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Why Not Start Younger? Implications of the Timing and Duration of Schooling for Fertility, Human Capital, Productivity, and Public Pensions

Skirbekk, V.

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Contents

Foreword

by Professor Axel Börsch-Supan, Director of the Mannheim Research Institute for the Economics of Aging, University of Mannheim, Germany

This publication makes a very helpful contribution to three debates: population aging, pension reform, and education reform. Its novelty is the way it establishes linkages among the three. The author's agenda is to show that, if the economic burden of population aging is to be alleviated, then education reform should be another important reform step in addition to pension reform.

The author makes three arguments: education can proceed faster without harming human capital formation; education reform may have important side-effects on fertility; and—the most controversial of the three—a later retirement age has less impact than often claimed because—the author argues—of the relatively low productivity of the later years of life. Finally, the author puts these arguments together in a simulation model that quantifies and compares the various mechanisms.

The real meat of the argument lies in two well-written case studies of the Swedish and the Swiss education systems, which link the duration of education to several achievement dimensions, such as income, test scores, and marriage. The author finds no evidence for any sizable negative effect on such achievements, either from an earlier school-leaving age (the Swedish case) or from a shorter schooling length (the Swiss case). He correctly concludes that a shortened education does not harm human capital formation. He does, however, find a striking pattern in the dominant role of the "social age" of the school cohort in influencing the timing of births and marriages for a long time after the cohort leaves school. The use of the Norwegian MOSART simulation model to pull all the elements together provides a natural and satisfying culmination to the arguments.

The publication is well written, making the author's approach and his line of thinking easy to follow and convincing. The empirical analysis is professional, and the chosen experiments and econometric analyses are admirably crafted. I take great pleasure in congratulating the author on his achievement.

Abstract

The relatively long periods of time required to complete the different educational levels in countries such as Norway lead to relative lateness in the school-leaving age and in the timing of subsequent events. A late entry to the labor market involves not only social costs, such as adverse effects on public pensions, but also individual costs in the form of a shortened working life, fewer years to achieve fertility intentions, and a later timing of childbearing that may negatively affect the health of mother and child.

The individual and social costs associated with a late school-leaving age raise the question as to whether similar educational standards could be achieved by shifting the timing of education to a younger age. We consider the impact of a reform that lowers the age of school graduation by two years by compressing the duration of primary and secondary schooling from 13 to12 years and also by decreasing the age of school entry from 6 to 5 years.

By lowering the school-leaving age, the reform would also lower the age of entry to the labor market. However, according to our estimates of the effects on student performance of marginal variations in the timing and duration of schooling, the human capital effects are likely to be either nonexistent or very small. To analyze the effects of the reform, we ran projections of the Norwegian public pension system with a large-scale microbased dynamic model. We find that the reform could have an alleviating effect on the sustainability of the public pension system by reducing the aging-induced growth in the contribution rate by one-tenth in the period from 2000–2100 and by one-fifth if fertility were to increase as a result of the reform.

Policies that aim to lower the school-leaving age while maintaining educational quality could play a role in expanding and rejuvenating the labor force and may represent an important contribution to the sustainability of the public pension system in aging economies such as that of Norway.

Acknowledgments

This publication might never have materialized had it not been for the generous support I received from a number of individuals and institutions. First, I would like to thank Alexia Fürnkranz-Prskawetz at the Vienna Institute of Demography for supervision, motivation, and help in overcoming numerous scientific challenges. I am also heavily indebted to Axel Börsch-Supan at the Mannheim Economics of Aging and Thusnelda Tivig at Rostock University. Their guidance, through discussions and seminars, gave me important insight and new ideas, which helped me improve the quality of my work.

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About the Author

Vegard Skirbekk graduated in economics from the University of Oslo, Norway, in 2000, having also studied at the University of Adelaide in Australia. In 2005 he was awarded his PhD at the University of Rostock, Germany.

In 2000–2001, he participated in the Advanced Studies Program in International Economics at the Institute for World Economics in Kiel, Germany. From 2001–2003 he worked at the Max Planck Institute for Demographic Research in Rostock, Germany. Since October 2003 he has been working as a research scholar within the World Population Program at IIASA. He has also spent time conducting research at other institutions, such as the Research Department of Statistics Norway, the Mannheim Institute for the Economics of Aging, the Department of Demography of the University of California at Berkeley, and the Institute for Futures Studies in Stockholm.

Dr. Skirbekk's research interests include the interactions between education reforms and social security systems, with a focus on how education affects fertility, how productivity varies over the life cycle, and the determinants of human capital production.

1

Introduction

1.1 Strengthening Public Pension Systems through Education Reform

Rapidly growing dependency ratios in the coming years will challenge the sustainability of public pension systems in most industrialized countries.[1] This is a particular problem for European countries with relatively generous pension systems and the prospect of a large increase in the size of their elderly populations (Gruber and Wise, 2001; United Nations, 2005). Unless pension benefits decrease, the growing number of people receiving a pension will mean that more contributions will need to be paid into the pension system. Other than raising tax levels, one relevant policy option would be to increase the proportion of contributors.

Extending the length of the working life by raising the retirement age has been suggested as one way of achieving this (OECD, 2002; Avramov and Maskova, 2003). As well as looking at the impact that this might have, we study another approach that, like later retirement, could increase the number of years spent in the labor market: whether shifting the timing of education to apply to a younger age range and compressing the amount of time spent at school would lower the age of entry into the labor market and ease the pensions burden.[2]

Although life expectancy has increased in recent decades, in European economies the working life has tended to become shorter, with the retirement age becoming lower and the age of entry into the labor market higher. As illustrated by the case of Austria (*Figure 1.1*), the strongest effect of reducing the length of the productive life span may have been a later entry into the labor market. Moreover, estimates by the Organisation for Economic Co-operation and Development

[1]Public pension systems based on the pay-as-you-go principle, where pensions are financed by current workers' contributions, are highly sensitive to changes in the age composition of the population. On the other hand, some estimates suggest that the effects on economic growth of a change in age composition is expected to be relatively moderate, as European annual growth per capita is projected to decline from 1.7% today to 1.1% by 2050, which would mean a doubling in per capita GDP (Turner *et al.*, 1998).

[2]This assumes that a lower school-leaving age would lead over time to younger labor-market entry. (This is discussed in Section 2.1.)

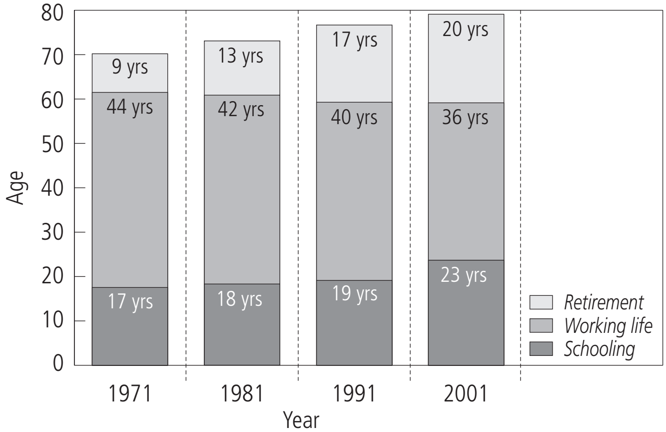

Figure 1.1. Austrian life cycle, 1971–2001.
Source: Statistics Austria (2003).

(OECD) suggest that in the 1950–1995 period in Norway, the average age of transition[3] to retirement for males dropped from 68 to 64 years and for females from 69 to 62 years (Blöndahl and Scarpetta, 1998). Conversely, the median age for entering full-time work reached 25 years in Norway by 1996 (OECD, 1999).

Using the case of Norway, we estimate the impact on the public pension system of an education reform under which the school-leaving age is lowered by two years: one year through a lowering of the school-entry age and one year through a compression in the length of schooling. Although such a reform might lengthen the productive life span and increase lifetime output, it might also decrease human capital and productivity levels, which would reduce its beneficial effects. Accordingly, we study the school systems of Sweden and Switzerland, where data availability and institutional settings allow us to analyze the impact on human capital formation of modifications in the timing and length of schooling.

We present a study based on birth-month-induced variation in the age at entering and leaving school in Sweden and find that going to school at a marginally younger age does not substantially affect human capital or productivity levels as measured by wage levels. We also analyze the impact of a variation in the duration of schooling based on Swiss regional differences in secondary school duration and find that, at least for Switzerland, going to school for 12 years instead of 13 years has no effect on student performance.

An education reform that lowers the school-leaving age could also lower the timing of childbearing (Corijn, 1996; Skirbekk *et al.*, 2004a; Skirbekk *et al.*, 2004b), and it may raise cohort fertility (Kohler *et al.*, 2002). Even if it is only

[3]Retirement is defined as complete withdrawal from work, as recorded in labor-force surveys.

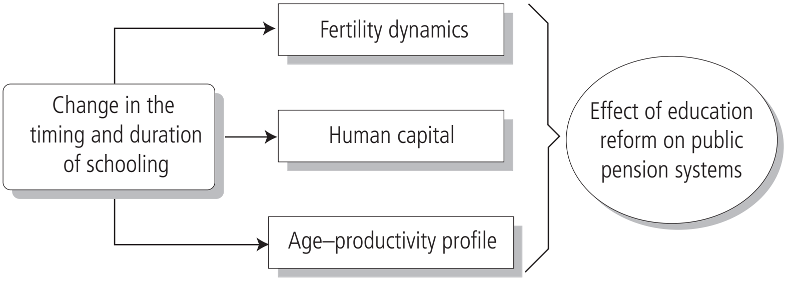

Figure 1.2. Outline of investigation into the effects of the school reform.

the timing of fertility that is shifted, leaving cohort fertility unaffected, a transition to a younger childbearing age could increase period fertility and thus rejuvenate the population's age structure (Lutz and Skirbekk, 2005). A younger age structure could further decrease the ratio of pensioners to workers and thus increase the sustainability of public welfare systems.

A further issue relevant to the age at entering and leaving the labor force is that individuals may be more productive relatively early in their working careers (Lazear, 1988; Hægeland and Klette, 1999; Crépon *et al.* 2002). Structural changes in the labor market caused by high rates of technological change increase the demand for individuals who are able to adjust quickly and absorb new knowledge, and these changes could favor younger people who tend to learn faster and be more flexible than older individuals (Avolio and Waldman, 1986; Autor *et al.*, 2003; Skirbekk 2004). Rejuvenating the labor force by lowering the age at labor-market entry could allow individuals to participate in the labor force during more of their most productive years.

In *Figure 1.2* we outline the issues that are the main focus of this publication: the effects of a change in the timing and duration of schooling on fertility, human capital, and the shape of the age–productivity profile. These findings are used to calibrate the impact of the reform in a microbased simulation model, MOSART.

Other suggestions for sustaining public pension schemes, such as increased immigration, are unlikely to provide substantial gains to the public pension system in European welfare states.[4] Nor are fertility policies likely to be very effective in

[4]Immigration could produce fiscal gains if the immigrants are highly skilled, but current immigration flows to Western countries tend to be relatively low-skilled (Lee and Miller, 1997; Storesletten, 2000; Börsch-Supan, 2002). Recent studies conclude that immigration cannot be a solution for aging societies in Europe and that it may even increase fiscal expenditure through weak labor-market attachment and high rates of welfare participation (Storesletten, 2003; Ekhaugen, 2005). This could exacerbate the problem of increasing public expenditure, particularly in countries with strong welfare systems (ECON, 1996; Ekberg and Andersson; 1995). There is also some evidence that support for public redistribution programs decreases as a society becomes more diverse (Luttmer, 2001; Smeeding, 2004). Finally, increasing immigration may be difficult to implement politically, as public

countering population aging. Policies intended to increase fertility, to date at least, have had only a modest effect on childbearing outcomes.[5]

1.2 Timing of Events over the Life Cycle: Identifying Causality

A central challenge for the current study, which considers the impact of an education reform, is to estimate the causal effects of a downward shift in the age at school graduation on the timing of childbearing and on human capital formation. Studies on the timing of events in adulthood suggest that individuals tend to sequence events according to fixed schemes. Billari *et al.* (2000, p.37) emphasize that leaving school typically affects the timing of family formation: "Having left full time education—or at least having left the parental home—seems to be a necessary condition for entering a steady cohabiting partnership. Furthermore, being in a steady cohabiting partnership seems to be an almost necessary condition for becoming a parent."[6]

Despite the emphasis on the role of education in the postponement of subsequent events, very few studies have succeeded in establishing any causal effects of the "age at school graduation" on fertility patterns and human capital levels. Such analyses are particularly hampered by the fact that unobserved characteristics associated with higher graduation ages are difficult to adjust for. Comparing individuals across educational attainment invokes selection problems, as people with more education also differ in terms of their preferences, abilities, and other variables relevant to the timing and outcome of fertility. Standard analyses of the relationship

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opinion favors a decrease (Bauer *et al.*, 2000; Statistics Norway, 2003), even though attitudes toward highly skilled immigration are generally more positive (Simon and Lynch, 1999).

[5]OECD (2003b) reviews 42 studies on the effects of fertility policies (family cash benefits, tax policies, maternity leave, and family-friendly working regulations) and concludes that "most studies seem to suggest a weak positive relation between reproductive behavior and a variety of policies." The studies discussed in the report suggest that, in several cases, fertility policies had no significant effect, while in the cases where they did work, the effects were modest and fertility seldom increased by more than 10%–12%. A Rand report surveying fertility policies came up with similar findings and argued: "It is also worth stressing that the impact that governments have is limited, inasmuch as it is likely to slow down the fall in fertility rates, as opposed to halting the fall or bringing it back to replacement level" [cited in Grant *et al.* (2004, p.132)].

For the EU15 countries, even substantial fertility increases would have only a slight effect on population aging because of increasing life expectancy. Even in the case of a hypothetical permanent increase in fertility to 2.2 children for the EU15 countries [an increase of about 50%, given that the total fertility rate (TFR) was 1.5 in 2000], the old-age dependency ratio in this region would still more than double in the period 2000–2050 (Lutz and Scherbov, 2003).

[6]A discussion of the relationship between the school-leaving age and other events in early adulthood, such as entering the labor market, is given in Section 2.1.

between education and fertility that compare individuals with different educational attainment are likely to be distorted for that very reason.[7]

Several econometric approaches have been used to overcome the endogeneity problems associated with analyses of education and fertility behavior (Retherford and Sewell, 1989; Neiss *et al.*, 2002) or of education and human capital formation (Raaum and Aabo, 2000; Plug and Vijerberg, 2003). Often, these studies rely on strong assumptions to identify any "causal influences" of education on fertility and human capital. To overcome this problem, analyses need to rely on instrumental variable techniques, fixed-effect models, or "natural experiments" (Rosenzweig and Wolpin, 2000).

We apply the latter approach—natural experiments—to identify the impact of a variation in the school graduation age on the timing of fertility. As outlined in *Figure 1.3*, the effect of variation in the school graduation age in Sweden is not correlated with any other influences on fertility and education because the enrollment of children in Swedish schools depends on their date of birth—children born during the two consecutive months of December and January belong to two different school cohorts and therefore graduate in two different calendar years. Hence, the age of graduation from compulsory schooling of children born in December and children born in January differs by almost one year, despite the fact that the children were born more or less one month apart.

On the assumption that parents cannot time the births of their children to the exact month, this characteristic of the Swedish school system results in exogenous variation 1) in the age of entry to and completion of compulsory education and 2) in the age of graduation from higher education of those who continue to study after compulsory schooling.[8] This institutional mechanism allows us to identify the causal effect of the completion of schooling on important demographic behaviors during the transition to adulthood, net of unobserved characteristics affecting schooling decisions and net of variations in human capital that are otherwise associated with differences in the age at school graduation.

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[7]This bias can be specified in the simple regression model for the relationship of, for example, fertility, denoted y_i, to years of education, denoted x_i. The regression then specifies that $y_i = \beta_0 + \beta_1 x_i + u_i + e_i$, where β_1 is the coefficient of interest and u_i and e_i represent unobserved characteristics. Endogeneity problems due, for instance, to unobserved characteristics arise if x_i is determined as $x_i = \alpha_0 + \alpha_1 z_i + \alpha_2 u_i + v_i$, where z_i represents observed determinants of education, such as parental characteristics, and v_i represents unobserved influences. Even if e_i is independent of v_i, the presence of u_i in the x_i equation implies that the education variable x_i is correlated with the unobserved term in the regression equation for y_i. In this case OLS does not provide unbiased or consistent estimates for the coefficient β_1. Instead, the regression yields $plim\,\tilde{\beta}_1 = \beta_1 + \alpha_2 \frac{var(u_i)}{var(x_i)}$, which differs from the true value β_1 whenever $var(u_i) > 0$ and $\alpha_2 > 0$.

[8]Graduating at younger or older ages is difficult because of the rigidity of the school system. The Swedish school system is explained in Section 2.3.

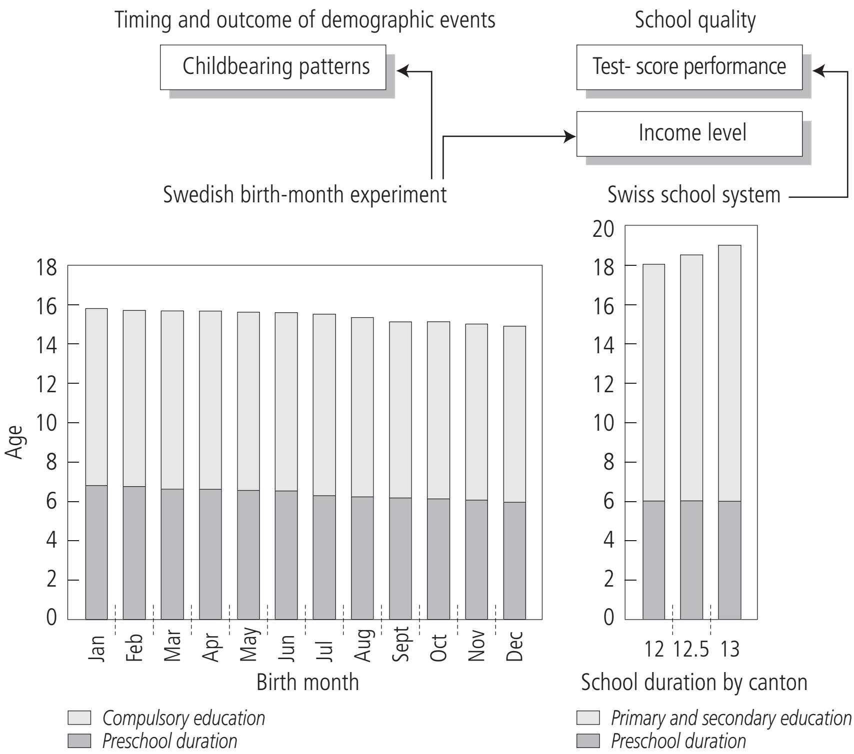

Figure 1.3. Institutional variation in the timing and duration of education: Sweden and Switzerland.

We use the same research approach in our studies on the effects of differences in the school-leaving age on human capital levels, and we consider variation in the variables of interest and in the duration and timing of schooling caused by institutional settings. In the Swedish case, the birth month determines the age at which a child enters and leaves school, and this allows us to analyze the impact of the variation in the timing of schooling on wage levels and other outcome variables related to human capital levels, net of other influences.

Furthermore, we consider the impact of a variation in the duration of schooling in the Swiss case, where the length of schooling is institutionally determined. In Switzerland the duration of (academic-track) secondary school depends on the canton and varies between 12, 12.5, and 13 years (as *Figure 1.4* illustrates). To investigate whether a marginal variation in the duration of schooling affects human capital levels, we consider the impact of the length of schooling on student performance, measured as test-score performance at the end of secondary school.

Our suggested education reform—compressing the length and shifting the timing of education to apply to a younger age group—will lower the school graduation

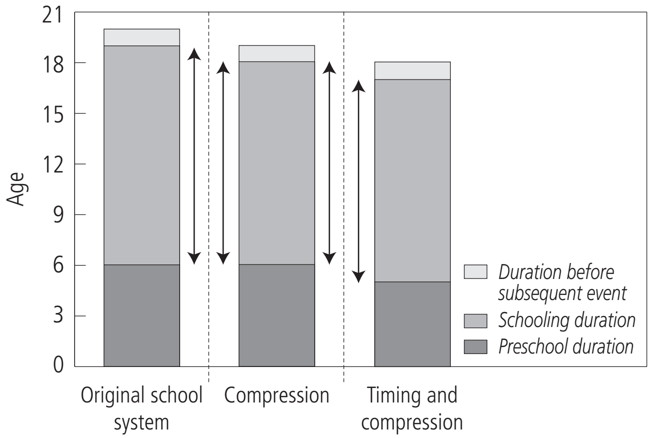

Figure 1.4. Effect of younger graduation age on the timing of subsequent events.

age and could cause a parallel shift in the timing of subsequent events (including childbearing and age at joining the labor force). This stylized situation is shown in *Figure 1.4*, where a younger graduation age shifts the timing of leaving school and events subsequent to it, while the spacing between these events does not change.

1.3 Outline of Chapters

Following an introduction, Chapter 2 discusses the effects of variation in the timing and duration of schooling on human capital formation. We show that, by international standards, there is scope for a shift in the timing and duration of primary and secondary schooling in Norway (where there is currently a school-entry age of 6 years and a school duration of 13 years, which leads to a relatively high school-leaving age). Under an education reform of the type suggested above, the Norwegian school system would adopt a length and timing framework that is found, for example, in the Scottish school system, which allows entry at 5 years and has a length of 12 years. We also discuss the importance of schooling relative to other factors in the human capital production function and show that a marginal variation in the length and timing of schooling is unlikely to play an important role in the formation of human capital. The intermediate schooling years matter relatively little for student performance because of *signaling* effects: attaining a degree signals that an individual has higher abilities that, regardless of schooling, would improve his/her performance in the labor market.

We consider the effects on human capital formation of the variations in the timing of schooling in Sweden (as affected by school entrance laws), and we find that starting school up to a year earlier increases subsequent income levels by 1%.

This could, however, be caused by the *relative class-age effect*, whereby those who enter school at a later age ultimately earn more (being among the oldest in the class and therefore more self-confident may have the effect of increasing pay levels). We also discuss the impact of the length of schooling on educational outcomes, using regional variations in the length of primary and secondary schooling in the Swiss education system. In Switzerland the number of years spent in school varies according to canton from 12 to 13 years, but this variation has not been found to have an effect on student performance.

Chapter 3 aims to identify the effects on fertility of a shift in the school-leaving age by analyzing the childbearing patterns of more than 850,000 Swedish women. In Sweden the strict laws on school entry mean that the age of leaving compulsory schooling is dependent on the month of birth. This allows us to study the causal effect of the graduation age on childbearing patterns. The differences in school-leaving ages provided by Swedish school enrollment laws are found to have strong effects on the timing of fertility. The birth-month-induced variation in the age at graduation from compulsory schooling is reflected in the age at conception of the first child (there is an average interval of 8–10 years between these events), with about 45% of the difference in the graduation age being reflected in the age at becoming a parent. The effects of the graduation age on the timing of the birth of the second child and of marriage are found to be of a similar order of magnitude.

Chapter 4 estimates the shape of the age–productivity profile by extensively reviewing the literature and constructing new estimates for the profile. Earlier studies tended to predict that productivity decreases or at least flattens off from mid–working life, while wages continue to rise. We estimate the relationship between age and performance using time-varying causal data (based on age-specific supply of abilities and industry-wide demand for abilities) and find that workers are most productive from age 35–44 or below, depending on the rate of technological change. Rejuvenating the labor force by lowering the age of labor-market entry could thus allow more individuals to enter the labor force in their most productive years. It also suggests that seniority-based earnings that increase over the life cycle may reduce opportunities in the labor market for older workers.

In Chapter 5 we apply a microbased simulation model, MOSART, to project the effects of a school reform (under which the school-leaving age is lowered by two years) on various variables related to the future of the public pension system in Norway. The findings from Chapters 2 and 3 are used to investigate the effects of the school reform on wages and its impacts on fertility patterns. Based on results from Chapter 4, we also estimate the impact of a decrease in productivity when the retirement age is raised. Some of the key findings from the projections follow.

In *Figure 1.5* we show the effect of a school reform on the *old-age dependency ratio* (i.e., the number of people aged 65 years and over relative to the number of people aged 15–64). According to these projections, the old-age dependency

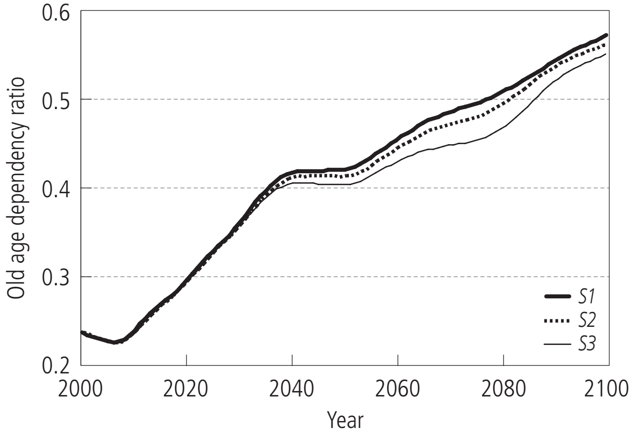

Figure 1.5. Old age dependency ratio (those aged 65 : those aged 15–64) in Norway, 2000–2100.
Notes: S1 = reference scenario; S2 = school-leaving age decreasing by 2 years; S3 = school-leaving age decreasing by 2 years and fertility levels increasing.
Source: Own calculations.

ratio increases throughout the period, but if the school reform is introduced and childbearing takes place at a younger age, the rise in the old-age dependency ratio becomes lower (S2) relative to the case without a reform (S1). If earlier childbearing is accompanied by a higher fertility level, this further reduces the increase in the old-age dependency ratio (S3).

The development in the number of workers is shown in *Figure 1.6*. We observe that implementing the school reform (S2) substantially increases the size of the labor force relative to the case where no reform is implemented (S1). The school reform (S2) is also projected to increase the size of the labor force to a greater extent than a postponement of the retirement age (S5). If the school reform increases fertility levels, this further adds to the size of the labor force (S3).

As shown in Figure 1.7, the development of the contribution rate (the share of wages used to finance public pensions) is projected to increase to 38% by 2100 in the benchmark case (S1). When the school reform is introduced, the contribution rate reaches a level of 36.9% (S2) in 2100. If the fertility level increases as a result of the school reform, then the contribution rate will increase to 35.4% (S3) by the end of the simulation period.

The effect of a later retirement on the contribution rate could be marginally stronger than that of a school reform, as it decreases the number of those receiving pensions while at the same time increasing the number of contributors. The contribution rate rises to a level of 34.8% in 2100 in the case of a two-year-later

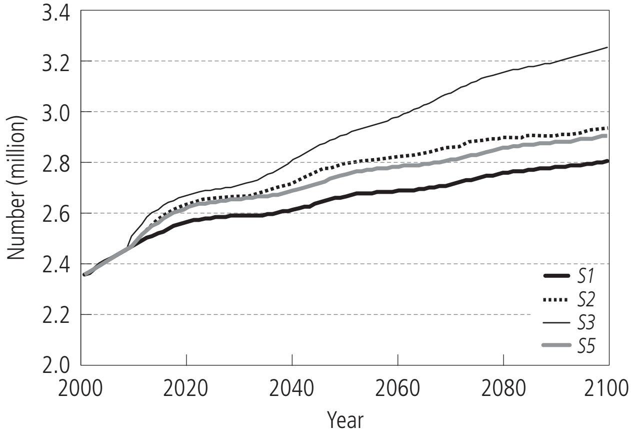

Figure 1.6. Number of workers in Norway, 2000–2100.
Notes: S1 = reference scenario; S2 = school-leaving age decreasing by 2 years; S3 = school-leaving age decreasing by 2 years and fertility levels increasing; S5 = Retirement age increasing by 2 years.
Source: Own calculations.

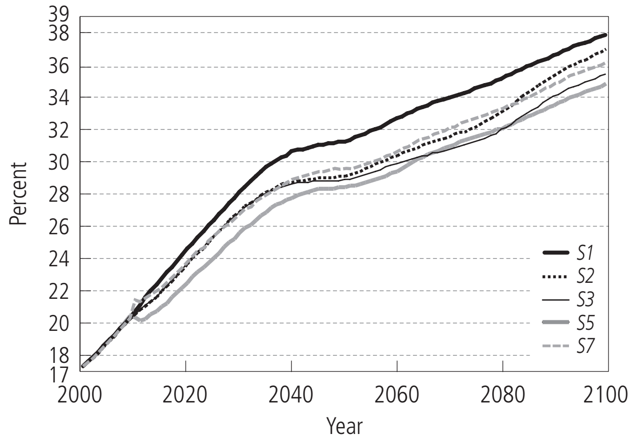

Figure 1.7. Projections for the contribution rate in Norway, 2000–2100.
S1 = reference scenario; S2 = school-leaving age decreasing by 2 years; S3 = school-leaving age decreasing by 2 years and fertility levels increasing; S5 = Retirement age increasing by 2 years; S7 = Retirement age increasing by 2 years and older workers' productivity decreasing.
Source: Own calculations.

retirement (S5). However, in the case where older workers' productivity and wages decline because of accelerating technological change, a two-year-later retirement leads to a contribution rate of 36.2% in 2100 (S7).

In Chapter 6 we summarize 1) the findings from the different parts of the study, 2) the effect of the education reform on human capital formation and fertility, and 3) the estimate of the age–productivity profile. We conclude that an education reform that lowers the graduation age by shifting the timing and duration of schooling could represent a substantial contribution to the sustainability of the public pension system in Norway.

