring Macroeconomic Shifts in Wages from Cohort Specifications. Unpubl. Manuscript, Stanford University and University of North Carolina

Mason WM, Fienberg SE (1985) *Cohort Analysis in Social Research. Beyond the Identification Problem*. Springer, Berlin Heidelberg New York

Müller W (1983) Frauenerwerbstätigkeit im Lebenslauf. In: Müller W, Willms A, Handl J (eds) *Strukturwandel der Frauenarbeit*. Campus, Franfurt and New York, 55–95

OECD (1988) Employment Outlook. OECD, Paris

OECD (1997) Education at a Glance. OECD Indicators. OECD, Paris, Chapt. E: Social and Labour Market Outcomes of Education, 239–276

Pencavel J (1986) Labor Supply of Men: A Survey. In: Ashenfelter O, Layard R (eds) *Handbook of Labour Economics*, vol. I, Chapt. 1

Rubery J, Smith M, Fagan C (1999) *Women's Employment in Europe. Trends and Prospects*. Routledge, London and New York

Shaw K (1994) The Persistence of Female Labor Supply. *Journal of Human Resources* 24:348–378

Shorrocks AF (1975) The Age-Wealth Relationship: A Cross-section and Cohort Analysis. *Review of Economics and Statistics*: 155–163