2

The Effect of the Duration and Timing of Education on Human Capital

In this chapter we consider whether lowering the age of school entry and shortening the duration of schooling would affect the transition from school to work. If school reform were to lead to a lower accumulation of human capital, this could decrease wages, which in turn would lower wage-indexed pension benefits. Thus, we also discuss the impact that a school reform of this type might have on human capital levels.

There are no relevant variations in the timing and duration of education in Norway that we can study to estimate their effects on human capital and productivity. To our knowledge, the ideal case study, where variations in the school-entry age and school duration can be observed simultaneously, does not exist. As we need to identify settings that will allow us to make this analysis, we focus on two different countries that are characterized by 1) a relevant variation in the variable of interest that is not explained by unobserved factors and 2) data availability. We investigate the effects of the *timing* of schooling on human capital in *Sweden*, a country where birth-month-induced variations in the timing of education can be observed and where a large-scale detailed data set is available. We also analyze variations in the *length* of education in *Switzerland*, where schooling length differs according to canton and where data exist on the effects of these variations on human capital. By combining the findings from Sweden and Switzerland, we can estimate the joint impact on human capital formation of shifting the timing of schooling and compressing its duration.

We divide Chapter 2 into four sections. In Section 1 we describe the current school system in Norway and discuss the potential for changing the secondary school graduation age and the effects that this would be expected to have on the age at labor-market entry. In Section 2 we investigate the importance of schooling relative to other determinants of human capital. Section 3 analyzes the effects on wages of a younger school-entry age using Swedish data. Section 4 estimates the impact on student performance of shortening the length of time required to graduate from secondary school, based on evidence from Switzerland.

2.1 The Norwegian School System: Schooling Duration and Age at Entry

The school reform under consideration here would shift the Norwegian school-entry age (currently 6 years) to 5 years and compress the duration of primary and secondary school (currently 13 years) to 12 years. By international standards, there seems to be scope for such a change.

The school-entry age ranges from 4 to 8 years in different countries of the world (UNESCO, 2004). When Norwegian children first enroll in school, their English and Welsh counterparts of the same age are already in their second year, while children of the same age in Luxembourg and Northern Ireland are in their third year and children in Denmark have not yet started school. The most common duration of primary and secondary school is 12 years, while some school systems have an even shorter duration (Mullis *et al.*, 1998; UNESCO, 1999 and 2004). The schooling duration in Norway, where it takes 13 years to complete primary and secondary school, is relatively long compared to other countries.

2.1.1 Organization of education

To study school systems and school reforms, a standardization of education according to school levels can be useful. The different school levels can be categorized according to the 1997 International Standard Classification of Education (ISCED) (UNESCO, 2003), which divides education into seven main categories, ranging from 0 to 6, that represent schooling from preprimary to advanced research training levels. See *Box 2.1*.

2.1.2 The timing and duration of schooling

The way a school system is organized in terms of formal school-entry age and the length of time required to achieve an academic qualification is often traditional to a country or stems from historical factors. Differing ideas on when a child is ready for school, changes in parental roles, and new ways of organizing work and family life have all influenced the school-entry age and the length of primary, secondary, and tertiary education in Norway (Høigård and Ruge, 1947; Levin, 1995; Jørgensen, 1997). However, the Norwegian school system was not designed with the current levels of educational attainment in mind, where a high proportion of each birth cohort pursue tertiary education and remain in the school system until at least their mid-twenties.

Universal schooling was introduced in Norway about 250 years ago. From 1889 onwards there were seven years of compulsory education, which was raised to nine years in 1969. The most recent extension of compulsory schooling took

Box 2.1. Different school levels according to the International Standard Classification of Education, 1997.

ISCED Level 0: Preprimary education. Institution-based and designed for children who are at least 3 years old.

ISCED Level 1: Primary education. Has systematic introductory studies in core subjects, such as mathematics, reading, and writing. School participation at this level is mandatory in all countries and generally lasts 5–6 years. Entry age varies between 4 years and 8 years.

ISCED Level 2: Lower-secondary education. Tends to have somewhat more subject-oriented education, the teachers are more specialized, and the number of instruction hours is higher than in primary education. In some countries, such as Germany, academic- and vocational-track students are separated at this stage, and in other countries, including Norway, not. Lower-secondary education is typically the last part of compulsory education.

ISCED Level 3: Upper-secondary education. Generally begins at the end of compulsory schooling and includes the Norwegian school *Videregende Skole*. In the upper-secondary school, subject teaching is generally more advanced than at earlier stages, and a separation of academic- and vocational-track students has usually taken place. Students have considerable freedom to choose specialized subjects. The stage lasts from 1–5 years, depending on country and school system.

ISCED Level 4: Postsecondary nontertiary education. Programs sometimes require a secondary school qualification. They typically have more subject depth, are more specialized than secondary education, and are often of too short a duration to fit into the ISCED 5 category.

ISCED Level 5: Tertiary education. Programs are more advanced than education offered at ISCED levels 3 or 4 and have a minimum duration of 2 years. They may require completion of a research project or a thesis and are meant to direct the participants to professions with high skill requirements or to research programs.

ISCED Level 6: Advanced tertiary degree. Requires the submission of a thesis or dissertation. Students who complete this stage of education should have proved their ability to carry out original and advanced research work.

place in 1997, lengthening mandatory education to 10 years by lowering the school-entry age from 7 to 6 years. The students now finish compulsory lower-secondary school the year they turn 16, though most continue with further education. Students who complete upper-secondary school after an additional three years in the school system graduate the year they turn 19.

The age of school entry has been lowered in some countries and regions over the last decades. In the United States only seven states required enrollment in school below the age of 7 years in 1965; 25 states required this in 1992 (U.S. Department of Health, 1965; Education Commission of the States, 1994). In Germany an industry-sponsored research project proposed lowering the school-entry age to 4 years, two years below the current school-entry age of 6 years (Lenzen, 2003). In Sweden the rules regarding school-entry age were liberalized in the 1990s. Parental choice as to when children should start school has now become more important, and this has had the effect of lowering the age of school entry.

There have recently been several political attempts to reduce the number of years required to attain a specific educational qualification. Education reforms that decrease the duration of schooling are either in the planning process or already in place at national and federal/state level in many European countries. In Germany, Norway, and Switzerland, a reduction in the length of schooling is being considered. In 2001 the German state of Saarland shortened the duration of primary and secondary school (Gymnasium) from 13 to 12 years, and other states are in the process of implementing similar reforms.

The relatively long duration of schooling in Norway has led public committees to suggest compressing the Norwegian school system to allow a younger leaving age (NOU, 1991:28; NOU, 2000:21). At the tertiary level the Bologna Declaration (1999), which aims to harmonize the length of tertiary education in Europe, was recently implemented in Norway. As a result, the most common Norwegian university degree, the four-year *cand.mag* degree was replaced by a three-year bachelor's degree (NOU, 2000:14). A similar reform aimed at shortening the duration of schooling has not, as yet, been implemented at the primary and secondary level; while it is not known whether such a reform will take place in the future, this is currently under debate (Utdannings- og Forskningsdepartementet, 2003), and the financial costs for shifting the timing and duration of schooling may be relatively low. On the other hand, certain interest groups may attempt to influence the timing of school entry and the duration of schooling. This includes teachers and education-sector unions who may oppose a reform that would decrease the demand for their services and reduce their bargaining power. Teaching unions, which supported the extension of primary and secondary school education from 12 to 13 years through a lowering of the school-entry age, opposed the suggestion by the Norwegian minister of education of shortening the length of school back to 12 years (NOU, 2002:10; Lektorbladet, 2003; NOU, 2003:16). Moreover, other interest groups may attempt to influence the timing and duration of schooling (e.g., the privately run Steiner schools that advocate school entry at 7 years (Steinerskolen, 2003).

2.1.3 School-leaving age and the timing of events in adulthood

Variation in the school-leaving age can affect the timing of demographic and labor market events. Studies on the timing of events in adulthood tend to show that individuals sequence events in adulthood according to rigid schemes and that a change in the timing of one life event affects subsequent events. Leaving school tends to precede parenthood and entry to the labor market, and increases in the graduation age have been associated with increases in the age of labor-market entry, age of childbearing, and the timing of other events in adulthood (Hogan, 1978; Rindfuss *et al.*, 1980; Marini, 1984; Blossfeld and De Rose, 1992; Gustafsson, 2001).

International comparisons suggest that the length of the period from finishing education to entering the labor force is not affected by the age at which a person leaves school (OECD, 2003c; UNESCO, 2004). *Figure 2.1* shows that countries' school-leaving ages are not associated with years spent not employed.[1] In *Figure 2.2* we observe that the age at leaving compulsory education [which tends to include ISCED levels 1 (primary school) and 2 (lower-secondary education)] is also unrelated to the time spent not employed. School systems with younger school-leaving ages do not have a longer transition from school to work than school systems with a higher school-leaving age.[2] This suggests that a variation in the school-leaving age (whether after completion of the highest educational qualification or simply compulsory schooling) does not affect the speed of transition to the labor market; it also suggests that a shift in the school-leaving age would lead to a similar shift in the age of entry to the labor market.

The speed of the transition from school to the labor market is, however, likely to be influenced by a number of other institutional factors. We discuss these to investigate which settings, in addition to a change in the school-leaving age, may possibly affect the length of the transition to adulthood. One example of a policy that can affect the spacing between events in adulthood is parental entitlement to welfare payments. In Norway a parent's entitlement to and the level of welfare support depend on parental income during six of the previous 10 months (Odelstingsinnstilling, 2001; Trygdeetaten, 2003). This policy may increase the length of time between leaving school and entering parenthood, as it provides an important incentive to work before having children so as to obtain a higher level of benefit during maternity leave.

Norms regarding whether marriage and leaving the parental home should accompany labor-market entry, as well as the role of the family in providing financial

[1]All countries of the Organisation for Economic Co-operation and Development (OECD) with relevant data (school-leaving age, length of compulsory schooling, years of unemployment) available are included in *Figure 2.1* and *Figure 2.2*.

[2]For the age group under consideration (15–29) in *Figure 2.1* and *Figure 2.2*, a younger school-leaving age implies that there may be more post-schooling years when one is not working. Thus, for a given employment rate, a younger school-leaving age would imply a longer period of not being employed. The lack of an association between the school-leaving age and the period spent out of the labor force for those aged 15–29 could thus imply a somewhat shorter transition from school to work in countries with a younger school-leaving age, if such a relationship exists.

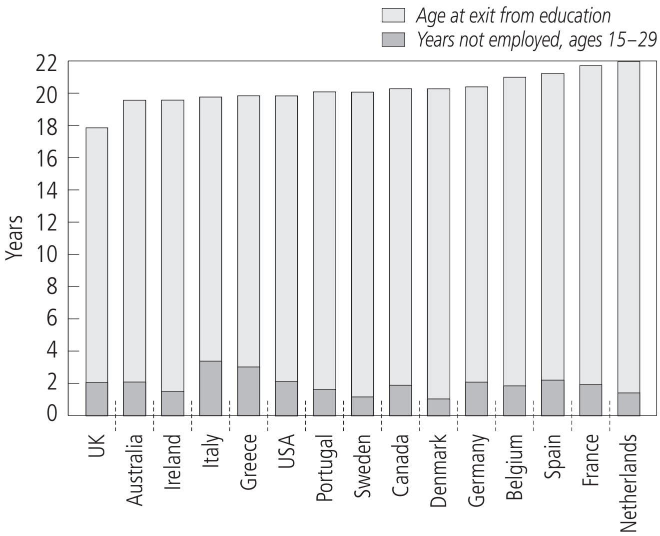

Figure 2.1. Graduation age and years spent not employed, ages 15–29.
Source: OECD (2003c); UNESCO (2004).

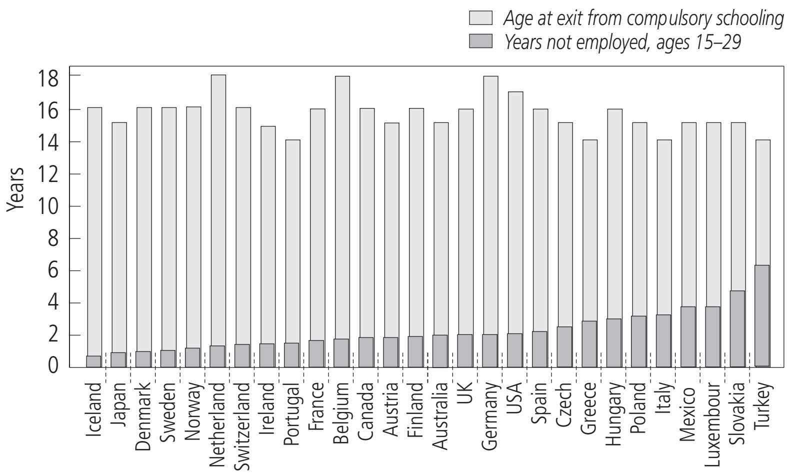

Figure 2.2. Age at leaving compulsory education and years spent not employed, ages 15–29.
Source: OECD (2003c); UNESCO (2004).

support, also affect the spacing of events in adulthood (Planas, 1999; Bentolila and Ichino, 2000). Other influences on the school-to-work transition include choosing to take a year off to travel, whether young men are required to enroll in military or community service, the effectiveness of education systems in easing the transition from school to work, and the degree of labor market flexibility (OECD, 1999, 2000, and 2003a).

The introduction of a reform to lower the graduation age could lead to a temporary increase in the number of new labor market entrants, as several cohorts would graduate at the same time. The increased number of new labor market entrants could lead to temporary increases in youth unemployment, as some studies of the cohort size of new labor market entrants suggest (Easterlin, 1978; Martin and Ogawa, 1988). Easterlin (1978) compares the time trends in American employment rates with variations in cohort sizes from the 1940s to the 1970s and argues that there is an inverse relationship between them. Martin and Ogawa (1988) consider the Japanese case and find that the wage ratios of 20–29 to 40–49 year olds in Japan are reduced by 1% when the share of the former increases by 10%.

More recently, Shimer (2001) considered detailed evidence from geographic entities in the United States which suggest that cohort size is positively related to employment rates. He finds that larger youth cohorts in a region are associated with higher labor force participation rates and decreased unemployment levels. Shimer (2001) argues that firms tend to relocate to where the labor supply is expected to increase (given that an increase in the number of labor market entrants can indeed be foreseen). The school reform that we investigate in Chapter 5 will be known about several years in advance, so that firms and labor market regulators will have time to prepare for and adjust to it.

The relationship between cohort size and unemployment is also likely to be influenced by labor market flexibility. Cohort size may increase unemployment when wage-setting systems are rigid (Jimeno and Rodriguez-Palenzuela, 2002). When real wage flexibility is high, as some evidence suggests is the case for Norway (Layard *et al.*, 1991, p.407), labor markets adjust to larger labor market inflows in a shorter time span. Because of differences in the educational attainment of those affected by the reform, the increase in labor market supply is likely to be spread over a number of years, softening the shock to the labor market.

Based on what the intercountry evidence provided here suggests, a marginally younger school-leaving age may lead to a parallel shift in the age of entry to the labor market, at least over time as labor markets adapt to changes in the supply of labor. In simulations where a lower school-leaving age is considered (Chapter 5), the time horizon extends to the year 2100. Any possible short-term adjustment problems in the labor market are unlikely to determine unemployment rates over this long time period.

2.2 Effects of Schooling on Human Capital and Productivity Levels

To predict whether a change in the timing and duration of schooling will affect educational outcomes, we need to understand the role of education in relation to other environmental and biological determinants of human capital. We therefore look at whether educational attainment serves to identify workers with different productivity potential and the extent to which schooling contributes to an individual's stock of human capital.

If the variation in human capital levels is largely determined by factors that have nothing to do with schooling, as suggested by the signaling theory, there will be few or no effects on human capital of changes to the duration and timing of schooling. However, if, in accordance with Mincer's (1974) human capital production theory, marginal variation in schooling does matter, then small changes in the length and timing of schooling could affect skill levels. We consider both theoretical and empirical studies on the determinants of skill differentials to see which theory fits best with the findings from the literature.

The Measurement of Human Capital

We are interested in estimating the effect of the duration and timing of schooling on human capital. Educational level is sometimes used as a proxy for human capital, but this measure can be misleading as 1) it conceals great heterogeneity between individuals with the same formal education qualifications and 2) it is an input factor in the human capital production function rather than a measure of output. A more valid measurement is found in measures of the quality of human capital, such as results from ability tests,[3] which are more closely associated with income differentials both at the macro and micro level.

At the aggregate level, Barro (1999) provides evidence that favors the use of measures of education quality (test scores) rather than education quantity (years of schooling), on the basis that measures of education quality are more closely correlated to economic growth than are the number of years spent at school. This argument is supported by Hanushek and Kimko (2000), who find that countries

[3]Tests of individual performance can be categorized according to whether they are aptitude tests, which measure the ability to learn, or achievement tests, which measure the amount of acquired knowledge. However, such a categorization can be misleading as: 1) both aptitude tests and achievement tests are able to predict individual productivity levels more accurately than educational attainment (Murnane *et al.*, 1995; Schmidt and Hunter, 1998); 2) results from different tests tend to be strongly positively correlated (Wechsler, 1997; Kunzel *et al.*, 2004); and 3) a test used as an achievement test in one setting can be an aptitude test in another, for example, a mathematics test can predict both the current proficiency in the subject and the ability to learn more (Atkinson *et al.*, 1993).

with one standard deviation higher mathematics and science test scores have over 1% higher economic growth.

At the individual level, test-score performance has been shown to be closely related to adult income levels in a number of studies (e.g., Boissiere *et al.*, 1985; Currie and Thomas, 1999; Tyler *et al.*, 2000). Ability tests tend to predict individual productivity better than other observable individual characteristics, including formal educational attainment (Schmidt and Hunter, 2004).[4]

Several longitudinal studies find that the correlation between test scores and wages has increased over time. Juhn *et al.* (1993) find empirical support for the increasing payoff to ability levels within narrowly defined school and occupational groups, and Murnane *et al.* (1995) show that the relationship between performance in mathematics at the end of high school and adult wages becomes stronger over time. Furthermore, cognitive skills have become increasingly in demand in the labor market as a whole for the last 40 years, at least in the United States, while physical abilities, such as manual dexterity, have decreased in importance (Autor *et al.*, 2003; Spitz, 2004). To sum up, the evidence gives weight to the argument that an output measure of human capital, such as test scores, should be used in the human capital production function rather than input factors, such as school attainment.

Assuming that the level of human capital is described by the variable T_{it} (for individual i at time t), the human capital production function can be stated as

$$T_{it} = {X_{it}}'\beta_1 + {Y_{it}}'\beta_2 + {Z_{it}}'\beta_3 + {D_{it}}'\beta_4 + \varepsilon_{it} \tag{2.1}$$

In Equation 2.1, β_1 is a vector of parameters that measures the impact of individual-level environmental influences (such as parental support), β_2 represents parameters for biological influences (such as innate ability), β_3 measures aggregate influences (such as educational expenditure in the region), and β_4 estimates the impact of the institutional settings we focus on (including the duration and timing of schooling). The respective variable vectors are X_{it}, Y_{it}, Z_{it}, and D_{it}, while ε_{it} is the error term.

2.2.1 Schooling and human capital levels: Screening and skill gains

Will school-entry age and school duration influence human capital and income? According to Mincer (1974), marginal increases in the length of schooling lead to

[4] Schmidt and Hunter (1998) investigate how different individual characteristics such as education, work experience, and general mental ability relate to productivity. They find that mental ability tests predict a person's work performance better than any other characteristic observable before a person enters the job. A range of other studies support the notion that differences in mental ability strongly affect productivity and wage levels, including Barrett and Depinet (1991); Bishop (1991); Dolton and Vignoles (2000); Grogger and Eide (1993); and Murnane *et al.* (2000).

higher productivity. Additional schooling improves individuals' skills, and this is reflected in the higher earnings of those who are better educated.

Equation 2.2 presents Mincer's (1974) schooling function in a simple form, in which only schooling matters for human capital production.

$$y_{it} = \alpha + \beta_1 \chi_{it} + \beta_2 \chi_{it}^2 + u_{it} \tag{2.2}$$

Here y_{it} is the wage level of an individual i at time t, while a is a constant, χ_{it} is the number of years of schooling, and u_{it} is the residual term. Wages are determined by the impact of schooling on human capital, and the effect of education length on wages is captured by the β_1 coefficient, while the β_2 coefficient measures whether the returns to schooling are diminishing, constant, or increasing.

In a comprehensive international survey on education and income, Psacharopoulos (1994) finds that returns to schooling are highest for the primary school years, while education at the secondary and tertiary levels have a considerably smaller effect on increasing wages. The lower wage gains for more advanced education could be explained by diminishing human capital gains to schooling. However, changes in the relative supply of and demand for highly skilled labor can provide another explanation for the decreasing wage returns to higher education, namely, that a strong increase in the supply of skilled workers can, at least for some periods of time, decrease their wages irrespective of human capital gains (Katz and Murphy, 1992; Teulings and Van Rens, 2002). Hansen *et al.* (2004) study the effect of education on cognitive abilities, which can represent a way of disentangling the effect of schooling on human capital from other influences. They find that gains in ability resulting from education are diminishing, that the marginal gains to cognitive abilities are lower for higher levels of education, and that the AFQT (Armed Forces Qualification Test) scores rise by only one-half by the time the students reach college relative to the early high school years.

The finding that schooling at lower levels does more to increase human capital levels may imply that one of the key functions of more advanced schooling is to identify the quality of the worker. This supports the screening or signaling theories of education which emphasize that preschooling heterogeneity in abilities determines educational attainment and adult wages. Different versions of these theories (Arrow, 1973; Spence, 1973; Stiglitz, 1975; Weiss, 1995) share certain common assumptions: 1) educational attainment is a signal of individual job proficiency; 2) these signals are easily observed by employers; 3) highly productive individuals acquire more education, as their cost of participating in education is lower; and 4) there are no externalities to human capital—productivity is fully person-specific.

In the strict sense of the screening theory, schooling is not productivity-augmenting, as shown in Equation 2.3, where z_{it} represents the individual's innate ability. The ability level is revealed through schooling, and there are no direct gains to human capital from schooling. The coefficient γ_1 measures the wage gains from a higher ability level, while γ_2 determines whether the wage gains from higher ability are diminishing, constant, or increasing. The variable y_{it} is the wage level of individual i at time t, u_{it} is the residual term, while α is a constant.

$$y_{it} = \alpha + \gamma_1 z_{it} + \gamma_2 z_{it}^2 + u_{it} \tag{2.3}$$

A synopsis of Mincer's (1974) human capital production function and the screening model is made when both the schooling selection and human-capital-increasing effects are taken into account as, for example, in Mincer (1980). Although the literature suggests that longer schooling is associated with higher income [see, for example, Harmon *et al.* (2001)], this is partly because those with higher innate abilities are more likely to attend higher education. This situation is captured by Equation 2.4 (the interpretation of the variables is the same as in Equation 2.2 and Equation 2.3).

$$y_{it} = \alpha + \beta_1 \chi_{it} + \beta_2 \chi_{it}^2 + \gamma_1 z_{it}^2 + \gamma_2 z_{it}^2 + u_{it} \tag{2.4}$$

In the case where $\beta_1 > 0$, $\beta_2 < 0$ and $\gamma_1 > 0$, $\gamma_2 < 0$, both schooling and ability positively influence the wage level, but there are diminishing wage returns for additional years of schooling and higher abilities.

2.2.2 Cognitive ability levels: Biological influences

In much the same way as there are genetic influences on personality (Lochlin, 1992) or psychopathology (Nigg and Goldsmith, 1994), cognitive abilities are also affected by hereditary factors (McGue and Bouchard, 1998). However, the relative effect of biological and environmental influences on cognitive abilities is difficult to estimate. To disentangle the effects of biological and environmental influences, one needs to disaggregate the phenotype (observed outcome) into genotype and environmental elements. One way of accomplishing this is to study monozygotic twins or siblings, as monozygotic twins share 100% of their genes, while dizygotic twins and siblings share about 50%. When human capital measurements are increasingly correlated, the higher the genetic similarity between two individuals, the higher the degree of heritability for mental abilities that is identified.

If IQ were determined entirely by family and socioeconomic influences, then adoptive siblings reared together should have an IQ correlation that is close to 1 and siblings reared apart should have a correlation closer to 0. Teasdale and Owen (1984) study Danish males (who completed a pre–military service IQ test) and find correlations of 0.47 for siblings reared apart, 0.52 for siblings reared together, 0.22 for half-siblings reared together, and 0.02 for adoptive siblings reared together.

Studies based on monozygotic twins reared apart also tend to find a strong hereditary influence on IQ levels, with correlations in the range of 0.64 to 0.78 (Bouchard *et al.*, 1990; Pedersen *et al.*, 1992). The genetic influences on ability levels have been found to increase with age and to become stronger from early childhood to adolescence (Lochlin *et al.*, 1997). In a study comparing monozygotic and dizygotic twins, the correlation was found to be around 0.68 for both groups when the twins were 3–6 months old; but at the age of 15 it increased to 0.86 for the monozygotic twins and decreased to 0.54 for the dizygotic twins (Wilson, 1983).

This age-induced increase in measured heritability may seem counterintuitive since, as the individuals grow older, they are exposed to more social influences, which should strengthen the impact of environmental influences. However, the increasing association between genetic similarity and ability levels can be explained by the fact that the freedom to choose one's environment also increases with age and that individuals are likely to select activities according to their own hereditary predisposition (Plomin and Petrill, 1997; Gottfredson, 1998).

2.2.3 Cognitive ability levels: Environmental determinants

Individual ability levels are influenced by a variety of environmental inputs, such as parental stimulation, nutrition, education, family type, existence and timing of parental disruption, as well as education costs and norms of school attainment.

Prenatal, Infancy, School, and Parental Influences

Environmental factors may influence cognitive ability levels even before birth, as fetal exposure to nutrients and hormones (environmental womb effects) are important influences on cognitive development. Twins share their womb environment for the months before birth; consequently, observed similarities may come from environmental womb effects rather than genetic similarities [see Devlin *et al.* (1997) for an overview of the topic].[5] Streissguth *et al.* (1989) provide further evidence on the importance of prenatal factors, showing that drinking or smoking on the part of the mother during pregnancy may adversely affect the child's health and cognitive abilities.

Infant nutrition and, in particular, whether a child is breastfed is another important environmental influence on infant intelligence. Certain ingredients in the breast milk, as well as the breastfeeding experience itself, may cause IQ differences. In

[5]Environmental womb effects should, however, also be present for dizygotic twins. Hence, differences between dizygotic and monozygotic twins are likely to reveal the effect of genetic differences net of environmental womb effects. An example of such a study on cognitive abilities is McGue *et al.* (1993) who find that adult monozygotic twins have a correlation of 0.83, while dizygotic twins have a correlation of 0.39, which suggests that genetic factors are considerably more important than environmental womb effects.

a test of the intellectual capacity of 300 prematurely born individuals, Lucas *et al.* (1992) argue that the type of nutrients given during the first weeks of life affect IQ scores by up to 10 points at the age of 8. In a meta-analysis of such studies, Anderson *et al.* (1999) find that breastfeeding increases the child's IQ by three points on average. Birch *et al.* (2000) argue that breastfeeding improves cognitive abilities through the effects of the fatty acids DHA and ARA. Other components of human milk may also affect intelligence levels (Uauy *et al.*, 1999).

The family situation seems to be of importance for human capital achievements, and growing up in a single-parent household has been found to lower an individual's school performance and adult productivity (Fronstin *et al.*, 2001; Ver Ploeg, 2002). Ermisch and Francesconi (2001) find that parental divorce is particularly unfavorable if the child is aged 0–5 when the disruption takes place. International data from the Programme for International Student Assessment (PISA) study on students' knowledge suggests that coming from a single-parent household significantly decreases human capital formation in a number of countries, although other social background factors, including low income level, often reinforce the relationship (OECD, 2001).

Schooling has been shown to positively affect IQ levels in several studies. A meta-analysis by Winship and Korenman (1997) concludes that an extra year of education raises IQ levels by around 2.7 points. However, studies that try to estimate the impact of schooling on IQ levels could be biased, as individuals with higher preschool abilities tend to achieve more education, and reliable and valid control variables for nonschooling factors tend to be missing or of low quality.

Ceci (1991) reviews studies that try to overcome the selection issue by analyzing the effect of potentially exogenous variation in schooling on individuals' cognitive development. Examples of cases he studies are the impact of a late school onset, the effect of early school termination, and historical interruptions of the school career (for example, due to war and a temporary lack of access to schooling). Nonetheless, some of the cases he investigates are likely to be influenced by other confounding factors (e.g., there could be independent effects on human capital formation in children who experience a war); other cases may overcome the selection problems that the more traditional approaches are subject to. Ceci (1991) finds that one missed year of education reduces IQ levels by from 0.25 to 6 IQ points.

2.2.4 *Test score increases over time*

Cognitive test performance has been shown to increase over a relatively long period of time, spanning the period from the beginning of the twentieth century to the present time (Tuddenham 1948; Flynn, 1987; Dickens and Flynn, 2001). By studying military test-score performances, Tuddenham (1948) finds that there were gains in measured IQ levels between World War I and World War II, while Flynn (1987) shows that this development continued in the post–World War II period. The size of the increase is, however, uncertain.[6] That there have been increases in IQ levels over time suggests a strong environmental influence on human capital levels, as the changes are estimated over a too short a time span to involve changes in the population's genetic makeup.

A likely cause of the improvements in military test-score performance could be the increase in educational attainment levels over the same period (military test scores measure the ability levels for a large proportion of the male population and may be affected by schooling). Another influence may be that such tests have become more common in candidate selection processes (Jenkins, 2001). This suggests that individuals from more recent cohorts are more motivated and better prepared to take such tests, as the test outcomes can be important for their career potential.

In contrast to IQ tests used for a broad cross-section of the population, the educational composition of which differs over time, the Scholastic Aptitude Test (SAT)[7] considers individuals with the same education (high-school diploma level) who should be motivated to take the test, as the results will affect their education outcomes. The SAT scores in verbal aptitude decreased from 1967–2000, however, while mathematical abilities in 2000 were similar to the 1967 level (College Board, 2002). The increasing share of the population taking this test (Fallows, 1980) may imply that the test participants are less selected and also explain why SAT scores have been stable or decreasing over time in contrast with military test scores.

The Impact of Schooling on Earnings

Surveys show that the estimated gain in income for an extra year of schooling in industrialized countries tends to lie in the range of 4% to 14% (e.g., Harmon *et al.*, 2001). For European countries the wage increases resulting from education are lower than in the United States, and for the Scandinavian countries they are particularly low, which is likely to reflect the more compressed wage distribution in these countries.

Simple, linear, ordinary least squares (OLS) estimates of the relationship between educational attainment and income can be criticized on several accounts. First, though presented as marginal income gains for each extra year of education,

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[6]Flynn (1987) finds that there has been a large rise in the average IQ level for several countries, with the largest increase in Holland, where test scores increased by 1.3 standard deviations between 1952 and 1982. However, Rodgers (1999) argues that these findings are likely to be upwardly biased because of methodological errors and that the true increase in IQ scores is likely to be considerably lower.

[7]The Scholastic Aptitude Test (SAT) is a test used to assess individuals' abilities before college entrance in the United States.

these estimates typically stem from the highest schooling level of completed education (i.e., high school diploma, bachelor's degree, or master's degree). This means that the term "yearly returns" is an approximation that does not take into account that certain years in school can be more skill-enhancing than others. Second, and more important, educational achievement is positively correlated with a number of individual characteristics that are difficult to observe and that, independently of education, could increase income.

Several authors find evidence of a *diploma effect*, where the wage returns for completing a school year in which a qualification is attained are higher than the wage returns from other school years. School admission and graduation are characteristics that employers use as an indication of a worker's productivity potential, while how many intermediate years there are is of no interest. The diploma effect supports the signaling theory: the attainment of a qualification matters, but the number of years of schooling matters less.

Empirical findings from Hungerford and Solon (1987) identify the first and the final year in school as having the strongest impact on future earnings. Other studies also support the existence of a diploma effect (Jaeger and Page, 1996; Frazis, 2002), as well as its validity for different education levels (Park, 1999) and across gender and race (Chatterji *et al.*, 2003).

OECD (1998) and Psacharopoulos and Layard (1974) find that the gradient of the age–earnings slope becomes steeper with the length of education, which can be taken as evidence in favor of the screening model of education. Abler individuals are screened into higher education. This leads to an increased steepness in the age–earnings profiles, as the higher productivity of these abler individuals comes to light gradually, the longer they work in the labor market. Adjusting for innate abilities, for example, by studying identical twins, tends to significantly lower the impact of schooling on wages (Ashenfelter and Rouse, 1998; Raaum and Aabo, 2000; Plug and Vijerberg, 2003). Moreover, twin studies would probably suggest an even weaker earnings effect if signaling effects could be adjusted for.

When employers determine how much to pay individuals with a given level of education, they include information from the average work performance of other individuals with the same formal qualifications. Signaling effects can therefore also play a role in the case of monozygotic twins, where innate abilities are equal. Attaining a higher level of education would signal a higher ability in the labor market, as the average person holding a more advanced school qualification has higher innate abilities. This implies that studies examining the effects of education on wages using twins data to overcome endogeneity problems may be upwardly biased.

2.2.5 Conclusion

To sum up, both environmental and genetic factors have strong impacts on cognitive ability levels. Analyses of large-scale data sets on twins, which permit a distinction to be made between environmental and genetic contributions, provide evidence of a strong hereditary influence. However, environmental issues, ranging from infant nutrition to parental behavior and schooling, are also found to substantially affect cognitive performance. Many psychologists argue that hereditary factors are stronger than environmental ones, at least in determining some aspects of cognitive abilities. An article written by a committee of leading researchers from the American Psychological Association concludes that the share of heritability in intelligence is close to 75% (Neisser *et al.*, 1996).

The strong impact of genetic influences on mental abilities is evidence in favor of a weak screening model of education. Consequently, although increasing educational attainment significantly raises ability and productivity levels, much of the variation found between schooling and human capital may be rooted in a person's genetic predisposition and in environmental factors that are unrelated to schooling.

Schooling is only one of many determinants of human capital, with a range of other environmental and biological influences also having substantial effects. The effects of signaling and selection account for a large proportion of wage differences resulting from school attainment. Studies that control for factors that are associated with, but not caused by, schooling find that the effects of schooling are much weaker than bivariate regressions between skills or income and schooling length suggest. Consequently, the evidence suggests that education, although having an important effect in terms of improving skills, is only one of many influences. It is therefore possible that a marginal variation in the duration and timing of schooling would be unrelated to the level of human capital output.

2.3 Age at School Entry and Wage Levels

The teaching of overly complex material to students at an age when they are developmentally unprepared for it may not only make them feel helpless and frustrated at what they perceive as their own shortcomings but also put them off studying, with long-term effects on their educational attainment and subsequent performance in the labor market. On the other hand, as the ability to learn declines with age, starting school too late can mean that some of a child's best learning years are lost. These two seemingly contradictory views on the costs and gains of variation in the school-entry age are, however, not mutually exclusive, as entry both too early and too late can be harmful for the student. In this section, we investigate whether a variation in the age of school entry of up to one year has any long-term impacts by studying the effect of such a variation on individuals' performance in the labor market.

2.3.1 Review of the literature

In several studies, student performance levels, usually measured by test performance or teachers' evaluations, are found to be slightly lower for those who enter school at a younger age (Teltsch and Breznitz, 1988; Alberts *et al.*, 1997). However, achievement differences related to age tend to be small in relation to other influences on human capital formation (Davis *et al.*, 1980; Jones and Mandeville, 1990). For instance, Jones and Mandeville (1990), in a study of reading skills, find socioeconomic and ethnic factors to be 13 times more important than a pupil's school-entry age. Moreover, some studies argue that the initial differences caused by an early school-entry age tend to diminish or disappear in later grades (Langer *et al.*, 1984; Shepard and Smith, 1986), although other studies suggest that the youngest in the class perform the least well throughout their school career (Uphoff and Gilmore, 1985; Sharp, 1995).

The majority of studies analyzing the effect of the school-entry age entry upon achievement investigate within-class age variation (comparing the achievement of younger and older students within a school class). Using this approach it is difficult to establish why there are differences in student performance, as different theories could account for the same results. Better performance by the older students in the class could be due to the *timing of education*, as the greater school readiness and maturity of the older children improves their performance. However, within-class differences in performance could also be caused by the *relative class-age effect*, whereby those who enter school at a later age earn more and perform better, as they are the oldest in their social reference group (the school class), an effect that is independent of the school-entry age (Thompson *et al*, 1991; Alton and Massey, 1998; Plug 2001). Moreover, Gredler (1984) shows that postponing the age of school entry does not seem to improve student performance, which demonstrates that is not age per se that is the main cause of within-class performance differences.

2.3.2 Birth month and school enrollment as a natural experiment

Previous investigations into the effects on earnings of the school entry age have several shortcomings that our study may overcome:

- Sample size is generally relatively small, and the test participants may come from only one school, which increases the risk of the sample being nonrandom and unrepresentative;

- The output measures used in some studies are subjective, such as the teacher's opinion of the students; and
- Earlier studies typically concentrate on students' performance and their adult income, while other relevant outcome variables, such as marriage and divorce patterns, are not considered.

In the current study we look at the Swedish school system, where the birth month of an individual determines the age at which he/she enters school. In Sweden rigid rules govern the school-entry age and duration of schooling for the cohorts we consider. As the month of birth determines the timing of school attendance, those born right after the school entry cut-off date are older when they enter and leave school.

Several studies have documented the effects of the birth month on phenomena such as the risk of suffering from schizophrenia, the sex ratio at birth, and life expectancy (Nonaka *et al.*, 1987; Sham *et al.*, 1992; Doblhammer and Vaupel, 2001). The use of the birth month in econometric studies of causal influences in behavioral relations, however, is relatively new. Angrist and Krueger (1991) pioneered this approach in their investigation of the relationship between earnings, educational attainment, and school regulations in the United States, where school regulations stipulate a minimum age at graduation that differs over time and across American states. The study shows that men born in the first quarter of the year earn slightly less than those born in the other three quarters. The authors attribute this finding to compulsory schooling laws that allow students to leave school after reaching the age of 16, even if they have not completed the school year. As a consequence, children born in the first quarter of a calendar year will have received less schooling if they drop out of school when they turn 16 as compared with children born later in a calendar year.

The study by Angrist and Krueger (1991) stimulated several follow-up investigations that have been critical of its conclusions. Bound and Jaeger (1996), for instance, provide evidence from cohorts predating the compulsory schooling laws that the link between season of birth and educational/labor market success can be at least partially explained by factors other than schooling laws.

The Swedish school enrollment rules, which differ from those of the United States, make Sweden a more suitable subject than the United States for using birth-month-induced variation in the timing of education and age of graduation as a natural experiment. A normal Swedish school year starts at the end of August and lasts until the beginning of the following June and consists of about 40 weeks, with children being taught every week from Monday to Friday. Compulsory schooling starts for almost all children the year they turn 7, lasts for 9 years, and finishes in the June of the calendar year in which the pupils turn 16 (or $n + 9$ if they started at the age of n).[8] Graduation from compulsory schooling therefore occurs when children are between 15.5 and 16.5 years old. Graduation at younger ages is impossible (except for a few cases of early enrollment), and graduation at older ages is rare, as very few students repeat classes and/or enter school at a later age.

The school entry cut-off-date mechanism means that those born in January enter school 11 months later than those born in the previous December. Upon completing compulsory schooling after the ninth grade, pupils can choose whether they would like to go on to a vocational or academic program in the upper-secondary school, which normally lasts three years. After graduating from upper-secondary school, roughly one-third of female students continue with tertiary education, while the remaining two-thirds pursue other activities, such as entering the labor market or starting a family.

The most important aspect of this system of enrollment and the compulsory completion of ninth-grade education is that the variation in the month of birth causes a systematic variation both in the timing of schooling and in the school cohort to which an individual belongs. This effect is most pronounced between children born in December and the subsequent January: these children belong to different school cohorts, and at each grade, and in particular at completion of compulsory education after the ninth grade, children born in January will still be only around one month younger than children born in the preceding December. This differential timing of schooling (and age at graduation) thus provides an important "natural experiment" through which to identify the effect of educational enrollment on demographic behaviors, as the childhood and early adulthood of those born during December and the following January take place during virtually the same time period. Any influences of that period on education or fertility, such as variation in the returns to education, economic upturns or downswings, or changes in family policy, affect these individuals identically.

At graduation from compulsory education, women born in December and January differ in the timing of their education but not in the level of their human capital: in both cases, the women have completed ninth grade education and face decisions about further options within the education system or entering vocational training.

[8]Almost all children start school when they turn 7, though some individuals bring forward or postpone school entry, for example, starting school at the age of 6 or delaying until the year they turn 8. The proportion of all female pupils entering school at the age of 6 constituted 1.6%–2% of all 6-year-old females in 1960, 1963, 1966, and 1969, the years for which data are available (Statistisk Tidsskrift, 1962; Statistiska Meddelanden, 1964, 1968, and 1970). The percentage starting to go to school at the age of 8 is not explicitly given. However, as the share of the 8-year-olds in school is only up to 2.4 percentage points higher than that of 7-year-olds, we may deduce that very few postponed school entry. The birth month of the individuals who brought forward or postponed school entry is not known. The change in Swedish school-entry rules, mentioned in Section 2.1, increased parental choice as to when their children entered school. This first occurred in the 1990s and is not relevant for the cohorts we study.

As many women extend their schooling beyond the ninth grade and there is little or no possibility of "catching up" within the school system, the difference in the timing of schooling also extends to upper-secondary school, twelfth grade, and potentially also to the timing of tertiary education among women who decide to continue in education. For women who pursue higher education, therefore, the month of birth is likely to have an effect on the age at graduation substantially beyond the ninth grade.[9]

2.3.3 Data

Our data set is based on the Swedish registration system and provides comprehensive information on fertility and other life-course events as well as socioeconomic background variables for almost all Swedish women born from 1946 to 1962. Our data cover 891,066 individuals born in Sweden from 1946 to 1962. We do not consider immigrants and we also omit one woman who is reported to have had her first child in 1897, despite having been born in 1960, which leaves the sample with 863,304 women. The data set includes longitudinal observations of demographic events (childbirth, marriage, divorce, death, emigration, and immigration) and income.[10] The income data are given in 1980 values. All demographic events are registered on a monthly basis up to 31 December 1999.

We have information on income in the period 1980–1998, which means that we can observe the cohorts' earnings through a 19-year-long window. The 1946 cohort's income can be observed for ages 34–52 years, the 1947 cohort for ages 33–51 years, and so forth. The 1962 cohort's income is observed for ages 18–36 years. When investigating the effect on income, we concentrate on the calendar years in which the respondents are aged 34–36, which are the only ages at which we can observe these variables for all women born from 1946 to 1962.[11]

[9]The design of the Swedish school system also avoids some of the weaknesses of the approach of Angrist and Krueger (1991). In their study, educational effects are based on the ability of the oldest children in the class to drop out of school. As the majority of students, regardless of the quarter of the year in which they were born, do not drop out of school at the youngest possible age, these laws are relevant only for a small proportion of the students. Our focus is on school legislation that affects the age at graduation for the whole population (Sweden), rather than compulsory school attendance laws that regulate the minimum age of graduation for the minority that drops out of school (United States).

[10]The income variable is the sum of taxable income (before tax), sick-leave benefits, and parental-leave benefits. However, as adjusting for fertility in the income regression, *Table 2.4*, does not alter the sign or the significance level of the birth-month effect on income, parental-leave benefits are unlikely to mediate the relationship between birth month and income. Given that sick-leave benefits are not substantially affected by the birth month, particularly between those born in December and those born in January, the association between birth month and the income variable is driven by variation in work income.

[11]Only annual income is observed. This means that the 34–36 age group in fact refers to individuals from a slightly wider age range. The largest deviations are found between those born in January, who

We present descriptive statistics for women aged 34–36 in *Table 2.1*, where income is given in 100 SEK (Swedish kronor). Those born earlier in the year earn about 1% more than those born later in the year. Swedish women born in the January–June period have an income of 47,936–48,268 SEK, while those born in the July–December period have an income of 47,607–47,878 SEK. Wage differences due to educational differences are, however, much greater than birth-month differences, with those who have three or more years of tertiary education earning on average 72% more than those with just a basic education (the income being 64,510 SEK for the former group compared to 37,470 SEK for the latter group).

We choose to focus on those aged 34–36 years for another reason; we are interested in the long-term effects of the age of school entry, and such effects may materialize only after several years in the labor market. For example, mathematics test scores from the eighth grade were found to be increasingly better predictors of earnings as the working life progressed (Murnane *et al.*, 1995). Thus, any effect of the age at school entry on the student's ability levels may be more accurately measured after a longer period in the workforce, when wages are more closely correlated with differences in job performance.

2.3.4 Hypothesis

The hypothesis we investigate is whether the age at school entry affects productivity in adult life. The Swedish school situation allows us to study the effect on adult productivity of up to one year's difference in the age at school entry, as the school entry cut-off date means that, at school entry, those born in January are 11 months older relative to those born in the following December.

We investigate the effect of the age at school entry on several outcomes that relate to "positive" events in adult life. These variables include marriage, educational attainment, and income. We also investigate the effect of the age of school entry on divorce, which can be characterized as a "negative" risk.

The hypothesis we would like to check is whether a higher age at school entry increases the risk of experiencing "positive" outcomes and lowers the risk of experiencing "negative" outcomes. That is, we would like to investigate whether

are observed from ages 34–36.92, and those born in December, who are observed from ages 33.08–36. However, as the age at leaving each stage of education is independent of the birth month, this does not pose a problem for our approach. Within every cohort, the number of years spent in the labor market is equal for individuals with different educational levels. Thus, the age differences we observe between those born in January and those born in December should not affect the number of years spent in the labor market. Consequently, the age differences in observed income between those born early and those born late in the year are not likely to affected by differences in the length of the working life.

Table 2.1. Average income by birth months and education. Swedish women born 1946–1962, aged 34–36 (100 SEK, 1980 value).

	Average income	Standard deviation
All women	479.86	263.2
Birth month		
January	481.32	262.30
February	483.42	263.77
March	482.68	261.74
April	482.55	265.72
May	482.96	273.59
June	479.36	258.29
July	477.55	258.00
August	476.97	266.81
September	478.78	267.31
October	477.34	260.35
November	477.62	259.63
December	476.07	258.24
Education		
Primary school	374.70	240.24
Secondary school, up to 2 years (mostly vocational study tracks)	443.20	218.25
Secondary school, 3 years or more (academically oriented study tracks)	487.73	263.76
Tertiary education, up to 2 years	531.79	238.47
Tertiary education, 3 years and above	645.10	326.89

Source: Statistics Sweden; own calculations.

those born in the first calendar months of a year have a higher risk of getting married, attaining higher education, and earning more, and are less likely to become divorced.

2.3.5 Findings

We analyze Swedish women born from 1946 to 1962 with respect to the effect of the school-entry age on variables that relate to outcome variables in adult life, namely income, education, marriage, and divorce.

The average income for different birth cohorts at age 34–36 is presented in *Figure 2.3*, which shows that for the cohorts of the mid- and late-1950s, the income of the older cohorts was, without exception, higher. These cohorts were aged 34–36 years in the early 1990s at a time when the Swedish economy was plunged into a state of crisis, with a rapid increase in unemployment and massive public-sector reforms. *Figure 2.4* shows the development of the unemployment rate over time and illustrates the magnitude of the economic crisis in Sweden in the 1990s.

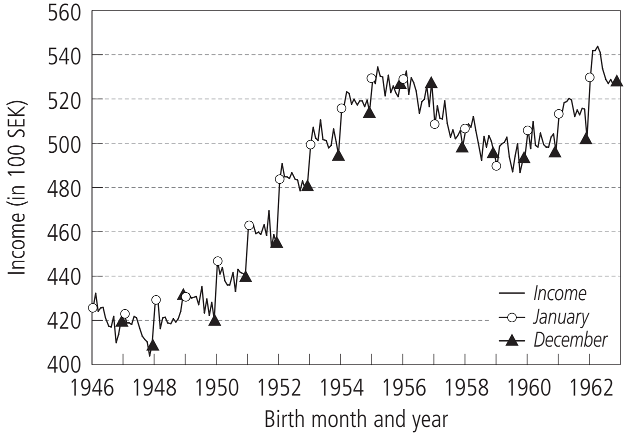

Figure 2.3. Average yearly income at ages 34–36. Swedish women born 1946–1962.
Source: Statistics Sweden, own calculations.

Figure 2.3 and *Figure 2.5* give the average annual income according to birth month. These results reveal patterns in support of the hypothesis that the age at school entry is a significant factor. Those who entered school at an older age have higher earnings in 15 of the 17 cohorts born from 1946 to 1962. On average, those born in January have a 1% higher income than those born in December.

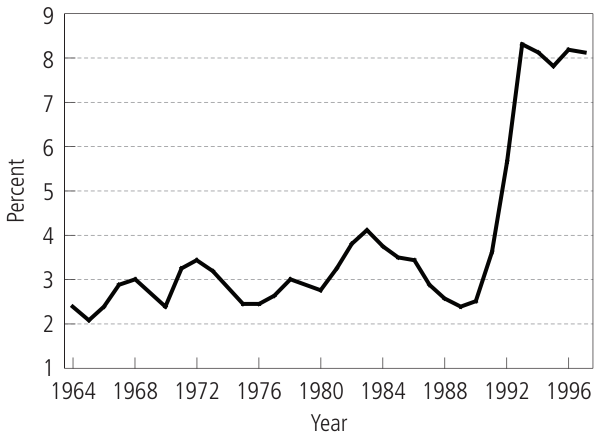

Figure 2.4. Swedish unemployment rates 1964–1997, men and women aged 16–64.
Source: Statistics Sweden; own calculations.

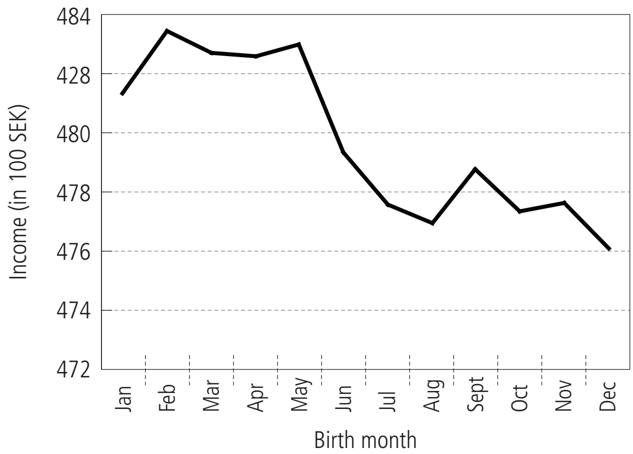

Figure 2.5. Pretax work income, ages 34–36. Swedish women born 1946–1962. Source: Statistics Sweden; own calculations.

We also find that those born in spring have a slightly higher income than those born in January. This is in line with the fact that women from higher social classes, who may be more likely to experience positive outcomes and less likely to experience negative ones, tend to give birth in spring (Smithers and Cooper, 1984; Bobak and Gjonca, 2001). The reason why women from higher social classes give birth in spring may be that they have a higher conception risk in the summer holidays when sexual activity is higher and stress levels lower. As women who are out of the workforce and women in part-time employment are likely to be less influenced by holidays, their seasonality patterns may be weaker. However, the effect of the spring peak does not jeopardize the hypothesis of income decreasing according to age at school entry. Moreover, the differences in income between December and January—only one month apart—cannot be explained by differences in the social class of the parents.

The finding that those born earlier in the year earn more is confirmed by results from the regression analysis, shown in *Table 2.2*.[12] The logarithm of the income for those born from August to December is significantly lower than for those born in January (first column). However, when education is adjusted for (second column), the birth-month differences are no longer significant. As shown in *Figure 2.6*, those

[12]The R-squared levels in *Table 2.2* and *Table 2.3* in the regression results for income and education are very low (ranging from 0.001 to 0.059), as we do not take into account the most important determinants of schooling variables, such as innate ability and socioeconomic background characteristics, but use a very restrictive set of variables, mainly relating to birth date. This does not represent a substantial problem for our analysis, as we are interested only in the effect of the timing of education, as observed by the birth date (which is unlikely to be affected by the omitted variables).

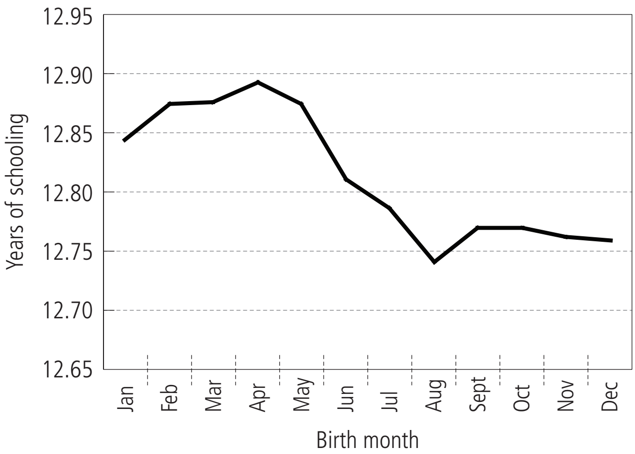

Figure 2.6. School attainment. Swedish women born 1946–1962.
Source: Statistics Sweden, own calculations.

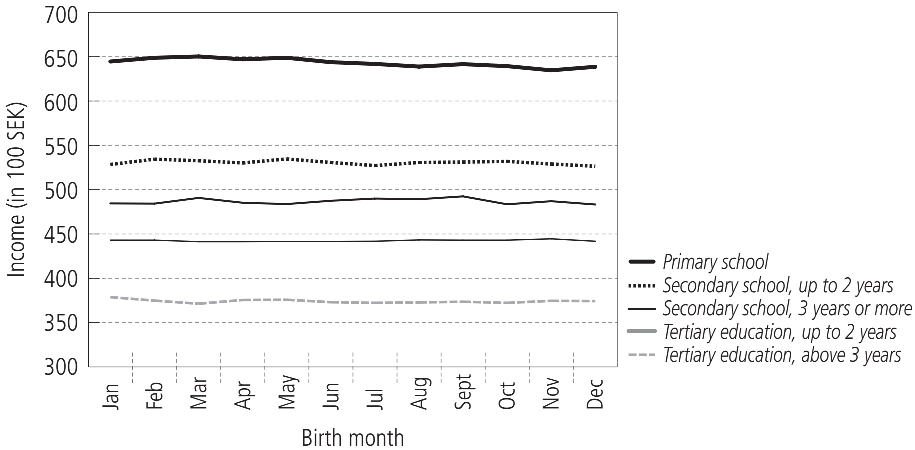

Figure 2.7. Birth month and income by education.
Source: Statistics Sweden, own calculations.

born in the earlier months of the year tend to have higher educational attainment. *Figure 2.7* provides further evidence that the income differences are primarily explicable by educational attainment: the birth month is found to have little or no effect on income when educational levels are adjusted for.

The effects of the birth month on education levels are presented in more detail in *Table 2.3* and *Table 2.4*. *Table 2.3* shows the relationship between the birth month and length of schooling among those born in different birth months. Starting school at a younger age is associated with lower educational attainment, the

Table 2.2. Income variables, ordinary least squares (OLS) regression (1980 values). Dependent variable: Log of yearly income (average annual income for 34–36 age group, 100 SEK). Those who died or emigrated before they turned 37 and those without known education are excluded.

	Coeff.[1]	Std. dev.[2]	Coeff.	Std. dev.
Constant	5.818	0.005 ***	5.570	0.005 ***
Birth month				
January	Ref. cat.[3]		Ref. cat.	
February	0.005	0.005	0.002	0.005
March	0.006	0.005	0.003	0.005
April	0.003	0.005	–0.001	0.005
May	0.005	0.005	0.002	0.005
June	–0.001	0.005	0.001	0.005
July	–0.007	0.005	–0.003	0.005
August	–0.011	0.005 **	–0.004	0.005
September	–0.008	0.005 *	–0.004	0.005
October	–0.010	0.005 **	–0.005	0.005
November	–0.012	0.005 **	–0.007	0.005
December	–0.010	0.005 **	–0.004	0.005
Birth year				
1946	Ref. cat.		Ref. cat.	
1947	0.018	0.005 ***	0.008	0.005
1948	0.028	0.005 ***	0.013	0.005 **
1949	0.032	0.005 ***	0.011	0.005 **
1950	0.073	0.006 ***	0.046	0.005 ***
1951	0.135	0.006 ***	0.108	0.005 ***
1952	0.201	0.006 ***	0.173	0.005 ***
1953	0.254	0.006 ***	0.227	0.005 ***
1954	0.300	0.006 ***	0.275	0.006 ***
1955	0.321	0.006 ***	0.293	0.005 ***
1956	0.311	0.006 **	0.284	0.005 ***
1957	0.259	0.006	0.231	0.005 ***
1958	0.229	0.006	0.202	0.006 ***
1959	0.200	0.006	0.173	0.006 ***
1960	0.199	0.006 **	0.171	0.006 ***
1961	0.209	0.006	0.179	0.006 ***
1962	0.230	0.006 ***	0.203	0.006 ***
Education				
Primary school			Ref. cat.	
Secondary school, up to 2 years			0.197	0.003 ***
Secondary school, 3 years or more			0.266	0.004 ***
Tertiary education, up to 2 years			0.408	0.003 ***
Tertiary education, above 3 years			0.601	0.003 ***
R-squared	0.015		0.059	
N	816,583		802,489	

***=Significant at $p < 0.01$ level. **=Significant at $p < 0.5$ level. *=Significant at $p < 0.1$ level.
[1]Coefficient; [2]Standard deviation; [3]Reference category.
Source: Statistics Sweden; own calculations.

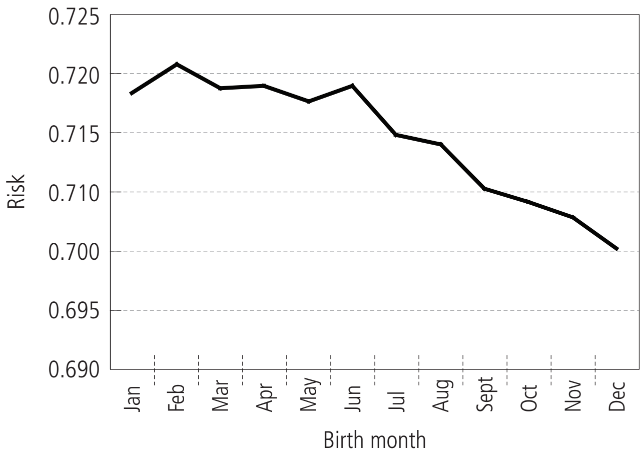

Figure 2.8. Marriage risk until age 37, Swedish women born 1946–1962. Source: Statistics Sweden, own calculations.

youngest in the class having one-twelfth of a year less schooling than the oldest in the class. *Table 2.4* shows the risk of attaining specific levels of education: those born early in the year are less likely to have primary or lower-secondary schooling as their highest educational attainment and more likely to have achieved more advanced education. Again, those born in spring are the most "successful" in terms of educational attainment, while the largest gap is between January and December, indicating the strength of the impact of the school entry cut-off-date mechanism.

In *Table 2.5* regression results from the women's marriage and divorce probabilities are shown. Those born later in the year are significantly less likely to marry, but they have a higher likelihood of divorcing; and the effect of birth date on divorce is slightly weaker at age 45 than at age 37, which suggests that it weakens slightly over the adult life course. Controlling for education in these regressions does not affect the significance levels or the sign of the explanatory variables. From *Figure 2.8* we see that the likelihood that individuals will marry increases with age at school entry, while *Figure 2.9* shows that an older age at school entry decreases the risk of divorce.

2.3.6 Concluding remarks

To what extent does an individual's age position in school relate to whether she is successful or not later in life? We consider all Swedish women born in the period 1946–1962 and study outcome variables related to educational attainment and performance in the labor market, as well as marriage and divorce risks. Entering school at up to a year older leads to slightly higher educational attainment and more

Table 2.3. Years of education, OLS regression.

	Coeff.[1]	Std. dev.[2]	
Constant	12.893	0.015	***
Birth month			
January	Ref. cat.[3]		
February	0.030	0.014	**
March	0.032	0.014	**
April	0.049	0.014	***
May	0.031	0.014	**
June	–0.033	0.014	**
July	–0.057	0.014	***
August	–0.102	0.014	***
September	–0.072	0.014	***
October	–0.073	0.014	***
November	–0.080	0.015	***
December	–0.084	0.014	***
Birth year			
1946	Ref. cat.		
1947	0.048	0.016	***
1948	0.017	0.016	
1949	0.071	0.017	***
1950	0.073	0.017	***
1951	0.053	0.017	***
1952	0.020	0.017	
1953	–0.060	0.017	***
1954	–0.116	0.017	***
1955	–0.082	0.017	***
1956	–0.132	0.017	***
1957	–0.128	0.017	***
1958	–0.133	0.017	***
1959	–0.136	0.017	***
1960	–0.134	0.017	***
1961	–0.094	0.017	***
1962	–0.127	0.017	***
R-Squared (adj.)	0.001		
N	807 927		

***=Significant at $p < 0.01$ level. **=Significant at $p < 0.5$ level. *=Significant at $p < 0.1$ level.
[1]Coefficient; [2]Standard deviation; [3]Reference category.
Source: Statistics Sweden; own calculations.

Table 2.4. Risk of educational attainment. Logistic regression results (odds ratio).

	Primary school	Secondary school, up to 2 years	Secondary education, at least 3 years	Tertiary education, up to 2 years	Tertiary education, at least 3 years
Birth month					
January (Ref.[1])	1.000	1.000	1.000	1.000	1.000
February	0.992	0.980	0.976	1.012	1.043 ***
March	0.980	0.989	0.981	1.005	1.039 ***
April	0.967	0.989	0.981	1.006	1.058 ***
May	0.981	0.997	0.977	0.998	1.042 ***
June	1.014	1.017	0.981	0.987	0.981
July	1.024 *	1.037 ***	0.956 **	0.976 *	0.955 ***
August	1.049 ***	1.059 ***	0.947 ***	0.944 ***	0.933 ***
September	1.021	1.043 ***	0.963 **	0.973 **	0.944 ***
October	1.020	1.064 ***	0.956 **	0.960 ***	0.943 ***
November	1.020	1.064 ***	0.965 *	0.949 ***	0.944 ***
December	1.028 **	1.062 ***	0.962 **	0.945 ***	0.948 ***
Birth year					
1946 (Ref.)	1.000	1.000	1.000	1.000	1.000
1947	0.897 ***	0.992	1.131 ***	1.077 ***	1.063 ***
1948	0.846 ***	1.034 ***	1.198 ***	1.154 ***	1.093 ***
1949	0.773 ***	1.002	1.244 ***	1.274 ***	1.146 ***
1950	0.692 ***	1.016	1.324 ***	1.365 ***	1.140 ***
1951	0.646 ***	1.035 ***	1.395 ***	1.454 ***	1.084 ***
1952	0.608 ***	1.046 ***	1.418 ***	1.567 ***	1.045 ***
1953	0.613 ***	1.084 ***	1.297 ***	1.595 ***	1.013
1954	0.668 ***	1.009	1.351 ***	1.638 ***	0.992
1955	0.569 ***	1.117 ***	1.251 ***	1.697 ***	0.980
1956	0.561 ***	1.174 ***	1.250 ***	1.670 ***	0.944 ***
1957	0.539 ***	1.205 ***	1.241 ***	1.690 ***	0.934 ***
1958	0.541 ***	1.207 ***	1.287 ***	1.638 ***	0.945 ***
1959	0.495 ***	1.277 ***	1.399 ***	1.578 ***	0.916 ***
1960	0.462 ***	1.342 ***	1.434 ***	1.590 ***	0.884 ***
1961	0.419 ***	1.377 ***	1.530 ***	1.568 ***	0.900 ***
1962	0.423 ***	1.362 ***	1.718 ***	1.572 ***	0.837 ***

***=Significant at $p < 0.01$ level. **=Significant at $p < 0.5$ level. *=Significant at $p < 0.1$ level.
[1]Reference.
Source: Statistics Sweden; own calculations.

Table 2.5. Risk of marriage and divorce. Logistic regression results (odds ratio).

	Marriage (all women)		Divorce (married women)	
Until age 37	to age 45	to age 37	to age 45	
Birth month				
January (Ref.[1])	1.000	1.000	1.000	1.000
February	1.015	1.017	0.983	0.989
March	1.005	1.016	0.994	1.000
April	1.009	1.032 *	0.984	0.988
May	0.999	1.026	0.985	1.002
June	1.005	1.000	1.010	1.012
July	0.982	0.972	1.029 *	1.013
August	0.977 **	0.989	1.052 ***	1.015
September	0.959 ***	0.957 **	1.053 ***	1.020
October	0.956 ***	0.966 *	1.042 *	1.017
November	0.949 ***	0.949 ***	1.041 ***	1.035 **
December	0.929 ***	0.922 ***	1.075 ***	1.066 ***
Birth year				
1946 (Ref.)	1.000	1.000	1.000	1.000
1947	0.904 ***	0.934	1.015	1.010
1948	0.847 ***	0.905	1.023	0.999
1949	0.739 ***	0.808	0.958 ***	0.941 ***
1950	0.654 ***	0.725	0.966 **	0.955 ***
1951	0.592 ***	0.671	0.944 ***	0.939 ***
1952	0.551 ***	0.619	0.894 ***	0.915 ***
1953	0.650 ***	0.587	0.858 ***	0.954 ***
1954	0.590 ***	0.536	0.845 ***	0.944 ***
1955	0.544 ***		0.852 ***	
1956	0.507 ***		0.867 **	
1957	0.473 ***		0.876	
1958	0.427 ***		0.867	
1959	0.398 ***		0.907	
1960	0.368 ***		0.910	
1961	0.342 ***		0.958	
1962	0.312 ***		1.021	

***=Significant at $p < 0.01$ level. **=Significant at $p < 0.5$ level. *=Significant at $p < 0.1$ level.
[1]Reference.
Source: Statistics Sweden; own calculations.

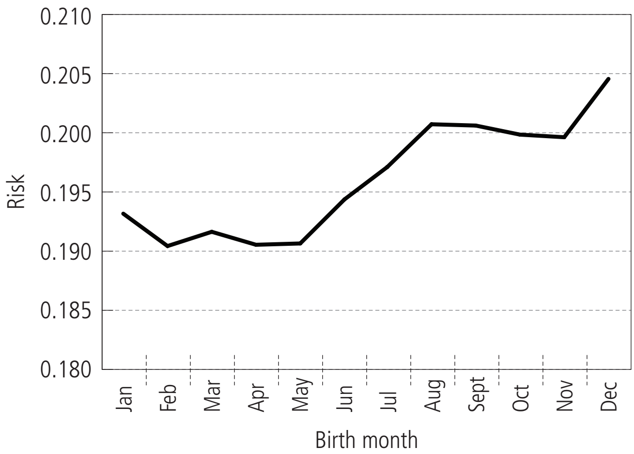

Figure 2.9. Divorce risk to age 37 (married women), Swedish women born 1946–1962.
Source: Statistics Sweden; own calculations.

income. We also find that those who were oldest when they entered school, while somewhat more likely to marry, are less likely to divorce.

The income gain from entering school up to a year older is explained by the fact that those who entered school at an older age received rather more education. The effects are relatively moderate; those who are 11 months older when they enter school have an education that is one-twelfth of a school year longer and earn about 1% more.

Our study is the first to identify the effects of school-entry age on the likelihood of getting married or divorced. We also identify that income and educational attainment depend on a pupil's age in class. The availability of a large data set (more than 100 times the size of the largest samples applied to date) and more objective outcome variables (administrative registers rather than individuals' subjective statements) could suggest that our approach is more valid and reliable than earlier studies.

Our finding that the oldest in class earn 1% more does not, however, necessarily support the theory that a later school-entry age improves school performance. The finding that older students perform better can just as well be explained by the *relative class-age effect* as by the *absolute age of school entry*. Those who are of a higher age in the classroom may be more likely to take a leading role and may feel that they should be in charge. Their relative age position may translate into greater self-confidence and better school performance.

Would a one-year-earlier start to education affect human capital formation? The evidence presented here suggests that if a child enters school one year later, her adult income will be about 1% greater. However, the higher income of those who enter school earlier could be due to the *relative class-age effect*. If the effects that we have observed, namely, income gains on the part of those who were among the older students in their class, are due to the students' relative age position, then a change in the school-leaving age is unlikely to have any net effects on individual productivity.

2.4 Duration of Schooling and Student Performance at the End of Secondary School[13]

A number of studies that investigate the effects of educational attainment on wages tend to identify a significant positive effect [reviews of the literature are found in Card (1999) and Harmon *et al.* (2001)]. However, as these studies base their analyses on the earnings outcomes of individuals with different educational qualifications, the estimates could be biased. Attaining higher education involves going through a strong selection process where screening and signaling mechanisms can increase wages independently of human capital gains. Studies of education level and earnings are therefore likely to be biased, as estimates of innate abilities are usually omitted or poorly measured; they are therefore of little relevance to our research question regarding the effect of variation in the length of schooling.

Shortening the duration of primary and secondary schooling by one year will not affect the screening mechanism, but it could influence the formation of human capital. A more relevant research approach, therefore, is to analyze the variation in the number of years required for a given qualification, which allows one to focus on the effects of variation in the length of schooling without having to control for signaling effects.

In one of the relatively few studies that consider the effects of the length of schooling on human capital levels, Pischke (2003) investigates a school cohort from several German states that lost two-thirds of a primary school year in 1966–1967 and hence graduated at an earlier age. He finds that those with shorter schooling did not achieve less in terms of higher education, nor were their earnings lower, although they did have a slightly higher grade repetition. Pischke (2003) argues that this supports the notion that the duration of schooling can be shortened without a concomitant decrease in human capital levels.

Two recent studies from Scandinavian countries investigate how extending compulsory education can affect human capital outcomes and find this to have been associated with higher wage levels (Aakvik *et al.*, 2003; Meghir and Palme, 2003). However, as these extensions of schooling resulted in the attainment of a higher

[13] A broader analysis of how school duration affects Swiss student performance is found in Skirbekk (2006).

educational qualification, signaling effects could at least partially explain observed wage gains.

Meghir and Palme (2003) analyze the effects of a Swedish education reform under which all students were required to complete nine years of schooling rather than seven or eight years, as was previously the case. The reform was gradually implemented across Sweden from 1949 to 1962. The reform was found to significantly raise the level of education and income for certain groups, while for others it had no effect. In particular, individuals from lower social classes with high productivity potential (revealed through their high ability levels) benefited significantly from the reform. Without it, these individuals might not have pursued higher educational attainment because of the costs involved (they had a low-skilled parent, which suggests normative and financial restrictions to continuing in the school system beyond compulsory schooling).

Aakvik *et al.* (2003) investigate the impact of an expansion of compulsory schooling (from seven to nine years) in Norway in the 1960s on the amounts earned by those aged 38–47 in 1995. They argue that the reform increased the propensity to complete subsequent schooling and raised wage levels. However, in contrast to Meghir and Palme's (2003) analysis, the data set of Aakvik *et al.* (2003) lacks information on the individuals' cognitive abilities, which may reduce the validity of their findings and bias their estimates.

Longer mandatory schooling may increase workers' wages simply because it leads to a temporary decrease in the labor supply: a relative scarcity of new labor market entrants would increase the wages of those in the labor market, net of any human capital gains (Oosterbeek and Webbink, 2003). Oosterbeek and Webbink (2003) study the effect of a Dutch school reform that led to a temporary decrease in the number of new labor market entrants and conclude that the reduced supply increased the wage levels of those already in the labor market. They argue that if studies, like that of Aakvik *et al.* (2003) and Meghir and Palme (2003), do not take such effects into account, their estimates are likely to be biased.

2.4.1 The length of primary and secondary school in Norway

By international standards, there seems to be scope for a shift in the duration of Norwegian education, as discussed in Section 2.1. Several countries have school systems that allow children to leave secondary school one to two years earlier than Norway does, without lowering human capital levels (Mullis *et al.*, 1998). The reasons why the same human capital level can be achieved at a younger age are not fully understood, although the way education is organized is likely to play a role. Efficiency gaps may be caused by the weight given to different subjects in school, the role of the education system in achieving egalitarian aims, and the type of teaching strategies being used.

One reason for variations in school length could be that school systems with shorter durations have more intense learning schedules with more hours of instruction per year. At the age of 7, Norwegian pupils receive only 570 hours of instruction per year; pupils of the European Economic Area (EEA) receive around 740, while Scottish pupils receive 950. At the age of 10, Norway's average is 770 hours, the EEA's average is 830, and Scotland's is 950. In secondary education, Norway's average is 855 hours of instruction per year, the EEA's is about 900, and Scotland's is 1,045 (Eurydice, 2000).

Separating students into practical and academic study tracks at a relatively late age may cause inefficiencies in the school system and slow students' progress, and this can lead to an unnecessarily long schooling duration. Braathe and Ongstad (2001) argue that the late age at which Norwegian students have to choose their study track (15–16 years) is intended to increase social equality. Its unintended consequence, however, is a school system that slows study progress, decreases the amount of learning, and postpones the age of labor-market entry.

If students were to enter school one year earlier and have one year of schooling less, they would need to make choices about specialization two years earlier than has been the case to date. They would have to choose whether they wanted to continue in an academic or vocational study track at the age of 13–14 instead of 15–16 years. Whether this would affect the quality of their choice is uncertain. By international standards, making this choice at the age of 13–14 is relatively normal. For example, in the Netherlands, the choice of study track is made after primary school at the age of 12; in Austria and Germany, it is made when the students are 10.

2.4.2 Variations in the duration of schooling: The case of Switzerland

Different nations apply different learning strategies, some teaching relatively advanced material in the early years of schooling and others waiting until later. This has the effect of a country's ranking and relative performance changing with each passing school year (Kjærnsli and Lie, 2002). Thus, studies that analyze the scholastic performance of, for example, fourth or eighth graders—the grades usually studied in large-scale international student evaluation surveys such as PISA or the Third International Mathematics and Science Survey (TIMSS)-Repeat (OECD, 2001; IEA, 2000)—would not be suitable for our research, as these surveys estimate students' performance in the intermediate school years, before education is completed. This could give misleading results as students' performance would not be representative of the whole schooling period. A study on the performance level of school systems should thus focus on scholastic outcome as late in the teaching process as possible—in our case, the final year of secondary education. At this stage, a student's educational achievement reflects the "end product," the human capital output of the full learning period we are interested in.

In effect, we need to investigate the impact of schooling variation in a setting where differences exist in the length of schooling. In Norway and the other Nordic countries, schooling length does not differ. We thus looked for a nation that was similar to Scandinavian countries in terms of educational attainment patterns and socioeconomic situation but where there was variation in the length of schooling. A nation that satisfied such requirements is Switzerland, where the length of academic-track schooling differs between 12, 12.5, and 13 years according to canton.

2.4.3 Description of data set

The measurement of the performance of Swiss students and their background variables is available from the TIMSS/III student evaluation data set (Mullis *et al.*, 1998). The TIMSS survey sampled a random selection of students across Switzerland to give a representative picture of the country's school system. In addition to test performance, TIMSS administrators collected information on students' background characteristics, including the student's family situation, his/her socioeconomic background, leisure activities, and whether both parents were living at home.

The Swiss survey of the final year of secondary school students was part of the international TIMSS study on student performance, conducted in 22 countries. The survey was administered by the International Association for the Evaluation of Educational Achievement (IEA), and experts from a number of countries participated in the planning and implementation of the survey. Rigorous procedures were put in place and extensive efforts were made to overcome the challenges of such a comparison of school systems. Quality control was given the highest attention in both the collection and processing of the data, so that a valid and reliable measure of student performance and background could be produced. The TIMSS survey was the largest, most comprehensive study ever carried out to make student performance and background information comparable at the national and international level.

The TIMSS data was collected in a way that emphasized the random selection of the survey participants (Gonzalez *et al.*, 1998). To ensure that the selection process was unbiased, a two-stage sampling process was used. During the first stage, TIMSS administrators chose schools from across the country in a nonselective way, and in the second stage, students were randomly selected within each of the sample schools to produce a representative sample for the whole Swiss student population.

The final year of Swiss secondary school students was tested in 1995. The students were chosen regardless of whether they had followed an academic, technical, vocational, or other type of study track. To improve comparability among different cantons, we limit our sample to students from academic-track schools.[14] Academic-track students are comparable because all receive an education that permits direct access to university education.

The sample of Swiss academic-track students consists of 1,018 students, randomly chosen across the nation to form a representative sample of the entire academic-track student population of Switzerland. In the sample, 110 individuals entered school systems requiring 12 years of schooling, 382 entered systems requiring 12.5 years, and 526 entered systems requiring 13 years. Information on test scores,[15] along with a large number of background variables is available for all students. We investigated the results from both the mathematics and the science literacy tests in the TIMSS survey.

As we are interested in the outcome in human capital terms from the complete duration of primary and secondary schooling, input factors in the human capital production function at the class and school levels are not investigated. Each student's performance in the final grade of secondary school is determined by a history of many different teachers and class settings in several schools, and information on these is not available in such a complete form. Moreover, even if teaching quality in the final school year were particularly good or bad, the student's human capital has already been formed by a number of teachers over a long period, and the influence of teachers in the final year is likely to play only a marginal role in the production of human capital. Thus, although we can observe such class-level influences in the last year of secondary school (which represents only a small proportion of the student's total schooling experience), controlling for these factors would not give a correct impression of their influence.

On the other hand, characteristics specific to the canton, including educational expenditure and the proportion enrolled in secondary school, tend to remain stable over time, and we therefore include them in the analysis. The same holds true for student-level background variables such as the language spoken at home and the number of books owned by the student's household.

2.4.4 Individual and canton-level data

The TIMSS data give information on student performance at the individual level. The data set provides test results from mathematics and science, as well as background information on student characteristics that are potentially relevant to school success, such as gender or family status. Canton-level variables were gathered from

[14]The TIMSS/3 final year of secondary school survey for Switzerland also sampled students who were not in the academic track, such as vocational-track students.

[15]On the basis of the students' answers to TIMSS questions, a score for each student is calculated. The description of the design of the test and the procedure for developing students' scores is found in Gonzalez *et al.* (1998).

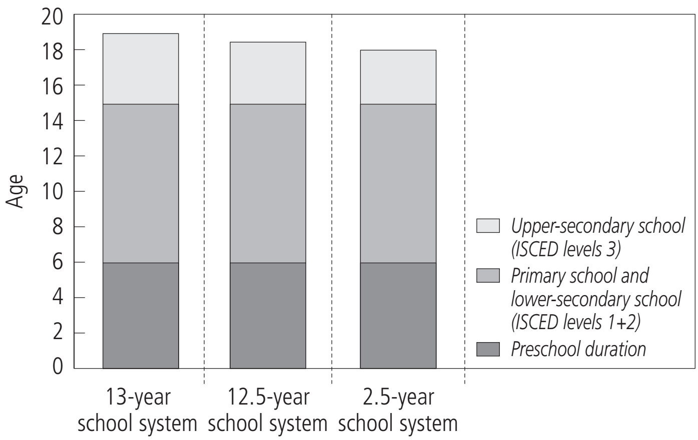

Figure 2.10. The Swiss school system, academic-track schools.
Source: EDK (2003).

the Swiss national statistical office and include educational expenditure and GDP per capita.

2.4.5 The Swiss school system

The Swiss school system is presented in *Figure 2.10*. After school entry, which takes place around the age of 6 years,[16] the students spend 9 years in compulsory schooling, which comprises primary and lower-secondary school. Thereafter, individuals participate in academic-track upper-secondary education, leave the school system, enter apprenticeships, or attend other schooling.

The variable we focus on—the duration of upper-secondary school in academic-track schools (*Maturitätsschulen*)—varies according to the school laws of the canton in which the school is situated. Each canton is allowed by law to set the duration of schooling. The full duration needed to complete primary and secondary school differs between 12, 12.5, and 13 years, according to the canton. As shown in *Figure 2.10*, the variation in the length of schooling comes from the length of upper-secondary school. However, when we look at student performance in the final year of secondary school, we are observing the human capital output from both primary and secondary school; thus students' performance could also reflect human capital formation from the primary and lower-secondary school levels.

[16]The school entry cut-off date is, according to school entry regulations in Switzerland, as follows: When an individual turns 6, he/she should enter school within four months either side of 30 June that year. The school entrants are on average over 6 years when they enter school, as schools tend to start in the fall. See also footnote 16 for information on school regulations.

Table 2.6. Description of the cantons.

	Population 1995	19-year-old population	Canton is considered in the analysis	Main language (G=German, F=French, I=Italian)
Aargau	528,887	6,187	√	G
Appenzell Inner Rhodes	14,750	194		G
Appenzell Outer Rhodes	54,104	587	√	G
Basel-city	252,331	2,668	√	G
Basel-country	195,759	1,712	√	G
Bern	941,952	10,347	√	G
Fribourg	224,552	2,768	√	F
Geneva	395,466	4,254	√	F
Glarus	39,410	413		G
Graubünden	185,063	2,262	√	G
Jura	69,188	895	√	F
Lucerne	340,536	4,238	√	G
Neuchâtel	165,258	1,928	√	F
Nidwalden	36,466	402		G
Obwalden	31,310	403		G
Schaffhausen	74,035	840	√	G
Schwyz	122,409	1,552	√	G
Solothurn	239,264	2,693	√	G
St. Gallen	442,350	5,338	√	G
Thurgau	223,372	2,546	√	G
Ticino	305,199	3,428	√	I
Uri	35,876	477		G
Valais	605,677	6,721	√	G
Vaud	271,291	3,421	√	F
Zug	92,392	1,131	√	G
Zurich	1,175,457	12,494	√	G

Source: Bundesamt für Statistik (1999), Mullis *et al.* (1998).

Of Switzerland's 26 cantons, five were not tested in the TIMSS survey (see *Table 2.6*), because the TIMSS data set did not take every canton specifically into account. However, the cantons excluded are the relatively small and the least-populated ones, constituting only about 2% of the Swiss population. A map of Switzerland, indicating which cantons were excluded, and which have a 12-, 12.5-, and 13-year duration of schooling, is given in *Figure 2.11*.

Descriptive statistics on canton-specific variables related to education, population, and wealth, are presented in *Table 2.7*. These variables vary greatly across cantons, with academic-track enrollment differing from 9% to 24%; calculated in Swiss francs, GDP per capita differs from 26,817 (Jura) to 47,488 (Zurich), and educational expenditure per capita differs from 6,368 (Thurgau) to 13,073 (Geneva).

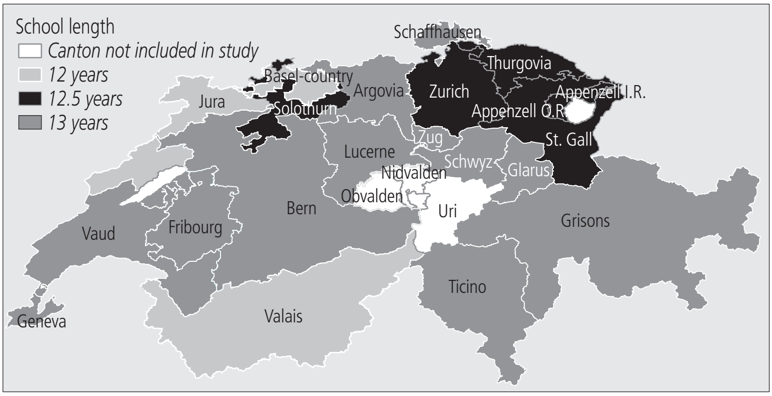

Figure 2.11. Length of schooling according to canton in Switzerland.

Table 2.7. Swiss-canton-specific variables.

	School expenditure per capita (5–19 age group) in 1995 (in Swiss francs)	GDP per capita 1995 (in Swiss francs)	Percent of population in academic-track school (Gymnasium) in 1995
Aargau	7,340	38,708	12
Appenzell Outer Rhodes	7,317	32,019	14
Basel-city	8,402	41,279	19
Basel-country	13,031	40,396	19
Bern	9,489	34,676	11
Fribourg	7,590	32,199	20
Geneva	13,073	38,941	22
Graubŭnden	7,209	32,999	12
Jura	6,879	26,817	16
Lucerne	7,625	35,124	10
Neuchâtel	8,999	32,048	24
Schaffhausen	7,712	39,251	12
Schwyz	6,872	36,318	11
Solothurn	7,468	36,268	12
St. Gallen	7,651	35,106	11
Thurgau	6,368	34,180	9
Ticino	7,483	31,431	19
Valais	6,369	28,126	17
Vaud	8,648	37,366	18
Zug	9,162	45,802	14
Zurich	9,860	47,488	14

Source: Bundesamt für Statistik (1999).

Table 2.8. Number of Swiss students surveyed in TIMSS according to duration of schooling in academic-track education.

School duration (years)	12	12.5	13	
Aargau			55	
Appenzell Outer Rhodes		6		
Basel-city		163		
Basel-country	21			
Bern			151	
Fribourg			21	
Geneva			69	
Graubünden			15	
Jura	13			
Lucerne			17	
Neuchâtel	19			
Schaffhausen			9	
Schwyz			45	
Solothurn		98		
St. Gallen		30		
Thurgau		7		
Ticino			112	
Valais	57			
Vaud			28	
Zug			6	
Zurich		78		
Total	110	382	526	(Full sample: N = 1018)

Source: International Association for the Evaluation of Educational Achievement.

Table 2.8 shows the number of students sampled from each school system according to the duration of schooling. The number of students surveyed from each region is closely correlated with the population size in each canton, as the aim of the TIMSS study was to choose students randomly across the country. Moreover, the number of students in 12-, 12.5-, or 13-year systems that were sampled varies considerably, mainly because longer school durations are more common than shorter ones.

Descriptive statistics for students' test-score performances for the three schooling durations is given in *Table 2.9*. We observe that GDP per capita was highest for those with 12.5 years of schooling, while education expenditure was highest for those with 12 years of schooling. Participants with 12.5 years of schooling performed the best, followed by those with 13 years, and those with 12 years. The regions with a 12-year school duration had the largest population share in academic-track education, while those with a 12.5-year school system had the lowest.

Table 2.9. Descriptive statistics. Swiss students who participated in mathematics and science literacy test.

Years of schooling	12	12.5	13
Mathematics literacy score	610.05	628.59	620.04
(Standard deviation)	(68.08)	(63.63)	(72.15)
Science literacy score	603.90	630.51	617.11
(Standard deviation)	(71.87)	(72.54)	(76.44)
Test language spoken at home (in %)			
always	88.18	87.36	87.31
sometimes	4.55	4.75	4.81
never	7.27	7.39	7.88
Males	50.44	55.39	54.19
Students born outside Switzerland	11.95	7.35	8.60
Students living with both parents at home	81.05	82.89	82.37
Skipped a class			
never	53.64	58.02	33.33
once or twice	32.73	34.22	40.7
three or four times	6.36	6.15	12.79
five or more times	7.27	1.6	13.18
Both parents have completed compulsory schooling	4.08	3.89	3.88
Student has computer at home	77.26	84.96	78.42
Study Track A and B (Greek and Latin)	20.41	31.72	23.37
Study Track C (mathematics and science)	47.81	29.3	41.18
Study Track D (modern languages)	13.12	10.89	12.58
Study Track E (economics)	17.78	27.31	21.89
Mathematics lessons	16.80	16.91	19.07
Physics lessons	7.21	7.87	8.14
School is situated in an isolated area	11.54	8.07	19.38
Parents have strong influence on curriculum	0	9.33	14.67
Teachers have strong influence on curriculum	9.91	4.35	7.15
Principal has strong influence on curriculum	0	13.91	11.04
GDP per capita (1995)	35,854	40,473	34,725
Educational expenditure 1995, per capita (those aged 5–19)	9,330	8,340	8,612
Proportion of 19 year old population attending academic-track school (Gymnasium)	19.3	13.2	14.5
German-speaking cantons	18.37	100	61.96

Source: International Association for the Evaluation of Educational Achievement

2.4.6 Analysis

Multilevel Modeling

To examine the impact of the duration of schooling on student performance, careful attention must be given to controlling for other influences at the student and regional level. Individual-specific variables could, for example, be gender, while regional-level variables could, for example, be educational expenditure in the canton.

We use a multilevel approach, where both microlevel and macrolevel influences are taken into account. An analysis that omits macrolevel influences could create erroneous or misleading results if students' outcomes are correlated within higher-level entities. This could lead to incorrect estimation of the variance and give wrong significance levels.[17]

Weighting of Students

Using stratified sampling techniques, a given number of students were sampled within each canton from a selection of schools. The sampling procedure aimed to make a representative selection of students from the different study tracks. The TIMSS data also provided weightings that were used to take into account differences in the probability that a student, class, or school is selected. Using these weightings allows us to take into account differences in the probability that a student is selected across class and schools.

Adjusting for the Population Share Participating in Academic Track Education

The proportion of the population attending academic-track education varies according to canton. We assume that the population's abilities follow a normally

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[17] If data is collected at different levels of aggregation, then the level of analysis should be at the most disaggregated level. We therefore choose to study student performance differences at the individual level, taking higher-level variables into account. When the data are analyzed at the lowest level, for example, at the individual level, individuals' group memberships need to be taken into account. If one ignores the fact that these individuals belong to clusters, in which individual characteristics are correlated, then the information needed to make an accurate estimate is omitted.

Analyses based solely on the lowest level would exaggerate the number of independent observations in the sample. Assume that there are m groups (independent observations), n individuals (who belong to the different groups), and that $n > m$. Under these circumstances, analyses based solely on the n level will tend to underestimate the true variance. Conversely, only considering data at the highest level could exaggerate the variance and underestimate the significance levels, creating an overly conservative estimate. If the hierarchical data structure is not taken into account, estimates of the variance may be incorrect, which increases the risk of bias in the regression results (Moulton, 1990). See also Snijders and Bosker (1999) for a more detailed explanation of multilevel modeling techniques.

distributed function and that the individuals with the highest abilities follow academic-track schooling. An increase in the proportion of the population participating in academic-track schooling implies that the students are less selected, so that their ability level on average decreases. We assume that students' abilities follow a standard normal distributed function, $(\eta = \Phi^{-1}(1-\gamma)$, where γ represents the percentile of the normal distribution.[18] Therefore, a decrease in the proportion participating in the test is associated with a higher degree of student selectivity and is reflected by an increase in η.

Model Assumption

We assume that our regression model takes the following form:

$$T_{ijh} = X'_{ijh}\beta_1 + Z'_{jh}\beta_2 + Q'_h\beta_3 + R_{ijh} \tag{2.5}$$

In Equation 2.5, the dependent variable T_{ijh} measures a student's human capital level performance (TIMSS test performance) for individual i in school j, living in canton h. β_1 is the vector of coefficients that measures the influence of student-level background variables X_{ijh}, such as gender. β_2 represents school-level influences Z_{jh}, such as whether the school is situated in an isolated area. β_3 measures the effect of canton-level influences Q_h, such as educational expenditure in the canton. The variable R_{ijh} represents the error term.

Observable differences at the group level include wealth, resources spent on education, and how selected the students are. To control for these cluster effects, we use multilevel regression techniques when analyzing the data. The econometric software package we apply to make the multilevel estimates is STATA (using the *survey* set of commands available in the software). This software allows multilevel data structures to be analyzed, with the standard errors being adjusted for the existence of intragroup dependencies (Deaton, 1997; StataCorp, 2001).

2.4.7 Regression analysis

Each canton is likely to try to maximize the students' education, as this is in the interest of all agents involved in the education process: students, teachers, parents, and school officials. We consider the extent to which length of schooling is a variable that matters in the production of human capital. The individual and canton-level variables used in the regression are briefly explained in *Table 2.10*. In the regression analysis we use control variables at both the individual and canton level, and weighting is used to make each canton equally influential. The findings from the regression analysis are reported in *Table 2.11* and *Table 2.12*.

[18] A similar adjustment for selection of students is applied in Jürges *et al.* (2003).

Table 2.10. Explanation of variables

Variable	Explanation
Student performance	Mathematics and science test results, standardized values
Test language spoken at home always sometimes never	Dummies indicating whether student speaks the language used in the test at home
Males	Dummy variable reporting student's sex
Student born outside Switzerland	Whether the student was born outside Switzerland
Student lives with both parents at home	Dummy variable indicating student's response that both mother and father live at home
Skipped a class never once or twice three or four times five or more times	Dummies indicating whether student skipped a class
Both parents have completed compulsory schooling	Indicates whether both parents have only compulsory schooling as their highest level of completed education
Student has computer at home	Indicates that the student has computer access at home
Study track	Dummies indicating the type of study track the student is following
Mathematics/physics lessons	Number of weekly lessons of mathematics or physics (data on other subjects are not available) in upper-secondary school. The total for upper-secondary school, from 10th to up to 13th grade.
School is situated in an isolated area	Dummy indicating population density at school location. Indicates that the school is situated in isolated or rural area
Parents/teacher/principal strong influence on curriculum	Indicates whether parents, teachers, or the principal have a strong influence on determining the school curriculum
GDP per capita	GDP per capita, measured at the canton level (1995 monetary values)
Educational expenditure per capita	Educational expenditure per capita (5–19 year age groups), measured at the canton level, 1995 monetary values
Proportion of population aged 19 attending academic-track school (Gymnasium)	Indicator of population share in academic track school, defined as $\eta = \phi^{-1}(1 - \gamma)$, where a decrease in the proportion participating in the test γ is associated with better student selection, so that η increases
German-speaking canton	Indicates whether the student lives in a canton where German is the main language
Years of school duration 12 12.5 13	Dummies indicating the duration of primary and secondary schooling, where the student is enrolled

Table 2.11. Dependent variable: Mathematics literacy. Swiss final secondary school year (academic track).

	Coeff.[1]	Std. dev.[2]		Coeff.	Std. dev.	
Constant	454.37	41.53	***	485.01	54.84	***
Individual-level variables						
Test language spoken at home						
always	Ref. cat.[3]			Ref. cat.		
sometimes	– 19.57	10.29	*	–15.33	10.74	
never	– 19.07	11.66		– 1.31	13.62	
Male	33.31	6.83	***	29.79	8.05	***
Student born outside Switzerland	–1.39	7.37		–9.76	8.69	
Student lives with both parents at home	1.71	7.53		–7.75	7.07	
Skipped a class						
never	Ref. cat.			Ref. cat.		
once or twice	–1.92	6.79		–2.96	8.32	
three or four times	4.18	12.56		4.75	14.87	
five or more times	–2.51	9.38		–5.54	11.20	
Both parents have compulsory schooling	–8.11	9.30		–14.25	8.49	*
Student has computer at home	22.13	7.64	***	27.65	8.13	***
Study track A and B (Greek and Latin)	Ref. cat.			Ref. cat.		
Study track C (mathematics and science)	44.57	18.45	**	48.91	20.40	**
Study track D (modern languages)	–37.70	11.75	***	–21.00	11.36	*
Study track E (economics)	–9.27	9.17		–0.59	9.95	
Mathematics lessons	–1.42	1.58		–1.11	1.88	
School-level variables						
School is situated in an isolated area				19.82	8.52	**
Parents have strong influence on curriculum				10.79	8.96	
Teachers have strong influence on curriculum				6.43	13.13	
Principal has strong influence on curriculum				–5.14	14.05	
Canton-level variables						
GDP per capita (in 1,000 Swiss francs)	1.47	0.91	*	2.69	0.93	***
Educational expenditure (in 1,000 Swiss francs)	–1.81	1.99		–5.82	2.10	***
Share of population in academic-track education (η)	124.64	25.67	***	82.08	26.31	***
Canton speaks German	–14.49	10.63		–25.31	10.61	**
Years of school duration						
12	Ref. cat.			Ref. cat.		
12.5	–4.09	12.63		–0.71	10.56	
13	–4.46	11.40		2.66	13.60	
Number of observations	814			650		
Number of cantons	21			15		
R^2 (adjusted)	0.29			0.30		

$*$ = 10 % level, $**$ = 5 % level, $***$ = 1 % level

[1]Coefficient; [2]Standard deviation; [3]Reference category

Source: Mullies *et al.* (1998); own calculations.

Table 2.12. Dependent variable: Science literacy. Swiss final secondary school year (academic track).

	Coeff.[1]	Std. dev.[2]		Coeff.	Std. dev.	
Constant	393.28	34.51	***	392.93	47.42	***
Individual-level variables						
Test language spoken at home						
always	Ref. cat.[3]			Ref. cat.		
sometimes	–37.05	13.27	***	–41.96	13.30	***
never	5.44	10.95		30.21	11.48	***
Male	49.97	7.29	***	47.93	8.30	***
Student born outside Switzerland	–13.05	8.69		–22.04	8.43	***
Student lives with both parents at home	–4.73	7.45		–10.94	8.41	
Skipped a class						
never	Ref. cat.			Ref. cat.		
once or twice	–4.00	7.02		–2.59	6.10	
three or four times	–12.76	15.12		–12.18	11.85	
five or more times	–14.97	11.06		–22.86	13.72	*
Both parents have compulsory schooling	5.37	16.08		–9.95	12.79	
Student has computer at home	21.52	8.02	***	25.73	9.53	***
Study Track A and B (Greek and Latin)	Ref. cat.			Ref. cat.		
Study Track C (mathematics and science)	34.64	13.54	**	48.32	18.53	***
Study Track D (modern languages)	–28.58	9.97	***	–6.46	11.35	
Study Track E (economics)	–3.46	10.06		14.89	10.84	
Physics lessons	0.21	2.49		0.76	3.40	
School-level variables						
School is situated in an isolated area				25.33	13.20	*
Parents have strong influence on curriculum				0.26	11.27	
Teachers have strong influence on curriculum				19.17	18.26	
Principal has strong influence on curriculum				3.99	14.21	
Canton-level variables						
GDP per capita (in 1,000 Swiss francs)	1.78	0.89	**	3.82	1.25	***
Educational expenditure (in 1,000 Swiss francs)	–0.56	2.11		–4.68	2.92	
Share of population in academic track education (η)	128.13	26.22	***	75.26	34.84	**
Canton speaks German	2.16	9.99		–9.54	15.39	
Years of school duration						
12	Ref. cat.			Ref. cat.		
12.5	–9.81	12.41		–1.51	17.23	
13	–4.20	9.38		6.50	14.79	
Number of observations	814			655		
Number of cantons	21			15		
R^2 (adjusted)	0.36			0.40		

[1]Coefficient; [2]Standard deviation; [3]Reference category
= 10 % level, **= 5 % level, ***= 1 % level
Source: Mullies *et al.* (1998); own calculations.

Length of Schooling

In none of the regressions is the length of schooling positively associated with the quality of schooling. Differences in school duration of up to a year do not appear to affect student performance, as neither mathematics nor science test results are significantly affected, whether it takes 12, 12.5, or 13 years to graduate. Those enrolled in a school system with a duration of 12.5 years scored slightly better (see descriptive findings, *Table 2.9*), mainly because this length of schooling is common in cantons with high student selection.

The result, namely, that the canton-based variation in schooling duration does not matter for student performance, does not change if one excludes any of the reported variables. The result is not sensitive to the removal of cantons with few respondents (i.e., whether or not one omits cantons with fewer than 10 respondents), and the results are also robust when other methods than weighted least squares (WLS) are used (e.g., OLS regressions give similar results).

Language Spoken at Home

If the language normally spoken at home is not the same language as the test language, this affects the student's score. For the science test, those who report that the test language is *sometimes spoken* at home, score about 0.5 standard deviations below those who *always speak* the test language at home. This finding may be due to the fact that those who sometimes speak the test language at home are second- or third-generation immigrants, who tend to have lower subject scores than native speakers.[19]

A somewhat surprising finding is that the effect of *never speaking* the test language at home increases the science test results substantially. One potential explanation for this is that the group which reports never speaking the test language at home may contain a high share of migrants from other Swiss cantons, where another of the official languages is spoken (French, German, Italian). If these are internal migrants (or their children) across the Swiss language barriers, this could be an indication of positive selection, which could explain their higher test scores.

Gender

Male students score significantly higher than female students in both the mathematics and the science tests. A similar gender difference between male and female students was also found in other international surveys of student performance (e.g.,

[19]For example, the PISA survey, which compared immigrant and native performance across a number of countries, found that immigrant students in the majority of countries surveyed perform significantly worse than the native students (OECD, 2001).

Mullis *et al.*, 1998; OECD, 2001). There is no clear consensus as to why such a gender gap exists; societal expectations and norms, as well as biological differences, could play a role [see Halpern (2000) for a discussion].

Student Born Outside Switzerland

Students born in a country other than Switzerland do not perform significantly differently on the performance tests from students born in Switzerland. The lack of significance level may reveal a large variation in student performance for first-generation immigrants, as some immigrant groups may be positively selected and outperform natives, while others may be negatively selected and underperform natives (OECD, 2001).

Both Parents Live at Home

Some studies suggest that being raised in a household with only one parent undermines a child's educational performance (Gruber, 2000; OECD, 2001). In contrast, we find that the impact of having both parents living at home does not affect a student's performance in mathematics or science literacy.

Student Having Skipped a Class

As a measure of a student's self-discipline and eagerness to learn, we consider the impact on students' school performance of having sometimes or often skipped classes. We find that there is no significant impact of this variable on mathematics or science literacy scores.

One possible explanation for this finding is that students skip classes because they are either negatively selected (e.g., because of social problems) or positively selected (and therefore skip classes because they do not feel they gain from participating in them). Hence, the effects of skipping class have opposing consequences on student outcomes and could lead to an insignificant net effect.

Both Parents Have Compulsory Schooling

The impact of parents' having a low level of education is found to have a negative effect on student performance. However, this effect is significant only in the mathematics test and only when school level variables are taken into account.

Student Has Computer at Home

The impact of having a computer at home has a strong positive effect on subject tests in both mathematics and science. Not having a computer at home may reflect that the student comes from a less-wealthy background, with less access to information and services available through computer use. This result contradicts earlier findings by Angrist and Lavy (2002) who, in a study of Israeli schools, argue that computer availability does not relate to student performance.

Study Track

The type of educational program in which the student is enrolled is of vital importance for student success (in Swiss academic-track education). Students participating in study tracks A, B (Greek and Latin), and E (economics) are not significantly different from each another. However, students in study track D (modern languages) are found to perform less well in both mathematics and science, but this becomes insignificant when school-level variables are controlled for. Students specializing in mathematics and science programs (study track C) perform much better in both subjects.

Number of Lessons

The number of lessons attended by students in mathematics and physics are not found to affect student performance in mathematics or science. This finding is somewhat surprising as one would expect that a longer time spent focusing on problems would improve performance. However, as Ramseier *et al.* (1999) point out, the variation in number of lessons taught may be too limited a factor to be relevant to student performance in Switzerland. Moreover, unobserved factors, such as efficiency and quality of education and how compatible the students are with each other and their teachers, may explain why the number of lessons does not seem to affect test scores.

School is Situated in an Isolated Area

In both subjects, students from rural or isolated areas perform substantially better than other students. This is possibly the case because a smaller and more positively selected share of the students attend academic-track schools in the more-rural areas of the cantons.

Influence of Parents, Teachers, and Principals on Curriculum

Schools reporting that parents, teachers, or principals have a strong influence on the curriculum do not perform differently from other schools. This finding suggests that whether the curriculum is determined centrally or at the school level does not affect student performance.

GDP per capita

The wealth of the canton, measured as GDP per capita, has a positive effect on both mathematics and science scores. The estimated coefficient suggests that when GDP per capita rises by approximately 2,900 Swiss francs or 2,300 Swiss francs[20] respectively, the corresponding test scores in mathematics and science go up by 0.1 standard deviations. This implies that the difference between the richest and poorest cantons, Zürich and Jura (around 20,671 Swiss francs) translates into about 0.7 (mathematics) and 0.9 (science) standard deviations.

Education Expenditure per capita

Higher per capita educational expenditure does not improve student performance in either mathematics or science and is actually found to be associated with lower test performance in the mathematics school-level regression analysis. This finding suggests that higher school expenditure leads to variation in the use of education factor inputs that are unrelated to student performance. This is in line with other regional and international studies on student performance which show that resource use does not improve, and can sometimes be negatively associated with, educational performance (e.g., Hanushek, 1997; Hanushek and Luque, 2003).

Population Share in Academic-Track Schooling

Based on the assumption that a student's abilities follow a normally distributed function, test performance improves when the share of the population participating in academic-track education is smaller. The regression results strongly support the fact that a higher population share participating in academic-track studies is associated with decreased selection and weaker student performance. This is in line with studies which conclude that heredity plays a strong role in determining ability. For example, a committee of leading intelligence researchers from the American Psychological Association argue that the share of heritability in intelligence lies close to 75% (Neisser *et al.*, 1996), although others have suggested a somewhat lower estimate [e.g., Devlin *et al.* (1997) who estimate it to be 48%].

In Switzerland, the most-selected students come from Thurgau. These students are high performers. As shown in *Table 2.7*, only 9% of the 19-year-old population in Thurgau are enrolled in academic-track education, as opposed to Neuchâtel, the canton with the lowest selection, where academic-track education encompasses as much as 24% of those aged 19. This may partially explain why students in Thurgau

[20]The standard deviation for the whole sample is 80.8 for mathematics and 87.0 for science. Hence, an increase of 2,900 Swiss francs (mathematics), $2.9 * 2.69 = 8.08$ or 2,300 Swiss francs (science), $2.3 * 3.82 = 8.7$ equals one-tenth of the respective standard deviations.

score 0.6 standard deviations higher in mathematics and 0.9 standard deviations higher in science than those in Neuchâtel.

Language Spoken in Canton

Living in a German-speaking canton is not found to have an overall effect on student performance. The only exception is when the mathematics results are being analyzed at the school level, with the German-speaking cantons being found to perform considerably less well than the rest.

Sample Size and Adjusted R-Square Levels

The sample size in the regression is slightly lower than the full TIMSS sample of 1,018 students. The reason for the omission of some of the students from the regressions is that information on some of their explanatory variables is missing. However, the students omitted represent only a small proportion of the total sample (about 2%), and including them (by excluding the explanatory variables with missing information) does not alter the sign of the variables or their significance levels.

Levels of adjusted R-squared in the analysis are relatively low: in the range 0.29 to 0.40, which is common in other analyses of test-score differentials. One example is Hanushek and Kimko (2000) who report adjusted R-squared at levels below 0.26 in a micro-econometric study of educational differences. This result is likely to be due to unobserved heterogeneity, as some of the most important determinants of human capital are not taken into account. For example, as the evidence put forward in Section 2.2 suggests, inherited influences on ability levels are one of the most important sources of skill variation, and our lack of this type of information is likely to substantially decrease adjusted R-squared values.

2.4.8 Conclusion

We assessed the effect of the duration of primary and secondary schooling on student achievement in the final year of secondary school. The hypothesis tested is whether having 12, 12.5, or 13 years of schooling affects student performance. Student performance in mathematics and science tests was investigated, and no significant impact of the school duration was identified. For the case of Switzerland at least, this evidence suggests that a primary and secondary school duration of 12.5 or 13 years does not lead to better student performance relative to a duration of 12 years.

3

Completing Education and the Timing of Births and Marriage: Findings from a Birth-Month Experiment in Sweden

This chapter investigates another effect of a school reform on public pension systems: the extent to which a younger school graduation age would bring down the childbearing age and increase fertility. The chapter has two sections. First, we review earlier studies on the relationship between graduation age and the timing of demographic events; then, we present our own findings on the subject.

The age at entering parenthood has tended to increase in parallel with an expansion of education in most Western countries, but past investigations have been unable to identify the causal effect of a change in the school-leaving age on the childbearing age. To identify the effects on fertility of a shift in the school-leaving age, we study the case of Sweden, where school-entry laws allow us to carry out such an investigation. We apply a method that can overcome the problems of endogeneity inherent in earlier studies and identify any causal relationship between the school-leaving age and the timing of demographic events in adulthood.

3.1 Graduation Age and the Age at Parenthood

Many analyses of changes in the timing of fertility in developed countries emphasize the fact that women have made a substantially increased investment in higher or professional education in response to increased returns to human capital, improved access to the labor market, and more effective contraception [see, for example, Westoff and Ryder (1977); Gustafsson (2001); Goldin and Katz (2002); Kohler *et al.* (2002)]. Goldin and Katz (2002), for instance, argue that the contraceptive pill has enabled women to enjoy sexual relations without jeopardizing the prolonged and expensive investments they have made in human capital by an unwanted birth. Consistent with this argument, Blossfeld and Huinink (1991) show that few women have children during their time in education. Demographic behavior in early adulthood has therefore been characterized by a very typical sequence in which the completion of education is followed first by entry into the labor market and then by the birth of the first child (Marini, 1984; Blossfeld and De Rose, 1992;

Corijn, 1996);[1] moreover, the extension of education in recent decades has shifted the onset of this sequence to increasingly older ages.

In explanations of the timing and level of fertility in developed countries, the role of education and human capital investments has been emphasized. Despite this, very few studies have succeeded in establishing any causal effects of "age at graduation" or "duration of education" on fertility patterns. Analyses of this question are often hampered by methodological challenges pertaining to sample selectivity and unobserved heterogeneity. In particular, studies of the relationship between completion of education and the timing of fertility are usually based on comparisons of subgroups of women with different educational qualifications. A common problem with these studies is that women whose ages differ at school graduation also have differences in terms of potentially unobserved characteristics that affect educational attainment, such as preferences, abilities, family backgrounds—all characteristics that influence fertility and behavior with respect to marriage. Standard empirical approaches therefore fail to identify the causal effect on fertility and marriage in early adulthood of a longer duration of schooling and an older age at completion of schooling.

Analyses that overcome the above problem frequently rely on instrumental variable techniques, fixed-effect models, or "natural experiments" (Rosenzweig and Wolpin, 2000). In this study we pursue the last approach—natural experiments—and utilize the fact that the enrollment of children in school in Sweden occurs in the calendar year in which they become 7 years old. Children born during two consecutive months, December and the following January, therefore belong to two different school cohorts and graduate from school in two different calendar years. They thus differ by almost one year in the age at graduation from compulsory schooling, despite being born an average of just one month apart. On the assumption that parents cannot time the births of their children to the exact month, this characteristic of the Swedish school system results not only in an exogenous variation in the age at entry and completion of compulsory education but also in the age at graduation from higher levels of education among those who continue their education after compulsory schooling. This variation allows us to identify the causal effect of completing schooling at a higher age on important demographic events during the transition to adulthood, net of unobserved characteristics affecting schooling decisions and net of variations in human capital that are otherwise associated with differences in the age at graduation from school.[2]

[1]This sequence has been particularly strong in Sweden, as the benefits paid for up to 480 days after the birth of a child increase with a woman's income prior to childbirth (Riksförsakringsverket, 2002). Entering the labor market and gaining work experience prior to the birth of a child, therefore, means higher benefits during maternity leave.

[2]Smith (1990) points out that natural experiments, such as the birth-month-induced age differences in school enrollment and graduation used in this paper, are powerful factors in terms of identifying the causal effects of different ages at graduation on demographic behaviors in early adulthood;

We find that small differences in the school-leaving age, while having relatively profound effects on the timing of fertility and marriage, do not seem to affect completed fertility and the probability of marrying before the age of 45. An eleven-month difference in the age at graduation between those born in December and those born in the subsequent January, for instance, results in an almost five-month difference in the timing of the first birth. About 45% of the difference in the age at graduation from compulsory schooling is therefore not compensated for during the average 8–10 years in early adulthood between graduation from ninth grade and the birth of the first child. Moreover, our study finds that the changes in the age at first birth (because of the different graduation years of women born in December and in the following January) have remarkably little effect on the timing between the first and second child, which indicates that there is no conscious compensation for birth-month-induced variation in the age at first birth. Our study also finds that the birth month has similar effects within birth cohorts, with women born in January tending to experience births and marriage at an older age than those born in the previous December.

The effects of this exogenous variation in the age at graduation on demographic behavior in early adulthood are relevant for several reasons. First, our study reveals the sensitivity of the timing and quantum of fertility and marriage behavior with respect to "shocks" that delay or anticipate the age at which young women graduate from compulsory schooling and subsequently make conscious decisions about 1) further human capital investments, 2) entry into the labor force, and 3) leaving the parental home. Second, our analyses are informative about the demographic importance of *social age*, defined as the average age of one's school cohort, as compared with biological age. In particular, in terms of demographic behaviors, our results indicate the considerable relevance of social interaction among individuals of the same school cohort as compared with interactions among persons of the same age. Third, the results of this study throw light on some of the potential effects on the timing and quantum of marriage and fertility of policies that are currently being implemented or discussed in several European countries (including, for instance, Germany) and that are intended to compress the duration of schooling without reducing human capital levels. Fourth, our results are informative for assessing the extent to which differences in the timing of fertility and marriage in cross-sectional country analyses may be related to differences in the schooling system and the age at which young adults complete compulsory education.

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however, these experiments cannot necessarily identify the causal mechanisms for such influences on behavior. As in other studies in the related experimental literature, our ability to empirically identify the behavioral mechanisms generating the different demographic patterns by birth month are limited by data that do not include extensive information on the determinants of fertility and marriage behavior and specifically do not include determinants related to the social environment in schools.

3.1.1 A case study of Sweden

To assess the effects of the graduation age on the timing of demographic events, we study a setting where variations in the timing of schooling are unrelated to other factors. In Sweden students are subject to laws on the age of school entry and graduation. The most important aspect of this system of enrollment and compulsory completion of ninth grade education is that variations in the month of birth cause systematic variations in the school graduation age and in the school cohort to which an individual belongs. A more detailed description of the Swedish school system is given in Section 2.3.

Based on the variations in enrollment and age at graduation, our study is able to formulate a simple hypothesis to identify the effect of school enrollment on subsequent fertility outcomes, net of unobserved characteristics affecting schooling decisions and net of variations in human capital that are otherwise associated with differences in the age at school graduation. Thus, if the school cohort and the age at school graduation have an effect on demographic behavior in early adulthood, the timing of demographic events—such as the birth of a child or a marriage—should differ according to birth month. This effect should be most pronounced between individuals born in December and individuals born in the subsequent January, where our analyses reveal the combined impact of graduating eleven months older/younger and being in different school cohorts. In addition, a gradual decrease in the age at graduation should occur *within* each birth cohort (e.g., women born in February graduate one month younger than women born in January), and within-cohort comparisons of the fertility and the timing of marriage by birth month can reveal the impact of changes in the age at graduation that depend on belonging to the same school cohort.

The basic assumption underlying the above interpretation is that the month of birth affects the variation in the tempo and possibly the quantum of demographic behaviors in early adulthood because of birth-month-induced variation in 1) the age at entering compulsory school, 2) the school cohort, and 3) the relative age within a school cohort. The school cohort also determines the age at graduation from compulsory schooling as well as the age at graduation from higher secondary and tertiary education for those who continue their education.

School cohort is also important because it determines the group of individuals who are likely to form the primary peer group in childhood and adolescence. Moreover, the simultaneous progression through the various school grades is an important factor that strengthens identification with peers in the same class and heightens the importance of the social influence exerted by members of the school cohort. If the influence of school cohorts is strong, then the *social age* should be an important indicator for describing demographic events in early adulthood. The variation in biological age between those born early and those born late in the year would matter less, as their social age is identical. Differences in social age would be associated with notable differences in the timing, and perhaps also quantum, of demographic behaviors.

The main competing hypotheses, other than the age at school entry and graduation, that can potentially explain the influences of the birth month on the timing of fertility and marriage are preferences for a specific season in which these events occur. For instance, it is well known that births peak in the spring and that marriages are concentrated in spring and summer. Preferences for such a seasonal timing of events can lead to birth-month effects: individuals born earlier in the year will tend to be older when they have children or marry later than persons born late in the year. However, we are able to rule out seasonality as a major factor driving our results. Preferences for a specific season cannot explain the stark differences in the timing of fertility and marriage, documented by this chapter, between women born in December and women born in the subsequent January. These women are of virtually the same age and are born at almost the same time. Seasonal preferences would suggest a similar timing of demographic events for those women. If this is not the case, as we find below, it is likely to be due to the difference in their social age, which stems from the cut-off-date mechanism pertaining to school entry.

3.2 Empirical Estimates of the Impact of the School-Leaving Age on Fertility Patterns: The Case of Sweden

Figure 3.1 shows the trend in the Swedish total fertility rate (TFR) and the mean age at first birth from 1975 to 2000. In common with many other European countries, fertility in Sweden started to decline in the 1970s and stabilized by the end of that decade. Whereas fertility levels continued to stagnate or decline in many European countries during the 1980s, Sweden experienced a baby boom after 1985. Between 1985 and 1990 the TFR increased from 1.74 to a level of 2.13, exceeding replacement level. This substantial increase in fertility was caused by an increased propensity for childbearing at very short birth intervals because of the introduction of the so-called speed premium on childbearing that provided financial incentives to space children closely (Andersson, 1999).[3] The sharp economic downturn in the early 1990s led to an equally swift baby bust in the late 1990s (Andersson, 2002; Hoem, 2000), and by 1999 the total fertility rate had declined to a historically low level of 1.5. This change in fertility levels over time was accompanied by a rapid

[3]The speed premium refers to rules introduced in the Swedish parental-leave system that allow parents (typically women) to maintain an earlier (and often higher) level of income compensation during leave if the next child arrives within a fixed period of time. In 1980 this period was set at 24 months and extended to 30 months in 1986.

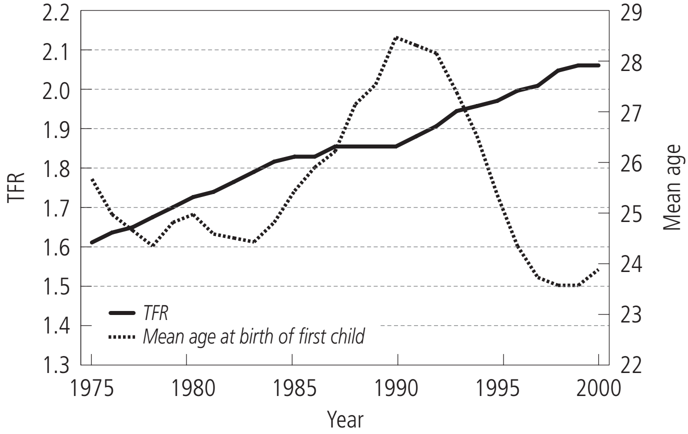

Figure 3.1. Total fertility rate (TFR) and mean age at birth of first child. Source: Statistics Sweden; own calculations.

postponement of fertility. The (period) mean age at first birth, for instance, increased from 24 to 28 years within the three decades from 1970 to 2000. The only slowdown during this fertility postponement occurred during the period of the baby boom, while the baby bust after 1990 coincided with a renewed increase in the pace of fertility postponement.

Figure 3.2 shows that the average number of years of school for females over the age of 25 also increased from about eight years in 1975 to about 11 years by 2000, that is, by almost the same amount as the mean age at first birth [see also Barro and Lee (2000)]. Although compulsory schooling in Sweden ends at the age of 16, most women and men stay in upper-secondary school for another three years (Stanfors 2003, pp. 75ff). In 1998, for instance, 97.1% of boys and 97.3% of girls entered upper-secondary school after completing their compulsory schooling. A similar increase in the schooling level occurred across birth cohorts (*Table 3.1*).

This extension of schooling was even more pronounced among women than men. For example, about one-third of all women in the 1929 cohort participated in upper-secondary education, while only 10% participated in tertiary education. These enrollment rates increased to 50% and 40% respectively for the cohort of women born in 1974.

A detailed description of the data we use in our analysis is given in Section 2.3. Our analysis primarily utilizes a woman's educational attainment variables, her month/year of birth, the month/year of birth of all her children, and the month/year of her first marriage. A basic summary of the statistics for these variables is given in *Table 3.2*.

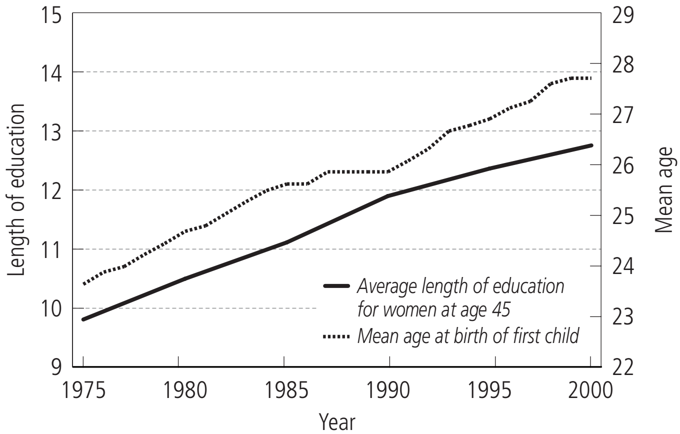

Figure 3.2. Years of education for women at age 45 and mean age at birth of first child.
Source: Statistics Sweden; own calculations.

Table 3.1. Highest level of education by birth cohort.

Birth cohort	Compulsory education	Upper-secondary education	Post–secondary education < 3 years	Post–secondary education ≥ 3 years	Missing values
1929	57%	29%	5%	6%	2%
1931	54%	31%	5%	8%	2%
1934	48%	34%	7%	9%	2%
1939	38%	39%	9%	12%	1%
1941	34%	41%	10%	14%	1%
1944	28%	44%	11%	16%	1%
1949	21%	46%	14%	18%	1%
1951	18%	47%	15%	18%	1%
1954	18%	46%	17%	18%	1%
1959	14%	51%	18%	16%	1%
1961	12%	53%	18%	16%	1%
1964	11%	54%	17%	16%	1%
1969	10%	53%	18%	19%	1%
1971	9%	51%	17%	22%	1%
1974	9%	49%	15%	26%	2%

Source: Statistics Sweden, Swedish Register of Education (Stanfors, 2003).

Table 3.2. Descriptive statistics.

Sample size	863,304		
Average number of children	1.95		
(standard deviation)	(1.19)		
	Birth cohorts		
Percentage who, before 31 December 1999	1946–1951	1952–1957	1958–1962
had a first child	86.83%	84.94%	82.93%
had a second child	71.16%	70.80%	69.64%
had a first marriage	83.61%	75.06%	64.16%
emigrated	2.06%	1.89%	2.37%
died*	3.00%	1.70%	1.12%
Highest completed education level	Share of the sample	Approximate no. of years of schooling**	
Compulsory schooling (Pre-Reform)***	4.50%	8.0	
Compulsory schooling (Post-reform)	13.55%	9.0	
Upper-secondary school, up to 2 years (mostly vocational study tracks)	38.59%	11.5	
Upper-secondary school, 3 years or more (academically oriented study tracks)	9.20%	13.0	
Tertiary education, up to 2 years	17.80%	5.0	
Tertiary education, above 3 years	14.10%	17.0	
Tertiary education, PhD/Licentiate degree	0.37%	21.0	
Unspecified education	1.91%		
	Birth cohorts		
Age at demographic events	1946–1951	1952–1957	1958–1962
First child	24.14	25.20	26.22
Second child	27.55	28.48	28.89
First marriage	25.18	26.88	27.14

* Of the individuals who died, 92 had first emigrated.

** Years of schooling estimated by the Swedish Level of Living Survey for 1945–1955 cohorts (Meghir and Palme, 2001).

***Between 1949 and 1962, compulsory schooling was extended from seven or eight years to nine years in Sweden (see Meghir and Palme, 2001 for details). Although the reform was introduced gradually, this was not done in any way that affected the cut-off month and the age pattern of school enrolment. We therefore do not distinguish between pre-reform and post-reform compulsory schooling in our analysis.

Source: Statistics Sweden; own calculations.

While the subset of women experiencing a first or second birth does not change substantially across birth cohorts, the percentage of women who marry declines in younger cohorts. There have also been substantial increases in the age at first and second birth across cohorts, paralleling the increase in the mean age at first marriage. In addition, about 82% of all women in our data set continued their education after finishing compulsory schooling, the most widespread levels of completed education being one or two years of upper-secondary education followed by tertiary education.

3.2.1 Results

In this section we first discuss results pertaining to the effects of a woman's birth month on her age at the birth of her first and second child and the age at her first marriage (*Figures 3.3*, *3.4*, and *3.5*; *Tables 3.3*, *3.4*, and *3.5*). We also use logistic regressions to report the probabilities of experiencing these events prior to age 37 or 45 (*Table 3.6*), and we provide an analysis of completed fertility and its relationship to a woman's birth month (*Figure 3.6*). To investigate the mechanisms mediating the effects of the birth month on the timing of fertility and marriage, we also report an analysis of the effect of the birth month on the level of completed education (*Tables 3.7* and *3.8*).

Age at Birth of First Child

As our analyses are based on register data that include a large number of women, even simple plots of the mean age at the birth of the first child by birth month and cohort can reveal the influence of the birth month and of the age at school graduation on the timing of fertility. In *Figure 3.3* we therefore depict the (cohort) mean age at first birth for women by birth month for the cohorts 1946–1962. Across all cohorts, the mean age at first birth increases from 23.8 years to 26.3 years, then stabilizes and declines for the youngest birth cohorts (those born 1960–1962). This stabilization and decline, depicted in *Figure 3.3*, are due to our data having been censored and to the fact that many women in the youngest cohorts had not, as of 1999, completed childbearing.

The two most important aspects of *Figure 3.3* pertain to 1) the trend in the mean age at first birth across birth months *within* each birth cohort and 2) the difference in the mean age at first birth between the two consecutive months: December, at the end of one calendar year, and January, at the beginning of the next. The first aspect shows the effect of birth month on the timing of fertility within a school (and birth) cohort, and the second aspect reveals the effect of different school cohorts and graduation ages for individuals who are of almost identical age. *Figure 3.3* shows that the greatest difference in the age at first birth between any two successive

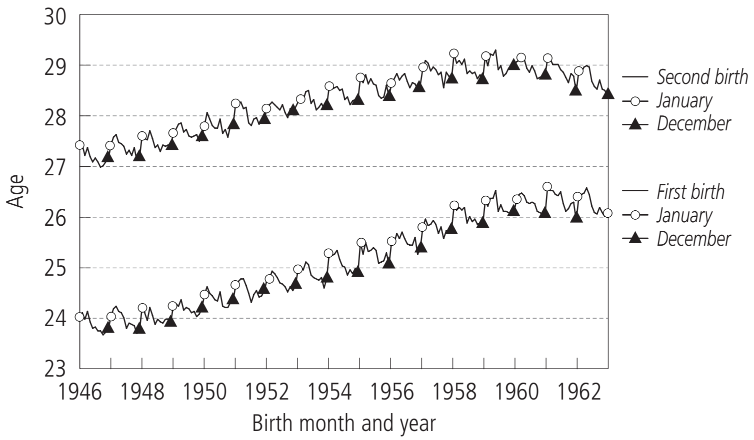

Figure 3.3. Age at birth of first and second child.
Source: Statistics Sweden; own calculations.

calendar months occurs between the December of one year and the January of the next. On average, women born in December experience their first birth 4.9 months earlier than women born one month later in the January of the next year. Adjusting for the *increase* of 2.5 years in the age at first birth across the cohorts 1946–1962 does not affect this finding.[4] Further, despite the trend toward delayed fertility across cohorts, there is a *decline* in the age at first birth within every birth cohort. On average, women born in January are 3.1 months older at the birth of their first child than women born in December of the same calendar year, and the highest age at first birth was found for those born in spring, in particular in April.[5]

In *Table 3.3* we investigate the above pattern further and report the results of a piecewise constant hazard rate model that includes dummies for birth cohorts.[6] By introducing an interaction between the birth month and the age of a woman, we

[4]The average age at first birth increased by 28.5 months from the 1946 to the 1962 cohort, which means that the monthly trend effect is 28.5 months/192 months = 0.15 months. Applying this will decrease the effect on the December-to-January difference from 4.9 to 4.7 months. However, this adjustment also means that the within-year January-to-December difference will increase from 3.1 months to 4.7 months.

One could also argue that the trend of increasing ages identically affects individuals born within a year, as they all belong to the same social age group and are therefore similarly affected by factors influencing the timing of demographic events. Hence, one should adjust for the effect of increasing ages for every subsequent cohort and not for every subsequent birth month. In terms of age at first birth this means that the age difference from December to the subsequent January would be 3.3 months instead of 4.9 months.

[5]A possible explanation of this could be that women from higher social classes, who tend to be older when they have children, are more likely to give birth in spring. See Section 2.3 for a discussion of this issue.

[6]Individuals are censored from these analyses when they emigrate or die.

Table 3.3. Risk of having a first child (all women). Piecewise constant hazard rate model (proportional hazard rates).

Baseline hazard	Up to 25 years	0.022	***
	25–28 years	0.139	***
	28 years and above	0.073	***
Born January–June: Age-specific effect	Up to 25 years	0.960	***
	25–28 years	1.012	**
	28 years and above	1.031	***
Women's birth year	1946 (reference)	1.000	
	1947	1.000	
	1948	1.000	
	1949	0.992	
	1950	0.977	***
	1951	0.960	***
	1952	0.949	***
	1953	0.942	***
	1954	0.920	***
	1955	0.917	***
	1956	0.905	***
	1957	0.904	***
	1958	0.901	***
	1959	0.886	***
	1960	0.889	***
	1961	0.876	***
	1962	0.882	***

***=Significant at $p<0.01$. **=Significant at $p<0.5$. *=Significant at $p<0.1$.
Source: Statistics Sweden; own calculations.

allow the effect of the birth month to differ according to three age groups: below age 25, age 25–28, and above age 28. These age categories roughly reflect first-birth childbearing at relatively young ages, at "prime" ages, and at relatively late ages.

Those born in the first half of the year and among the oldest in the class have a lower risk of having a first child at relatively young childbearing ages compared with those born in the second half of the year. As the first-birth risks increase with age in this age period, women born during the first half of the year "act younger" than those born later in the year. During the prime and relatively late ages of first-birth childbearing, however, this pattern reverses: women born early in a calendar year have a *higher* first-birth hazard than women born late in a year. As, at older ages, first-birth rates begin to decline with age, this pattern again indicates that women born early in a calendar year behave as if they were biologically younger, while those born later in the year behave as if they were older than those born early in the year. These results suggest that it is the birth month of a woman that primarily affects the timing of fertility, while leaving unaffected the overall probability of experiencing a first birth (see also *Table 3.6* that shows the absence of significant birth-month effects in logistic regressions for the probability of having at least one child prior to the age of 37 and 45).

The observation that women born early in a calendar year "act younger" and that those born late in a year "act older" is consistent with our earlier interpretation that relate birth-month effects to school-cohort influences. The social age is below the biological age for those born early in a year, and it exceeds biological age for those born late in a year. Within a birth cohort, the timing of fertility is therefore "pulled" toward the timing that corresponds to the social age that is equal to the average age within school cohorts. Furthermore, at the end of one birth year and the beginning of the next, differences in biological age diminish, while differences in social age are large because women belong to different school cohorts. This difference in social age, occurring when the difference in biological age diminishes, coincides with a "jump" in the age-specific risk of first birth (as can be observed in *Table 3.3*) because it combines the coefficients for birth year and birth month. Hence, differences in social—but not biological—age are associated with important changes in fertility behavior in early adulthood.

In summary, our analyses of the timing of first birth reveal that the eleven-month difference in the age at graduation from compulsory school at around the age of 16 between children born in December and children born in January results in a 4.9-month delay in the age at first birth. That is, 4.9/11 = 45% of the increase in the age at school graduation that occurs between individuals who are of virtually the same age but belong to different school cohorts is *not* caught up with in early adulthood and is still reflected in the age at first birth. This effect is striking because the first birth occurs on average nine years after graduation from compulsory schooling and 5.5 years after graduation from tertiary education.[7] Moreover, our analyses in *Table 3.3* reveal that a woman's birth month has different effects at different stages in life. Being born early in a calendar year decreases the risk of having a first birth at a young age as compared with women born later in the year, and this pattern reverses at older ages. Consequently, the birth month exerts an important effect on the timing of fertility by shifting the pattern of first-birth fertility rates to older or younger biological ages. The overall probability of having a first child, however, remains unaffected by birth month (*Table 3.6*).

[7] Assuming uninterrupted educational careers and using data on the duration of education from the Swedish Level of Living Survey, women with primary school (pre- and post-reform) wait 7 years after leaving school before having their first child. Individuals with a short secondary-school education wait 5.6 years, women with a long secondary-school education wait 6 years, while those with short and long tertiary education (excluding the few individuals with Ph.D./licentiate degrees) wait 4.7 and 4.2 years, respectively. The mean duration from school graduation to first birth is 5.5 years.

From a theoretical perspective, the above findings are important because many economic or rational choice theories about the timing of fertility suggest that women have specific preferences about what their age at first birth should be. If this were the case, one would expect the period between leaving school and having the first child to provide sufficient opportunities to make up for the difference in the age at graduation. Our analyses suggest that it is the social age, as determined by school cohort, rather than the biological age, that is an important determinant of the age at first birth; this shows the long-term effect of belonging to different school cohorts—despite a possibly very similar biological age—on the timing of demographic events during the transition to adulthood.

Seasonality patterns in the number of children born could possibly provide an alternative explanation for our results if women aimed to have their first births in the summer. However, the highest number of first births is in spring, and the lowest number is in late fall (the ratio of births in March to births in November is 1.27). The number of births gradually increases again after November until March. The Swedish seasonality pattern of birth cannot therefore explain the almost linear change in the age at first birth by birth month *within* calendar years. Moreover, a preference for a specific birth season cannot explain the difference in the age at first birth between women born in the two consecutive months, December and January, as any sizable difference in the age at first birth between these women necessarily implies different birth seasons.

Age at Second Birth

Figure 3.3 also shows that the age at second birth has increased from 27.2 years to 29 years across the 1946–1962 cohorts, following a trend that is very similar to that in the age at first birth. Underlying this overall trend across cohorts is again a systematic variation across birth months that closely mirrors the pattern for first births. Within the same birth (and school) cohort, women born in January are three months older at their second birth compared with women born in December, despite the fact that the 10–12 years between graduation from compulsory schooling and the second birth would have provided an ample opportunity to compensate for birth-month differences in school enrollment and graduation. The difference in the age at second birth between birth months increases to four months if women born in December are compared with women born in the subsequent January—women who are of virtually the same age but belong to different school cohorts. This effect is again sizable and implies that 4/11 = 36% of the age difference at graduation from compulsory schooling is perpetuated to the age at second birth. This result suggests that birth-month-induced differences in the timing of first births across birth months are not compensated for by a differential interbirth spacing between the first and second child. On the contrary, neither the duration between the first

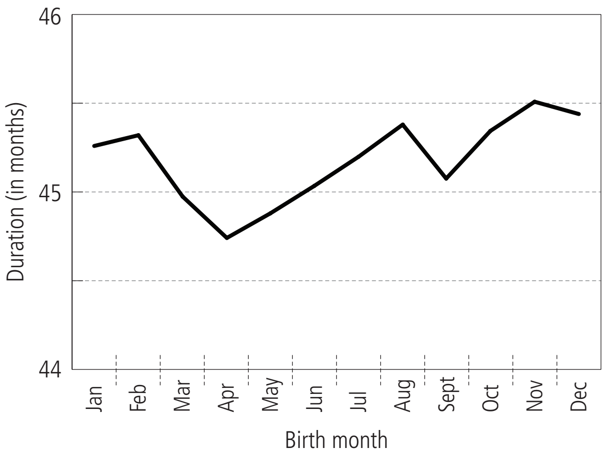

Figure 3.4. Length of time from first to second birth.
Source: Statistics Sweden; own calculations.

and the second child (*Figure 3.4*), nor the overall probability of giving birth to a second child (*Table 3.6*), varies systematically with birth month.

The above findings can be further supported with event-history models.[8] *Table 3.4* presents the results of a piecewise constant hazard rate model that includes birth-year dummies and interactions between a woman's birth month and age. In common with our analysis of first births, the effects of the birth month on the hazard of experiencing a second birth differ according to a woman's age. Below the age of 28 (i.e., at relatively young ages of second-birth childbearing) women born in the first half of a calendar year experience a *lower* hazard rate than women born in the second half of the year. This relationship reverses for women aged 28 to 32, which is the age group with the highest risk of second childbirth; and this reversal becomes even stronger for women over the age of 32. Just as for first births, this pattern indicates that women born early in the year gravitate in their behavior toward their social age and "act younger," while those born late in the year "act older." The reversal in the effect of the birth month on the second-birth risk at young and older ages also implies that, in terms of the overall probability of having a second child, women born early in a calendar year tend to catch up with their cohort mates who are born late in the calendar year, thus restricting the influence of birth month to a pure timing effect. Our results therefore suggest that, as in the case of first births, the age pattern of second-birth rates by birth month is shifted—without quantum changes—toward the pattern corresponding to the social age that is determined by the school cohort.

[8]For a description of event-history estimation techniques, see Blossfeld and Rohwer (1995).

Table 3.4. Risk of having a second child (all women with one child). Piecewise constant hazard rate model (proportional hazard rates).

Baseline hazard	Up to 28 years	0.015	***
	28–32 years	0.122	***
	32 years and above	0.056	***
Born January–June: Age-specific effect	Up to 28 years	0.958	***
	28–32 years	1.009	*
	32 years and above	1.024	***
Women's birth year	1946 (reference)	1.000	
	1947	1.000	
	1948	1.010	
	1949	1.022	***
	1950	1.027	***
	1951	1.026	***
	1952	1.032	***
	1953	1.056	***
	1954	1.063	***
	1955	1.074	***
	1956	1.085	***
	1957	1.103	***
	1958	1.106	***
	1959	1.119	***
	1960	1.147	***
	1961	1.149	***
	1962	1.164	***

***=Significant at p<0.01. **=Significant at p<0.5. *=Significant at p<0.1.
Source: Statistics Sweden; own calculations.

Age at First Marriage

Figure 3.5 presents our analysis of the timing of first marriage, an important event in early adulthood that is potentially related to a woman's age at the birth of her first child. Despite the fact that the share of out-of-wedlock births in Sweden increased to 55% by 1999 (Statistics Sweden, 2000) and that marriage has become increasingly disconnected from childbirth, most women in the 1942–1962 cohorts eventually married: 82% in the cohorts born from 1946–1953 and 68% in the cohorts born from 1954–1962. Across cohorts, women's average age at first marriage increased from 24.6 years to 27 years, following a pattern that closely resembles the delay in childbearing.[9]

[9]In the youngest cohorts there is likely to be substantial censoring because not all women who intend to marry have married (the youngest cohorts in our study have only reached the age of 37 by the end of the period studied), and the trend toward delayed marriage is likely to prevail in the youngest cohorts despite the data in *Figure 3.5* showing a leveling off.

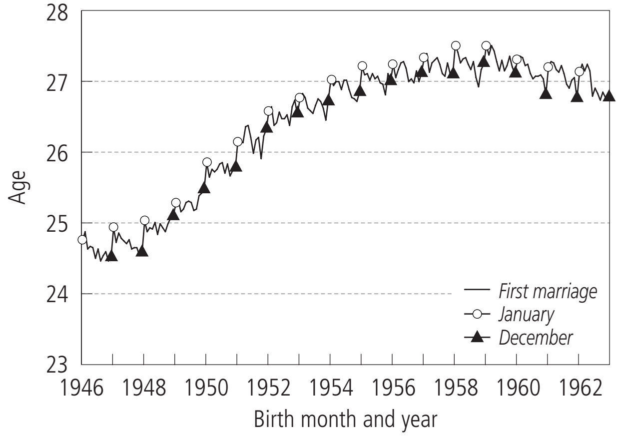

Figure 3.5. Figure 3.5. Age at first marriage.
Source: Statistics Sweden; own calculations.

The most striking fact of this trend toward delayed marriage—similar to our analyses of the timing of fertility—is that the postponement of marriage does not occur gradually across birth months. The biggest average increase of 3.5 months is observed between women born in the two consecutive birth months, December and January, that mark the transition from one birth and school cohort to the next. Hence, 3.3/11=32% of the difference in the age at leaving school is still present in the age at first marriage. Within a birth cohort, women born in January are on average 2.1 months older when they marry for the first time than women born in December. Event-history models for the entry into first marriage also show that women born from January to June have a lower risk of marrying up to the age of 26 compared with women born in the second half of the year (*Table 3.5*). At age 26 and above, the risks of marriage exhibit a reversed pattern and are higher for women born in the first half of the calendar year. This relative increase in marriage risks at older ages for women born in the first half of the calendar year not only compensates for the initially lower rates of marriage prior to the age of 26 but actually leads to a slightly higher overall probability of ever marrying prior to the age of 45 (*Table 3.6*).[10] In addition, the divergent birth-month influences on the marriage risk below and above the age of 26 are again consistent with the influence of school cohort and social age, as hypothesized above. Again, the alternative explanation in

[10]This higher marriage probability for women born in January, which is not associated with higher probabilities of having a first or second child, may be linked to issues of self-esteem caused by the relative class-age effect. This effect, which refers to the higher self-confidence of those who are of an older age in class, has been found to affect performance in school (Sharp, 1995; Alton and Massey, 1998), athletic performance (Thompson *et al.*, 1991), and income levels (Plug, 2001).

Table 3.5. Risk of first marriage (all women). Piecewise constant hazard rate model. (Proportional hazard rates).

Baseline hazard	Up to 26 years	0.023	***
	26 years and above	0.069	***
Born January–June:	Up to 26 years	0.991	***
Age-specific effect	26 years and above	1.054	***
Women's birth year	1946 (reference)	1.000	
	1947	0.969	***
	1948	0.930	***
	1949	0.886	***
	1950	0.842	***
	1951	0.812	***
	1952	0.784	***
	1953	0.770	***
	1954	0.742	***
	1955	0.720	***
	1956	0.704	***
	1957	0.691	***
	1958	0.667	***
	1959	0.655	***
	1960	0.635	***
	1961	0.622	***
	1962	0.598	***

***=Significant at $p<0.01$. **=Significant at $p<0.5$. *=Significant at $p<0.1$.
Source: Statistics Sweden; own calculations.

terms of seasonality preferences in the age at marriage cannot explain the observed effects of birth month. In particular, the "summer marriage effect"—the fact that individuals are more likely to marry in summer time than other months of the year (about 57% of the marriages in Sweden take place during the four-month period from May to August)—is consistent with the observation that those born early in the year would marry at an older age than those born later in the year. However, the summer marriage pattern does not provide a satisfactory explanation for the difference in the age at marriage between women born in the two consecutive months of December and January.[11]

[11] Seasonality preferences can explain this effect only if the summer preference is also coupled with a wish to marry at the same time as one's school cohort. Hence, the seasonality pattern needs to be coupled with a school cohort influence.

Table 3.6. Logistic regression for women's overall probabilities of giving birth to a first and second child and of getting married (odds ratio).

	First child		Second child (assuming that there is a first child)		Marriage	
	Until age 37	Until age 45	Until age 37	Until age 45	Until age 37	Until age 45
Birth month						
January	0.988	1.016	0.959 ***	0.995	0.995	0.998
February	0.974 *	1.008	0.967 ***	0.998	1.010	1.015
March	0.971 **	0.996	0.972 ***	0.988	1.000	1.014
April	0.976 *	1.016	0.991	1.001	1.004	1.030 *
May	0.987	1.008	0.993	1.033 *	0.993	1.026
June (reference)	1.000	1.000	1.000	1.000	1.000	1.000
July	0.979	0.981	1.003	1.039 *	0.977 **	0.972
August	0.977	0.991	0.978	0.978	0.972 **	0.989
September	0.975 *	0.993	0.995	0.995	0.954 ***	0.955 **
October	0.972	0.979	0.986	0.997	0.951 ***	0.964 **
November	0.984	0.994	0.979	0.994	0.944 ***	0.947 ***
December	0.976	0.992	0.969 **	0.976	0.924 ***	0.920 ***
Birth year						
1946 (reference)	1.000	1.000	1.000	1.000	1.000	1.000
1947	0.991	1.000	0.979	0.998	0.904 ***	0.934 ***
1948	1.045 ***	1.064 ***	0.989	1.016	0.847 ***	0.905 ***
1949	1.006	1.032	0.999	1.035 **	0.739 ***	0.809 ***
1950	0.943 ***	0.987	0.977	1.035 **	0.654 ***	0.724 ***
1951	0.900 ***	0.945 ***	0.960 ***	1.035 **	0.592 ***	0.671 ***
1952	0.866 ***	0.912 ***	0.965 **	1.038 **	0.551 ***	0.619 ***
1953	0.846 ***	0.898 ***	0.999	1.093 ***	0.650 ***	0.587 ***
1954	0.796 ***	0.849 ***	1.001	1.112 ***	0.590 ***	0.536 ***
1955	0.793 ***		1.020			0.544 ***
1956	0.773 ***		1.030 *		0.507 ***	
1957	0.776 ***		1.065 ***		0.473 ***	
1958	0.775 ***		1.071 ***		0.427 ***	
1959	0.742 ***		1.094 ***		0.398 ***	
1960	0.738 ***		1.152 ***		0.368 ***	
1961	0.708 ***		1.155 ***		0.342 ***	
1962	0.710 ***		1.196 ***		0.312 ***	
N	863304	477862	734743	412706	863304	477862

***=Significant at $p<0.01$. **=Significant at $p<0.5$. *=Significant at $p<0.1$.
Source: Statistics Sweden; own calculations.

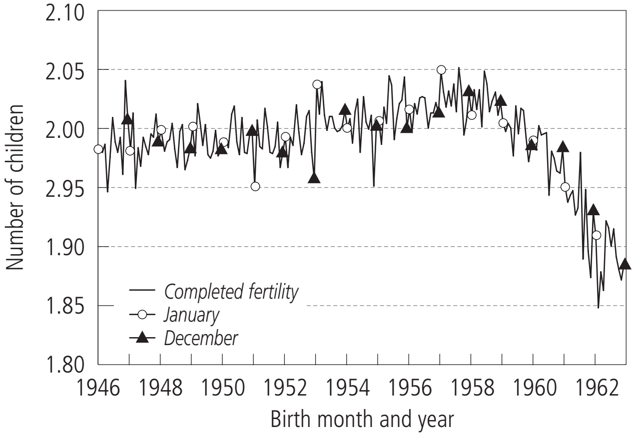

Figure 3.6. Figure 3.6. Completed fertility.
Source: Statistics Sweden; own calculations.

Completed Fertility

The number of children born to women—or completed fertility—is an additional central aspect of demographic behavior that is potentially related to the birth month of a woman. *Figure 3.6*, which shows the completed fertility of women by birth cohort and birth month, does not, however, confirm this expectation. While there are substantial fluctuations in completed fertility across birth months within each birth cohort, these fluctuations do not follow a specific pattern. Moreover, the difference in the age at first birth between women born in December and the subsequent January is not associated with a systematic difference in completed fertility. This absence of a systematic pattern is confirmed using regression analysis (not reported here in detail), with fertility at age 45 (for cohorts born from 1946–1954) or age 37 (for cohorts born from 1946–1962) not being found to be systematically influenced by the birth month. [For a detailed discussion, see Skirbekk *et al.* (2003).] In summary, therefore, the effect of the birth month and the resulting variation in the age at entering/graduating from school is concentrated on the timing of fertility and does not extend to completed fertility: neither the probability of having one or two children (*Table 3.6*) nor the overall level of fertility (*Figure 3.6*) differs systematically across women's birth months.

Educational Attainment

In our final analyses we investigate whether the overall educational attainment of women constitutes a mechanism that mediates the effect of the variation in the age at graduation from compulsory schooling on the timing of fertility and marriage according to the birth month.

The basic assumption of our analyses is that the birth month does not affect the school-leaving age through any other mechanism than the age at school entry, as determined by the school enrollment laws. Because of the rigid Swedish school system up to the completion of compulsory schooling, this assumption is very plausible. For upper-secondary and tertiary education, however, women (and/or their parents) make conscious decisions about continuing their education. These decisions can potentially include the consideration of the birth month and its implications for the age at graduation and the timing of demographic events.

This possibility was investigated using logistic regressions, where we estimate the probability that a woman completes primary school, fewer than two years or at least three years of secondary school, and fewer than two years or at least three years of tertiary education. The results of these logistic regressions are presented in *Table 2.4*. This table reveals that the risk of attaining primary education or up to two years of secondary school as one's highest educational attainment is higher for women born from July through December than for women born from January through June. The opposite is the case for higher schooling levels, where those born from January through June are more likely to complete secondary school or any kind of tertiary education than those born later in the year.

We have no direct evidence on the underlying causal mechanism [see also, Smith (1990)]. The difference in birth month in terms of the propensity to pursue additional education after compulsory schooling can be attributed to the relative class-age effect: those born late in the year are among the youngest in their school class. This young age relative to classmates tends to reduce self-confidence and school performance, which in turn can reduce the risk of completing tertiary education. However, the observed educational differences caused by the birth month could also be due to differences in the timing of education, where those born late in the year are younger when they attend school, which could affect their performance. For a discussion of the alternative theories as to why birth month could influence educational attainment, see Section 2.3.

The moderate difference in level and duration of education observed between those born early and those born late in a calendar year does not, however, explain why the birth month affects the timing of demographic events. Two facts support this conclusion. First, at all educational levels, women born early in a calendar year are older at first or second birth and at marriage than women born late in a calendar year across all educational levels (*Table 3.7*).[12] In particular, the effect of

[12] Some of the effects of the birth month observed on the timing of demographic events is explained by the higher educational attainment of those born earlier in the year. Adjusting for education in the regression analyses produces somewhat smaller effects but does not alter significance levels. For example, the January-to-December difference in the age at the birth of the first child for all women is

the birth month tends to be even stronger, the higher the level of secondary education achieved. The difference between those born in January and those born in December is greater for women with a long upper-secondary education in comparison with those with a short upper-secondary education, and it is longer for those with a short upper-secondary school education relative to those with only compulsory schooling. The reasons for this effect are likely to be related to the fact that the length of time between the school-leaving age and subsequent demographic events is shorter for those with an older school-leaving age. This reduces the time available to compensate for the effect of the birth-month-induced variation in the age at graduation on demographic events in early adulthood. In effect, it prolongs the influence of the school cohort—and thus the school-cohort-based influence of social age—on the timing of fertility and marriage.[13] Furthermore, despite the fact that the educational attainment of a woman is associated with variation in the first birth risk,[14] additional analyses—not reported here in detail—show that 1) the slightly higher educational attainment of those born early in the year is not significantly related to the level of fertility and 2) controlling for education does not alter the pattern and significance of birth-month effects in the analyses shown in *Tables 3.3*, *3.4*, and *3.5*.

3.2.2 Discussion

In recent years many theoretical and empirical studies have focused on explaining the changes in the timing of demographic events during early adulthood and in particular, the postponement of fertility and marriage. We utilize differences in women's age at graduation from school in Sweden, resulting from the combined

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reduced to 2.4 months when education is adjusted for, as opposed to the unadjusted estimate of 3.1 months.

[13]Although the timing of demographic events for women with a tertiary education still supports the cut-off-date hypothesis—those born in January are older than those born in December—these differences are of a smaller magnitude than those for women with an upper-secondary education. According to the above argument, we would rather expect an increase in the difference as those with a tertiary education are older when they graduate. However, the fact that tertiary education comprises a large variety of studies implies that the variance in graduation ages might be larger among women with a tertiary education as opposed to those with an upper-secondary education.

This less-structured duration of tertiary education may therefore dilute the effect of the birth month and partially explain the smaller difference in the age at experiencing demographic events across birth months. The role of social interactions in the timing of demographic events may constitute another argument for the lower age difference for demographic events among women with a tertiary education. Women with tertiary education, unlike those with a shorter education, tend to study more with individuals of different age groups and to a much lesser extent exclusively with individuals born in their own calendar year.

[14]Percentage of women having a child: 86.4% of women with primary school as their highest education; 88.4% of those with up to two years of secondary school; 83.9% of those with three years of secondary school; 84.8% of those with a tertiary education.

Table 3.7. Age difference (in months) between individuals born in January and December in the same year.

Highest completed education	First child	Second child	First marriage
Compulsory school, 8–9 years	1.27	1.74	1.78
Upper-secondary school, >2 years	2.61	2.67	1.33
Upper-secondary school, 3 years	5.91	4.65	3.14
Tertiary education, any length	1.76	1.65	1.42

Source: Statistics Sweden; own calculations.

effect of birth month and the Swedish school-enrollment laws, to investigate how variation in the age at finishing compulsory school (15.5 to 16.5) affects the timing of demographic events in early adulthood for female cohorts born from 1946–1962.

A striking finding of these analyses is that differences in the age at graduation from ninth grade have substantial and long-lasting effects. For instance, 45% of the eleven-month age difference in graduation between women born in December and women born in the subsequent January is still present in the age at first birth. This happens despite the first birth occurring on average eight to ten years after the graduation from compulsory schooling after the ninth grade. Moreover, 36% of the age difference at graduation prevails in women experiencing their second birth, and 32% of the age difference is reflected in the age at first marriage. Birth month, however, has no influence on the probability of ever giving birth to a first or second child, and birth month has only a weak effect on the probability of ever marrying. Differences in the age at completion of compulsory education therefore have repercussions on the timing of demographic events that follow several years after the statutory nine years of education are over. These patterns of tempo changes by birth month are surprising because the substantial time interval between finishing compulsory school—at around age 16—and the first marriage or the first/second birth would seem to provide ample opportunity to compensate for the age difference at completion of the ninth grade. The findings are therefore in contrast to arguments that women's childbearing preferences are limited to the *age* at which they experience these demographic events in early adulthood.

In addition to stressing the importance of sequencing and duration from the time of graduation, the above effects point to a potentially important social influence on individuals of the same *school cohort* rather than on individuals of the exact same age. In particular, the biggest changes in the timing of demographic events in early adulthood occur between school cohorts, that is, between women born in December and women born in the subsequent January, despite the fact that women born during December and January differ on average by only one month in their age. Hence, women tend to synchronize the timing of demographic events—such as fertility and marriage—with women in their school cohort rather than with women of a similar age. Consequently, for women born early in the year, a woman's social age is lower as compared with her biological age, and for those born late in the year it is higher. Our findings suggest that the timing of fertility and marriage for women is strongly influenced by this social age, and women born early (late) in a calendar year gravitate in terms of the timing of demographic behaviors toward the lower (higher) social age defined by their school cohort.

These findings suggest that a change in the school-leaving age would be likely to affect fertility patterns and that a younger school-leaving age would be likely to lead to a younger childbearing age. However, the impact of a school reform on fertility may be higher than the evidence presented here implies. When one considers within-class differences in the school-leaving age, one does not capture the effect of variation in the social age, as the social age is constant within the class. A school reform that lowers the school-leaving age would not only decrease the individual's school-leaving age but also the social age of the individual's school cohort. The net effect of these factors may be to cause a stronger shift in the timing of demographic events and also, potentially, an increase in the childbearing outcome.

4

Age and Individual Productivity[1]

This chapter considers another issue relevant to the question of shifting the age at entering and leaving the labor market: the shape of the age–productivity profile. If workers are at their most productive early on in their careers, then a school reform that lowers the labor-market-entry age could extend the most productive part of a worker's working life. If, however, senior workers are more productive, then raising the retirement age may be the more efficient policy option.

This chapter is divided into two sections. The first describes findings from earlier studies regarding how productivity varies according to age. In the second section we attempt to evaluate the effect of structural changes in the economy on the age–productivity profile by making job performance measurements endogenous, based on ability levels and industry-wide task demand.

4.1 Age and Productivity: A Review of the Literature

In this section we focus on age differences in individual productivity and why such differences are observed. Studies on how job performance differs according to age come from several disciplines, including social psychology, medical science, and labor economics. The type of research angle used to address this question varies widely and frequently according to the discipline of the researchers. For instance, psychologists tend to use managers' performance ratings, while economists primarily analyze matched employer–employee data sets.

In general, there is no definitive way of estimating how productivity varies according to age, with findings that are valid without restrictions or that do not entail a large degree of uncertainty. Many studies rely on strong assumptions that are likely to bias the estimates, while other investigations consider only a narrow set of jobs and may not be valid for other occupations. In this section we discuss several different approaches to measuring how job performance differs according to age. We also focus on the causes of such productivity variations, particularly age differences affecting cognitive abilities.

[1] A slightly different version of Section 4.1 is published in Skirbekk (2004).

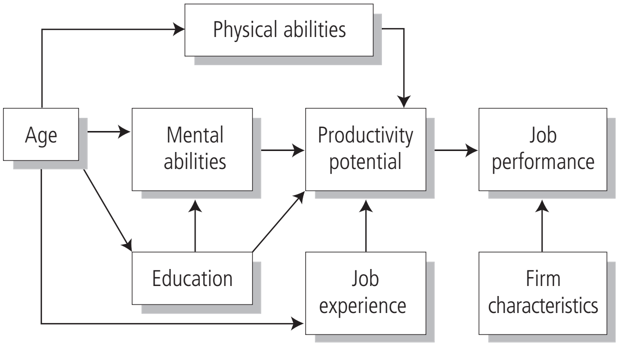

Figure 4.1. Outline of key factors affecting job performance.

4.1.1 Age and cognitive ability levels

Figure 4.1 outlines the main causes of productivity differences: physical abilities, mental abilities, and education and job experience that, in combination with the characteristics of individual firms, can determine an individual's job performance. How these different factors influence job performance has changed over time. Cognitive abilities have become increasingly important and physical abilities less so.

As several of the factors that affect job performance, including mental abilities and experience, differ in their functional level over the life cycle, the shape of the age–productivity curve could vary according to the changing importance of these different abilities in the labor market. If abilities more common in older workers grow increasingly important, then the relative job performance of the older workers will improve. The same applies if there is an increased demand for abilities that are more common in younger workers.

Cognitive abilities[2] are likely to be among the most important determinants of job performance (see Section 2.2). However, mental ability levels differ across age groups, and there is much evidence that they decline in late adulthood, which could influence the shape of the age–productivity profile. Verhaegen and Salthouse (1997) analyze 91 case studies and conclude that important cognitive abilities, such as reasoning, speed, and episodic memory, decline significantly by the age of 50.

That cognitive abilities decline according to age seems to be a relatively universal phenomenon that holds good for both men and women: individuals with high ability levels are subject to the same changes in cognitive function as those with low ability levels, and similar patterns are observed in different countries (Park *et al.*, 1999; Deary *et al.*, 2000; Maitland *et al.*, 2000). Age-related reductions in

[2]Cognitive or mental abilities refer to broad aspects of intellectual functioning. They include reasoning, spatial orientation, numerical capabilities, verbal abilities, and problem solving. The most commonly used measurement of cognitive abilities is the IQ score.

memory and learning capabilities have also been documented among many nonhuman species, ranging from fruit flies to primates (Minois and Bourg, 1997; Bunk, 2000).

Certain cognitive abilities tend to be relatively robust against age-induced declines (Schaie, 1994). A division can be drawn between crystallized abilities, which remain at a high functional level until late in life, and fluid abilities—mental abilities that are strongly reduced over the life span (Horn and Cattell, 1966 and 1967). Crystallized abilities concern the accumulation of knowledge, such as the meaning of words and vocabulary size, which tends to increase or be stable until late in life. The second group, fluid abilities, concerns the performance and speed of solving tasks related to new material and include perceptual speed and reasoning abilities.

Based on psychometric test results of men in different age groups, Schwartzman *et al.* (1987) find that verbal skills (crystallized abilities) remain virtually unchanged, while reasoning and speed (fluid abilities) decline with age. In a test–retest study of twins, Blum *et al.* (1970) provide similar findings: vocabulary size is observed to remain constant from youth to old age, despite a general reduction in other cognitive abilities.

Cross-sectional analyses describing the current population's abilities typically find a younger ability peak than longitudinal data, which follow a panel of individuals' ability levels over their life cycle. This is the case, for example, in the "Seattle Longitudinal Study" (Schaie, 1996), where data on both longitudinal and cross-sectional ability differences according to age are collected. Findings from the longitudinal data set indicate that *word fluency* does not decline before the age of 53, while according to cross-sectional data from the same study, word fluency starts to decline after the age of 25.

Both longitudinal and cross-sectional approaches to measuring age–ability differences are problematic. The weaknesses of longitudinal studies could suggest that the age–ability estimates are upwardly biased (Willis and Baltes, 1980); large attrition, where those who are lost are likely to be negatively selected, means that the sample remaining in later waves is positively selected.[3] Another source of error stems from test practice, meaning that individuals who participate in the survey in subsequent waves perform better simply because they have taken similar tests before and are therefore more used to being in a test situation as well as trained as to the type of questions being asked.

On the other hand, analyses of data based on a cross-sectional approach could lead to a downward bias in the age–ability curves. This is because average ability levels for young individuals have increased over time, possibly because of increasing educational attainment (see Section 2.2).

[3]In one of the most influential longitudinal studies of how cognitive abilities develop over the life cycle, the Seattle Longitudinal Study (Schaie, 1994), more than half of the initial sample was lost by the time of the third wave, after 21 years.

4.1.2 Experience and learning

Advancing age is typically associated with a decrease in the functional level of the fluid cognitive abilities (related to learning and speed); but it is also generally related to a longer work experience. Warr (1994) suggests a categorization of professions based on whether workers become more or less productive according to age; the author argues that for occupations where more experience is important, senior workers can be at least as productive as younger ones, while in jobs where fluid abilities matter, senior workers' job performance declines. Typing is one example of a job where experience is important. In this occupation, older workers compensate for their reduced speed by developing more efficient work strategies for typing, so that their productivity remains stable over the life cycle (Salthouse, 1984).

The decline in functional ability levels over the life cycle can be mitigated, and targeted training may provide a way of halting the decline in cognitive abilities. Schaie and Willis (1986a and 1986b) conclude that targeted training can stabilize, or even reverse, age-specific declines in inductive reasoning and spatial orientation in many individuals. Ball *et al.* (2002) also find that older individuals who frequently exercise their perceptual speed, reasoning, and memory can enhance the performance of these abilities.

Fewer training opportunities are offered to older workers than to younger ones, something which could affect human capital and productivity levels. Companies often make a decision as to whether to invest in their workers' human capital based on the expected number of years left in the working life before retirement. As senior workers have less time to repay firms' investments in human capital and productivity, they are offered fewer opportunities to participate in training programs. If the retirement age increases, however, the company's expected payoff from human capital investments would be higher, which could increase the amount of training offered to older individuals and improve their human capital levels.

Older individuals tend to learn more slowly, particularly if what they learn is qualitatively different from what they already know. Rybash *et al.* (1986) argue that as people grow older, they undergo an *encapsulation* of job know-how, implying that individuals' skills are increasingly attached to certain work domains. This means that senior employees can remain highly productive within a field that they know well and where long experience is beneficial. Colonia-Willner (1998) asserts that managers can maintain a high productivity level at an older age because of the age robustness of their *tacit knowledge* (i.e., procedural knowledge used to solve everyday problems). However, when they perform unfamiliar work their performance decreases, as they have to rely on the ability to learn and adjust, which are the skills that decline most with age. Senior individuals are less able than their young counterparts to reorient themselves to new task requirements and to solve novel problems (Smith, 1996), which could explain why age-related productivity reductions tend to increase with the complexity of the work task (Myerson *et al.*, 1990).

The productivity profile may change over time as a result of structural changes in the labor market. Accelerating technological progress can increase the importance of being able to learn and adjust to new ways of working. This can make lengthy work experience less important, which is particularly problematic for older employees because of age-related declines in the speed at which they can process information and in their learning capacities (Baltes and Lindenberger, 1997; Hoyer and Lincourt, 1998).

Work experience is one characteristic that can improve older employees' productivity relative to that of their younger counterparts. However, there comes a point at which further experience no longer has any effect on productivity. Ilmakunnas *et al.* (1999) assess a broad sample of Finnish manufacturing employees and find that the length of time in a job improves job performance for only up to 3.8 years. Ericsson and Lehmann (1996) argue that it takes roughly 10 years to achieve expert competence in games and situations where strategic and analytic competence is important. The 10-year estimate is supported by findings from a variety of job domains, ranging from livestock evaluation and x-ray analysis to scientific performance in medical and natural sciences (Raskin, 1936; Lehman, 1953; Phelps and Shanteau, 1978; Lesgold, 1984).

4.1.3 Measuring productivity of individuals at different ages

This section surveys the main approaches used to measure job performance differences according to age. The approaches discussed include supervisors' ratings, piece-rate samples, employer–employee matched data sets, as well as age-specific employment and earnings structures.

Studies based on supervisors' ratings typically find that the employee's age has no effect or a weak negative impact on productivity. Medoff and Abraham (1980 and 1981) studied workers at large corporations and identify that their length of tenure is either unrelated to or negatively associated with performance evaluations. A meta-analysis by Avolio and Waldman (1994), based on 18 supervisor assessment samples, found a slightly negative productivity impact. Analogously, McEvoy and Cascio (1989) review 96 studies on the impact of the employee's age on supervisors' assessments and sales records and find no clear effect of age on productivity. Facts and figures about the work capacity of older individuals should be highest in firms with a higher share of older workers, as this is where there should be the best insight into older workers' performance. Remery *et al.* (2003) survey 1,007 Dutch personnel managers and show that older individuals are seen as less productive than young ones, particularly in workplaces with a high proportion of older employees.

A general disadvantage of using supervisors' ratings to assess individuals' productivity is that it is a subjective measure. Managers may wish to reward older employees for their loyalty and past achievements, which can inflate the evaluations of senior employees and bias the results (Salthouse and Maurer, 1996). Dalton and Thompson (1971) investigate performance evaluations not only from supervisors but also from other employees in six large companies undergoing rapid technological change. The results from the combined ratings of employees and managers suggest that workers in their thirties put in the most effort and perform the most sophisticated technical work, while, as they move into their forties and beyond, their productivity declines.

A second approach to measuring the impact of age on job performance is based on *piece rates*: measuring the quantity and quality of a worker's output. Studies based on this approach tend to find that older employees have significantly lower productivity levels. For example, a study by the U.S. Department of Labor (1957), based on a broad range of industries, finds that job performance increases until the age of 35, then steadily declines. At the end of the career, productivity is reduced by 14% in the men's footwear industry and 17% in the household furniture industry. Mark (1957) and Kutscher and Walker (1960) find that factory workers' productivity fell after the age of 55, while mail sorters and office workers kept their productivity relatively stable until late in their working life. Eva (2002) finds that the productivity of medical doctors declines substantially from around 50 years of age.

These task-quality/speed tests are potentially more objective, as they rely less on subjective managerial assessment; but they may be influenced by the fact that the workers are selected in terms of age groups and occupational types (Rubin and Perloff, 1993). Furthermore, the time limit common in such studies biases results. For example, older employees may maintain a higher work speed in the short period they are studied than they would be able to maintain in a normal job situation (Salthouse and Maurer, 1996).

The productivity of individuals doing "creative" jobs, such as researchers, authors, and artists, can also be measured by the quantity as well as the quality of their output. Stephan and Levin (1988) study quality-adjusted publications in the natural sciences (quality being measured as the standard of the journal) and find that individuals' young years are the most productive ones. Similar evidence is found in the field of economics, where Oster and Hamermesh (1998) conclude that older economists publish less in leading journals than younger ones and that the rate of decline is also the same for top researchers, among others. Miller (1999) analyzes how age affects creative output by studying the number of paintings, albums, and books produced by a sample of artists (739 painters, 719 musicians, and 229 writers). He finds that artists tend to produce the most when they are in their 30s and 40s.

A third way of measuring productivity according to age is based on the analysis of *employer–employee matched data sets*,[4] where individual productivity is measured as workers' marginal impact on the firm's value-added. Such data sets tend to give information on both wages and productivity, enabling a comparison as to whether individuals' productivity curves differ from their wages. These studies are likely to be less subjective than those based on supervisors' ratings, and there are fewer sample selection problems than in investigations based on piece rates. The main challenge in this approach is to isolate the effect of employees' ages from the other influences on the firm's value-added. In effect, such studies tend to have strong identifying assumptions. They also demand high-quality longitudinal data on the characteristics of both the firm and individuals.

An overview of employer–employee studies is given in *Table 4.1*. For most employer–employee studies, an inverted U-shaped work performance profile is found (Haltiwanger *et al.*, 1999; Hægeland and Klette, 1999; Ilmakunnas *et al.*, 1999; Andersson *et al.*, 2002; Crépon *et al.*, 2002; Hellenstein and Neumark, 2004). Individuals in their thirties and forties tend to have the highest productivity levels. Employees over the age of 50 are found to have lower productivity than younger individuals, in spite of their higher wage levels.

Exceptions to findings suggesting that productivity decreases according to age include Hellerstein and Neumark (1995), whose findings suggest that productivity increases over the life span in Israel. However, the authors stress that no conclusions about age and productivity can be drawn because of the high influx of young immigrants to Israel and because their manufacturing-firm data set is of a relatively poor quality.

In another study of American firms (Hellerstein *et al.*, 1999), productivity is estimated to increase with age, with those above 55 contributing the most to output levels. However, the authors find that peak productivity shifts to workers aged 35–54 when the firms' value-added—rather than output levels—is used as an indicator of productivity. Moreover, an earlier analysis based on the same data set (Hellerstein *et al.*, 1996) concludes that workers' productivity also *decreases* with age in cases where the firms' output is used as an indicator of productivity.

Analyses of employer–employee data sets could be biased if a firm's success leads to an increase in the number of new young employees working there. The fact that a young age structure may be the consequence rather than the cause of the firms' success could affect the validity of the estimates. An important problem

[4] A survey of analyses based on matched employer–employee data can be found in Abowd and Kramarz (1999).

Table 4.1. Overview of employer–employee data sets

Authors	Region/ country	Sample size	Individual variables	Age categories	Control variables	Productivity measurement	Age–productivity profile	Remarks
Hellerstein and Neumark (1995)	Israel	933 firms	Occupation	<35, 35–54, <54	Industry type, no. of employees, firm's capital and input factors, R&D spending	Firm's output	Productivity peaks at 55 years and older	Poor quality of data and high inflow of young immigrants; lower study validity
Haltiwanger *et al.* (1999)	Mary-land/ USA	Not stated (all firms in Maryland 1984–1997)	Gender, education, immigrant status	<30, 30–54, <54	Firm's age and size, industry type, period effects	Sales per employee	Workers above 55 have lowest productivity	All industries
Hægeland and Klette (1999)	Norway	7,122 firms, 270,636 employees	Education, experience, no. of hours worked	Dependent on length of education and length of experience	Firm's age, industry type, region, public ownership, foreign ownership	Firm's value-added	Productivity peaks in the thirties, declines for those with over 15 years' experience (in their late thirties and older)	Manufacturing
Hellerstein *et al.* (1999)	USA	3,102 firms, 128,460 employees	Gender, race, occupation, whether married, education	<35, 35–54, <54	No. of employees, region, type of establishment, industry type	Firm's output or value-added	Productivity peaks at 55 years and older if output is used as estimate. Productivity lowest for 55 years and older if value-added is used	Manufacturing

Table 4.1. Overview of employer–employee data sets (continued)

Authors	Region/ country	Sample size	Individual variables	Age categories	Control variables	Productivity measurement	Age–productivity profile	Remarks
lmakunnas *et al.* (1999)	Finland	>3,882 firms, 279,181 employees	Education, experience, no. of hours worked	Average employee age at each firm examined	Firm's age, capital	Firm's value-added	Productivity peaks around age of 40.	Manufacturing
Andersson *et al.* (2002)	Sweden	2,874 firms	Education	16-29, 30–39, 40–49, 50–59, 60–64, <64	Period, plant, and industry effects	Firm's value-added	Workers above 50 with primary and secondary education have lower productivity; tertiary-educated above 50 have higher productivity	Manufacturing and mining industries. Longitudinal analysis confirms findings.
Crépon *et al.* (2002)	France	77,868 firms, <3,000,000 employees	Gender, occupation, no. of hours worked	<25, 25–34, 35–49, <49	Firm's age and size, industry type, capital	Output	Productivity peaks for those aged 25–34, lowest for those over the age of 50	Manufacturing and non-manufacturing
Hellerstein and Neumark (2004)	USA	<3,101 firms, <265,412 individuals	Occupation, race, education, marital status	<35, 35–54, <54	Capital, materials, region, no. of employees	Firm's output	Productivity highest for 35–54 age group	Manufacturing

with cross-sectional evidence is that seniority leads to occupational shifts. Good workers get promoted, while inefficient workers lose their jobs or are demoted. This can cause estimation bias, as a higher age implies increased selection. Using a lagged measure of the firm's age composition to estimate current productivity can partly overcome this problem, as it can limit the bias induced by age-specific influx and outflow of workers. Andersson *et al.* (2002) use such lagged measures in their analysis of employer–employee data, and their findings support the findings that older workers tend to be less productive than younger ones (with the exception of tertiary nontechnical workers who have a later productivity peak).

Age–earnings profiles can provide information on productivity profiles in settings where wages reflect current productivity. Boot (1995) describes age–earnings profiles for British workers in the first half of the nineteenth century when the labor market was hardly regulated. For the physically demanding work analyzed, men reach their peak earnings at the beginning of their thirties, and wages decrease substantially from around 40 years of age. Another example is a study by Lazear and Moore (1984) that examines the difference between the earnings profiles of the self-employed (who are paid according to productivity) and salaried workers (who have long-term contracts). They find that the self-employed tend to have little wage variation across ages, while salaried workers have increasing wages throughout their career; this suggests that productivity remains stable over the life cycle, while seniority-based wage systems can imply that earnings nonetheless increase according to age.

Changes in the labor market attachment of workers from different age groups could also provide evidence on how workers from different age groups perform in the labor market. If older workers cope less well with technological change, this should be observable by an increase in the risk of job loss. Bartel and Sicherman (1993) put forward evidence that when the rate of technological change is highest, most job losses do, in fact, take place among older workers. Similar results are also found in analyses of interindustry and international data (Clark *et al.*, 1999; Ahituv and Joseph, 2000).

Investigations of the relationship between changes to the age structure of the population and aggregate measures of performance, such as technological progress or economic growth, can also provide insights into worker productivity. Nishimura *et al.* (2002) investigate the impact of age structure on technological progress and value-added growth in Japanese industries for the years 1980–1998. They find that the share of educated workers over 40 years of age was positively correlated to the firm's technological progress in the 1980s but that this relationship became negative in the 1990s. One possible explanation for the changing relationship over time is that the skills needed to promote technological progress, such as speed and the ability to learn, are those that younger workers tend to be relatively good at.

Lindh and Malmberg (1999) and Malmberg and Lindh (2002) find that the initial size of the share of those aged 50–64 in the labor force is positively correlated to economic growth in each subsequent five-year period in the Organisation for Economic Co-operation and Development (OECD) for the period 1850–1990. No clear effect is ascertained for younger age groups. Although the causal mechanism of this correlation is not identified, it could suggest that productivity peaks late in the working life. However, there may be other, more plausible reasons. One possibility is an unobserved factor that affects both the level of economic progress and demographic indicators such as life expectancy and thus influences economic growth and age structure. Furthermore, life cycle investment and consumption patterns could explain why economic growth is associated with a high share of older workers. Hence, the association between age structure and growth is not necessarily due to a productivity peak late in the working life.

In the Global Entrepreneurship Monitor (GEM) (GEM Consortium, 2004), age and entrepreneurship is measured using Total Entrepreneurial Activity (TEA). TEA, based on surveys of representative samples of the adult population in each GEM 2004 country, is the sum of 1) those individuals involved in the business start-up process (nascent entrepreneurs) and 2) individuals who are active as owner–managers of firms established for a period shorter than 42 months. Those qualifying for both definitions are counted only once. In all 34 countries where the survey was carried out,[5] individuals aged 25–44 are most likely to contribute to entrepreneurial activity and those above 50 are least likely. The share of the population under 35 years and TEA correlates strongly and significantly in cross-country analysis (GEM Consortium, 2004).

4.1.4 Age–earnings profiles

A wage analysis provided by the OECD (1998) shows gross wages peaking for those aged 45–54 in 17 of 19 countries observed.[6] The age–earnings profile is characterized by a relatively steep increase in wage levels until the peak is reached, followed by a mild reduction in earnings in the last years before retirement. The average earnings of those aged 25–29 and those aged 55–64 is 72% and 91%, respectively, of the earnings of the 44–54 age group.[7] Age differences in wages also

[5]Argentina, Australia, Belgium, Brazil, Canada, Croatia, Denmark, Ecuador, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, Ireland, Israel, Italy, Japan, Jordan, Netherlands, New Zealand, Norway, Peru, Poland, Portugal, Singapore, Slovenia, South Africa, Spain, Sweden, Uganda, United Kingdom, and United States.

[6]The countries in the study were Australia, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Sweden, Switzerland, and United States. For Czech Republic and United Kingdom, the wages peak for the 35–44 age group.

[7]These percentages represent unweighted averages for the countries in the study.

increase with educational level. Individuals aged 25–29 with less than an upper-secondary education earned 81% of the earnings of the 45–54 age group; and those aged 25–29 with a university education earned only 53% of the earnings of the 44–54 age group.

4.1.5 Age–earnings and age–productivity profiles

Based on the evidence presented in previous sections, the late peak in the age–earnings profile does not overlap with the relatively young peak in productivity levels. This suggests that there is a discrepancy between productivity and wages, with wages being lower than productivity levels at younger ages and higher at older ages.[8]

Several theories have emerged to explain the reasons behind age–earnings profiles tending to peak later than age–productivity profiles. One important reason is employers' initial uncertainty about new employees' productivity levels (Harris and Holmstrom, 1982). Older workers are paid above their marginal productivity because upward-sloping wage profiles 1) strengthen the employees' work effort by raising their shirking costs, 2) lower the firms' need to train new workers, and 3) decrease the risk of sensitive information about the firm being shared with competing firms if workers leave the company. Furthermore, when older workers receive higher wages as a reward for past productivity, junior workers' loyalty to the firm may rise, as they will also wish to reap the rewards of a long-service bonus. Hutchens (1989) notes that this type of incentive system, *delayed payment contracts*, is used most frequently when workers' performance is difficult to observe and measure.

An important reason why it is in the interest of firm owners to have a wage peak at a relatively high age is that, on average, workers used to be rather young (because of the population's age structure). This means that the firms, until recently, have gained from having a delayed payment contract, as the average worker, who is young, has been paid below his/her marginal productivity. However, as Lazear (1988) asserts, population aging challenges the financing of such systems, by increasing firms' incentives to either lower older workers' wages or to lay the workers off.

Figure 4.2 shows a stylized situation in which younger workers are assumed to be underpaid and older workers overpaid relative to their productivity, making it profitable for firms to employ the young. In the case of population aging, profits

[8] Alternatively, one could argue that wages and productivity levels match at all ages. Age–earnings profiles indisputably slope upward, while there is uncertainty about the shape of the age–productivity curve. One could therefore assume that wages reflect current productivity, that the age–productivity profile is incorrectly estimated, and that the true productivity profile is identical to the age–earnings profile.

Figure 4.2. Stylized presentation of productivity and earnings across the life span. Based on Lazear (1979) and Jackson (1998).

decrease as the share of unprofitable older workers increases; hence, the incentive for firms will be either to lower the workers' wages or lay the workers off.

Delayed payment contracts may implicitly require individuals either to have lifelong contracts with their employees or that job switches are made between firms with similar wage systems. However, if a worker could choose between working in firm A, where the wages peak early in life and firm B, where the wages peak late in life, this type of payment system becomes unsustainable. The profit-maximizing worker could spend his/her younger years in firm A with high initial wages, then switch to firm B with high seniority wages in the middle of his/her career, and firm B will lose workers who would otherwise bear the costs of seniority wages. Moreover, the frequency of shifting jobs has increased (Burgess and Rees, 1996; Bergmann and Mertens, 2002), which suggests that the age–earnings profiles of firms employing the same type of workers would need to be harmonized. This can affect the shape of the age–earnings profile, making it more similar to the age–productivity curve, where wages peak at younger ages.

4.1.6 Summary of the literature review

Studies that estimate the influence of age on individual productivity base their analyses on different job performance indices, including piece-rate studies, analyses of employer–employee data sets, and supervisors' evaluations. Most piece-rate studies, measuring the quantity and quality of the workers' output, and analyses of employer–employee data sets, where the marginal effect of the workers' on the firms' productivity is estimated, suggest that productivity follows an inverted U-shaped profile, with significant decreases in productivity being found after the age of 50. Supervisors' evaluations on average show little or no relationship between the assessment score and the age of the employee. However, these subjective performance indicators may be biased; for example, the management's opinions of older employees may be inflated for loyalty reasons.

One problem with estimates of how productivity varies according to age is the high degree of uncertainty associated with measuring productivity. For example, older individuals who remain in the workforce longer are likely to be positively selected and have higher productivity than those who leave the workforce early. This would mean that a cross-sectional study of workers' productivity-related age differences could suggest an upward bias in the estimates.

Older workers may, however, possess characteristics that are important to the success of the firm but difficult to measure. Senior employees can have a wider professional network, give training and guidance, provide tacit knowledge, uphold norms that prevent shirking and opportunistic behavior, and know better how to deal with problems that arise only infrequently. Such influences are difficult to quantify, particularly in studies of quantity of output, such as studies of piece-rate firms. However, analyses of employer–employee data sets should be able to capture such effects. These studies still tend to find that productivity declines with age.

4.2 Age and Individual Productivity Potential: New Evidence Based on Ability Levels and Industry-Wide Task Demand

Studies on age and productivity tend to use "output" measures of productivity, such as the quantity and quality of goods produced by workers of different ages. Few analyses have given weight to the question of *why* productivity varies according to age. In this section, we estimate the relationship between age and productivity potential by looking at the causes of age-related productivity differences, basing our analysis on age-related variations in individuals' abilities and the changing importance of these abilities in the labor market. This framework is used to show that the age–productivity curve can vary as a result of changing labor market requirements and is not necessarily static.

Previous investigations of age and productivity may have several shortcomings that could decrease their validity:

- They usually neglect causal factors as to why productivity varies according to age;
- Earlier studies have not considered that the shape of the age–productivity profile can change over time;
- Investigations based on piece-rate samples or supervisors' ratings are restricted to a limited set of occupations. Findings from these approaches are therefore not necessarily relevant for other jobs; and
- Analyses of employer–employee data sets rely on strong assumptions regarding the relative impact of the workers' age on firms' value-added, which can bias results.

Our investigation may overcome some of these shortcomings by focusing on the potential causes of age-related productivity differences. We acknowledge, however, that our approach has shortcomings. One cannot take into account all possible factors that determine productivity and accurately model each factor's importance in determining job performance. Furthermore, several influences that determine the shape of the age–productivity curve cannot be taken into account. In spite of these weaknesses, we believe that an attempt to understand how causal, time-varying factors affect the shape of the age–productivity curve could provide new insights into life-cycle variation in productivity. This work can be best understood 1) as a possible framework for use in assessing the impact of changing labor-market demand on age-related productivity differences and 2) as a tool to promote understanding of the role of some of the factors relevant to determining age-related variations in job proficiency.

4.2.1 Factors affecting productivity: Work-related abilities

The data on the age-specific supply of abilities are taken from the General Aptitude Test Battery (GATB), a workforce survey carried out by the U.S. Department of Labor [the data is presented in Avolio and Waldman (1994)]. The GATB consists of detailed ability scores from 16,134 white American male and female workers from a wide range of educational and professional backgrounds. The subjects are aged 16–74, but those over 65 are excluded from this study.

Table 4.2. Description of Aptitude Test Battery of the matched ability supply and demand

Supplied Ability (Source: General Aptitude Test Battery, Avolio and Waldman, 1994)	*Demanded Ability* (Source: *Dictionary of Occupational Titles,* Census data [cited in Autor *et al.* (2003)]
Numerical ability	GED* mathematics
Managerial ability	Direction, control, and planning of activities
Clerical perception	Set limits, tolerances, or standards
Finger dexterity	Finger dexterity
Manual dexterity	Eye–hand–foot

*General Education Development

We take into account the abilities for which there is knowledge about relative labor-market importance.[9] The relative labor-market demand for five abilities is provided by Autor *et al.* (2003), who estimate how the demand for work tasks has changed over the last 40 years in the American labor market. The "matching" of the supply and demand of abilities is given in *Table 4.2*, where numerical ability, managerial ability, clerical perception, finger dexterity, and manual dexterity are matched estimates of ability demand.

A description of the GATB abilities, taken from Hartigan and Wigdor (1989), follows. Complementing the findings of Autor *et al.* (2003), additional studies on the relevance of these abilities to the labor market are reported in some cases.

Numerical ability. This measures the extent to which arithmetic and advanced mathematics are required on the job and the speed and accuracy with which an individual is able to perform such tasks. Numerical abilities and quantitative skills are relevant to a large number of professions, ranging from accounting to engineering. Several studies have documented the importance to the labor market of mathematics and have identified a close association between numerical skills and wage levels (Murnane *et al.*, 1995; Mitra, 2002).

[9]The General Aptitude Test Battery subtests comprise nine abilities: We use five of these abilities in this study: numerical ability, verbal aptitude, clerical perception, finger dexterity, and manual dexterity. The four abilities we do not use are: general intelligence (this is an aggregate of all cognitive abilities), spatial aptitude (the ability to comprehend geographic forms and visualize two-dimensional objects on a three-dimensional form), form perception (ability to perceive relevant detail in objects and graphic material), and motor coordination (ability to coordinate eyes and hands when making precise movements).

We omit general intelligence; this is an aggregate that is not well suited to age studies, as it includes both verbal aptitude, which is relatively age-robust. We also omit numerical ability, which declines substantially over the life cycle. The other abilities we omit tend to overlap with the abilities we include; we exclude motor coordination, as we use finger dexterity and manual dexterity. Moreover, form perception and spatial aptitude are closely related to clerical perception; thus, we do not consider them in our study.

Table 4.3. Average ability levels. Measured as share of those aged 25–34 years, standard deviation.

Age	Numerical ability	Managerial ability	Clerical perception	Finger dexterity	Manual dexterity	Experience
0–19	–0.30	–0.17	0.14	0.05	0.16	–0.40
20–24	–0.11	0.00	0.17	0.10	0.35	–0.40
25–34	0.00	0.00	0.00	0.00	0.00	0.00
35–44	–0.39	0.00	–0.28	–0.40	0.05	0.27
45–54	–0.63	0.00	–0.55	–0.92	–0.49	0.27
55–65	–0.85	0.00	–0.80	–1.42	–0.94	0.27

Source: Avolio and Waldman (1996); Ericsson and Lehmann (1996); Colonia-Willner (1998); OECD (1999); and own calculations.

Managerial ability. This measures the extent to which interpersonal and communication skills, managerial skills, and nonroutine communication are needed in the workplace, as well as the extent to which a person is able to understand the meaning of words and language. This ability is relevant for most jobs, particularly where communication, transmitting information, and making strategic decisions are a central occupational task. Managerial skills are often required in the labor market, and various measures of verbal aptitude are closely associated with income levels (e.g., International Adult Literary Survey, 2001). Increases in managerial ability at younger ages are due to an increase in verbal aptitude, as suggested by the GATB survey. Thereafter, verbal aptitude is unaffected according to age, as found in Colonia-Willner (1998).

Clerical perception. This is the ability to discriminate and perceive relevant detail in visual and tabular stimuli. This ability is relevant for those who oversee routine clerical tasks to check for errors in transcribing or who do simple filing.

Finger dexterity. This is a measure of the accuracy and speed at which one can manipulate small objects with hands and fingers. It shows how well one is able to use one's hands to carry out repetitive movements over time. It could be relevant for jobs where finger skills are important, such as shoemaking or shirt production.

Manual dexterity. This is the ability to coordinate hand and foot movement. This measure is important in occupations that require coordination and physical agility, for example, fire fighting.

The age-specific test-score results for these abilities are presented in *Figure 4.3* and *Table 4.3*. Crystallized abilities (such as verbal abilities) decline the least, while fluid abilities (such as numerical competence) decline the most, which is consistent with findings from other studies (Blum *et al.*, 1970; Schaie, 1996). However, the age decline is of a considerably smaller magnitude than that found in other similar cross-sectional studies [as shown in a survey article by Verhaegen and Salthouse (1997)].

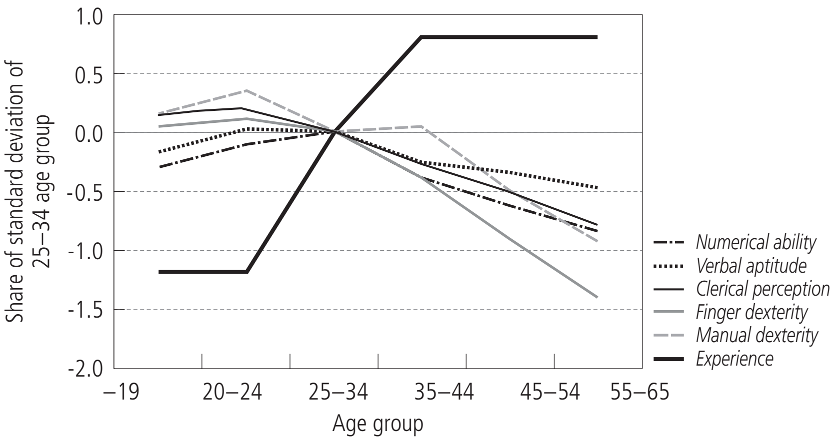

Figure 4.3. Ability levels according to age.
Source: Avolio and Waldman (1996); Ericsson and Lehmann (1996); OECD (1999).

4.2.2 Demand for abilities

To estimate the labor-market value of the different abilities, we apply data on how the importance of different job tasks has changed over time (Autor *et al.*, 2003). The data are considered appropriate for this study as they present the level and change of task demands for all employees in the labor force. The information on task-demand structures can also be matched with information on age-specific ability levels, as shown in *Table 4.2*.

Autor *et al.* (2003) analyze how task input for total U.S. employment has evolved during the period 1960–1998. They use data from the *Dictionary of Occupational Titles* (U.S. Department of Labor, 1972) that describe the average task input required by labor in the economy, and they merge this with data from population censuses that describe how the job structure is changing over time. The labor input of American workers aged 18–64 in more than 450 job categories is examined. By combining information on both the skill intensity and the composition of employment structures with within-job estimates, Autor *et al.* (2003) are able to produce estimates on the extent to which each task input changes over time.

In addition to the five abilities discussed above, we include an estimate of experience in the model. The supply of experience is calculated in a similar way to the abilities, with age-specific supply being measured relative to the standard deviation of the 25–34 age group. There is no direct evidence as to how important experience is in the labor market. To look at the effect of experience, we assume that it is rated as highly important, which is in line with surveys on employers' valuation of workers' skills, where experience is ranked as the most important trait

Table 4.4. Demand for abilities. Scale: 0 to 10, where 10 represents the most important.
Source: Autor *et al.*, 2003; own calculations

Ability	1960	1970	1980	1990	1998
GED math	3.61	3.72	3.76	3.87	3.97
Direction, control, and planning	2.40	2.40	2.46	2.68	2.89
Set limits, tolerances, or standards	4.53	4.70	4.61	4.40	4.11
Finger dexterity	3.78	3.90	3.90	3.83	3.75
Eye–hand–foot coordination	1.37	1.29	1.24	1.17	1.16
Experience	8.00	8.00	8.00	8.00	8.00
Decreasing importance of experience	8.00	7.50	7.00	6.50	6.00

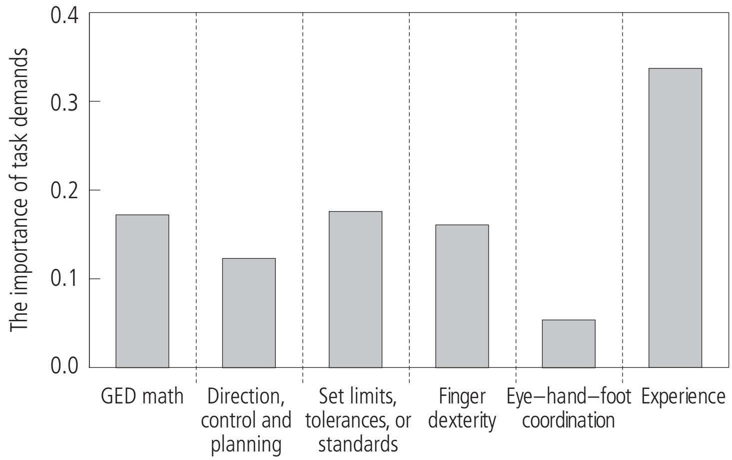

Figure 4.4. The relative importance of job abilities in the U.S. labor market (1998). Source: Autor *et al.* (2003); own calculations.

(e.g., Golini, 2004); and we thus assign to it the value 8 on a scale from 0 to 10. To estimate the effect of a decrease in the importance of long experience, one of the scenarios estimates the effect of a labor-market rating of experience that decreases from 8 to 6 over the period analyzed (see *Table 4.4*).

The relative importance of these abilities in 1998 is shown in *Figure 4.2*, and the changes in their relative importance between 1960 and 1998 are shown in *Table 4.4* and *Figure 4.4*. We look at the time period 1960–1998 because this is the period for which we have data. The time period allows us to look at past and current patterns in the demand for abilities. We use the development of five task categories to assess changing the labor-market demand for the abilities, as described in *Table 4.4*.

4.2.3 Supply of experience

The number of years for which additional experience increases work performance is uncertain, and estimates vary between 3.8 years and 10 years, as discussed in Section 4.1. The outcome for the productivity profiles estimated later in this section is, however, not substantial. All the estimated age–productivity curves decrease, while wages continue to rise for senior workers.

To identify for how many working years experience increases productivity, we use Ericsson and Lehmann's (1996) 10-year estimate,[10] combined with data on age of labor-market entry and data on age-specific labor-force participation from OECD (1999), as well as age-specific experience levels from Avolio and Waldman (1994). This means that members of the 20–24 age group are categorized as having no job experience, as the average person in this group has not yet entered the labor market. In 1996 the median age of labor-market entry was 22.9 years, and the average individual in this age group was aged 22.5 years. The average worker in the 25–34 age group, taking age-specific labor-force-participation rates into account, is estimated to have 6.04 years of experience (with a standard deviation of 5 years).[11] Individuals aged 35–65 have at least 10 years of labor-market experience and have thus acquired the maximum productivity-enhancing effect of experience. The effect of experience on potential productivity is shown in *Figure 4.1*.

4.2.4 Method

The productivity measurement is based on the functional level of cognitive and noncognitive abilities at different stages across the life span. The strength of the impact of each ability on the productivity level is determined by the demand for that ability in the labor market. This may be a strong assumption, as many jobs are not affected by ability variation, unless, for example, the ability level drops below a certain threshold. We therefore relax this assumption later in the section.

We start by postulating the equation for the age-specific supply of abilities.

$$\hat{a}_{X,S,g} = \frac{\bar{a}_{X,S,g} - \bar{a}_{X,S,\text{25–34 year olds}}}{\sigma(a_{X,S,\text{25–34 year olds}})} \tag{4.1}$$

In Equation 4.1, $\hat{a}_{X,S,g}$ is the estimate for the supply S of ability X for age group g. The mean ability score for those aged 25–34 years is subtracted from

[10]The 10-year estimate as to how long experience raises productivity for is supported by findings from a variety of job domains, ranging from livestock evaluation and X-ray analysis to scientific performance in medical and natural sciences (Raskin, 1936; Lehman, 1953; Phelps and Shanteau, 1978; Lesgold, 1984).

[11]The length of experience that the different age groups have is calculated from responses to the question: "How much experience (in years and months) have you had in your present occupation? Include time with both your present and previous employers" (Avolio and Waldman, 1994).

the average ability score for each age group and the difference is divided by the standard deviation of ability X for the 25–34 age group. Thus, $\hat{a}_{X,S,g}$ expresses the ability level X of an average individual from age group g in relation to the mean of the 25–34 age group in proportion to the standard deviation. The standard deviations of $\hat{a}_{X,S,g}$ are found in *Table 4.3* and the various age-specific abilities are given in *Table 4.4* and *Figure 4.1*.

$$\hat{a}_{X,D(t)} = \frac{a_{X,D(t)}}{\sum_X a_{X,D(t)}} \tag{4.2}$$

Equation 4.2 gives the estimate for the demand for ability X at time t. By dividing the importance of ability X, $a_{X,D(t)}$, by the sum of all task scores $\sum_X a_{X,D(t)}$ we obtain a measurement of the relative importance of task input X in the economy $\hat{a}_{X,D(t)}$. The values for the relative demand are given in Equation 4.4 and shown in *Figure 4.5* and *Figure 4.6*.

$$\hat{a}_{X,g,t} = \hat{a}_{X,S,g} {}^{*}\hat{a}_{X,D(t)} \tag{4.3}$$

In Equation 4.3 the supply of each ability $\hat{a}_{X,S,g}$ by age group g is multiplied by its demand $\hat{a}_{X,D(t)}$. This equilibrium index is used to give an estimate of the market value of the amount of ability X possessed by each age group.

$$\hat{a}_{g,t} = \sum X \hat{a}_{X,g,t} \tag{4.4}$$

Equation 4.4 estimates $\hat{a}_{g,t}$, the sum of the equilibrium index scores. The variable $\hat{a}_{g,t}$ is the *potential productivity index*, an estimate of potential job performance that takes all considered abilities into account. If one of the abilities is less demanded than the others, its impact on the potential productivity index is lower.

To illustrate the way in which the potential productivity index is constructed, let us assume an average person from the 55–65 age group works in an occupation that requires 50% numerical abilities and 50% finger dexterity. An average person from this age group scores 85% of a standard deviation below the 25–34 age group mean on numerical abilities and 142% lower on finger dexterity. This means that the person from the 55–65 age group has a potential productivity index score that is 114% of a standard deviation below the average of the 25–34 age group. If there were more demand for numerical abilities, the potential productivity of the senior employees would increase relative to younger individuals, as numerical abilities decline less than finger dexterity.

Assume a given maximum productivity index level γ_t is needed, and when $\hat{a}_{g,t} > \gamma_t$, the impact of a higher productivity potential on job performance is reduced. This situation is given in Equation 4.5, where the variable $P_{g,t}$ represents the adjusted productivity index. The indicator function $I_{<a,b>}(c)$ is 1 when c is

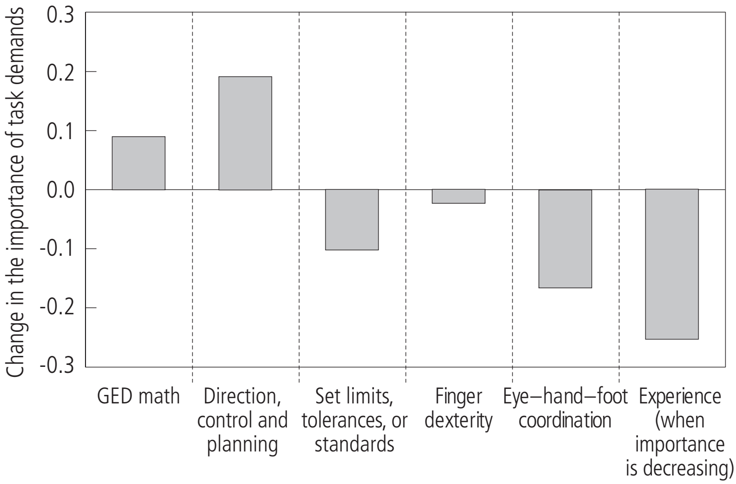

Figure 4.5. Variation in task demand, change in job task input, 1960–1998. Source: Autor *et al.* (2003); own calculations.

between a and b, and 0 otherwise. The coefficient β is positive but below 1, and the lower it is, the stronger the reduction in the adjusted productivity index.

$$P_{g,t} = I_{(-\infty,\gamma_t)}(\hat{a}_{g,t})\hat{a}_{g,t} + I_{(\gamma_t,\infty)}(\hat{a}_{g,t})[\beta(\hat{a}_{g,t} - \gamma_t) + \gamma_t] \quad (4.5)$$

The opposite can be the case if a certain minimum productivity level needs to be fulfilled, with a lower productivity potential strongly reducing performance. In Equation 4.6, when $\hat{a}_{g,t} < \lambda_t$, the adjusted productivity is more rapidly reduced when ability levels are below the minimum level. Here, ϕ is a coefficient above 1, and the higher its value, the more a productivity index below the minimum level will reduce productivity.

$$P_{g,t} = I_{(\lambda_t,\infty)}(\hat{a}_{g,t})\hat{a}_{g,t} + I_{(-\infty,\lambda_t)}(\hat{a}_{g,t})[\phi(\hat{a}_{g,t} - \lambda_t) + \lambda_t] \quad (4.6)$$

4.2.5 Results: Productivity potential by age

The estimates of the age–productivity index, taking experience into account, are shown in *Figure 4.7*. The potential productivity continues to increase until around 40 years of age, when the productivity-reducing effects of lower ability levels outweigh the productivity gains from long experience. Thereafter, a linear decline until retirement age occurs, with the productivity potential of the 55–65 age group being 0.34 standard deviations lower than that of the 25–34 age group, although it is still above the productivity potential of those aged 24 or younger. The effect of

Figure 4.6. Age potential productivity index, based on 1960 and 1998 task demand profile.
Source: Own calculations.

changing labor-market demand, with an increasing importance of verbal abilities, is very slight. The relative potential productivity of workers aged 55–65 in 1998 (the solid line) is only marginally higher than that of workers in 1960 (dashed line).

Figure 4.8 shows the effect of a decline in the importance of experience (as shown in Equation 4.4). This leads to a shift in the peak of potential productivity toward younger ages, where it reaches its maximum for the 25–34 age group and

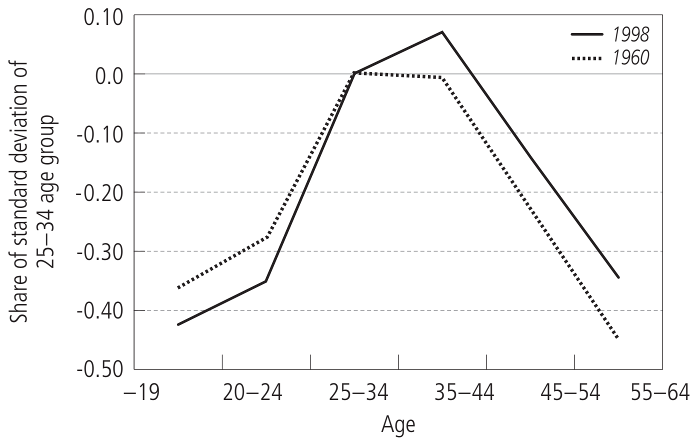

Figure 4.7. Age potential–productivity index, with decreasing importance of experience.
Source: Own calculations.

Figure 4.8. Age potential–productivity index, given no impact of experience. Source: Own calculations.

declines thereafter. The potential productivity for those in the 55–65 age group is 0.44 standard deviations lower than for the 25–34 age group.

Figure 4.9 shows the situation where experience does not influence potential productivity. The highest productivity is then found for the 20–24 age group. Thereafter, it falls, and the oldest age group 55–65 has a productivity of 0.61 standard deviations below that of the 25–34 age group. If experience raises productivity for a period that is positive but shorter than our 10-year estimate, the productivity profile would peak somewhere in between the two scenarios presented in *Figure 4.9*. The scenario where experience does matter is, however, not likely to be realistic, as it plays a role in job performance in almost any profession.

Figure 4.10 shows the impact of a maximum index threshold, based on Equation 4.5. When the productivity index is higher than the threshold, we observe only a very moderate productivity-increasing effect, as shown by the adjusted productivity index (dashed line). This could apply to simple light work, where only a minimum cognitive and noncognitive ability level are needed, with abilities above this threshold only very moderately improving productivity. Such a threshold would decrease age differences in productivity and could even lead to a flat productivity profile.

Figure 4.11 displays the case of a minimum-productivity-index threshold, that is based on Equation 4.6. When the productivity index is below the minimum threshold, there is a stronger decrease in productivity. An example of a profession with such a threshold could be computer engineering, where a too-low productivity potential may have a strong negative effect on job performance. We observe that such a threshold would increase age differences in productivity.

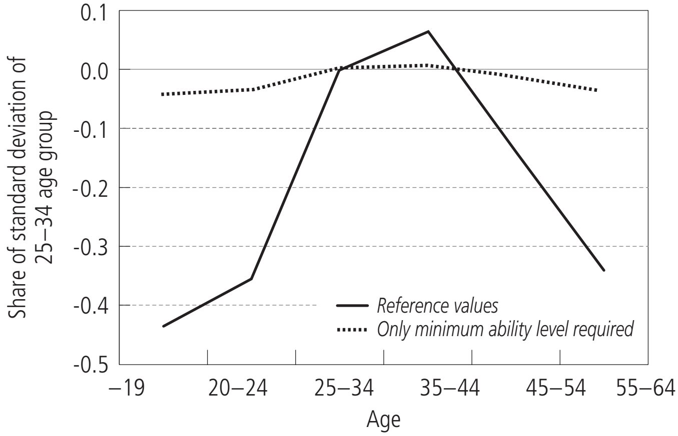

Figure 4.9. Adjusted age potential–productivity index, given a maximum ability threshold level, where higher values only very moderately increase productivity. Based on Equation 4.5, with $\gamma = -0.5$ and $\beta = 0.1$. Demand structure from 1998. Source: Own calculations.

4.2.6 Discussion

Earlier studies tend to neglect the causes of age-related job performance differences and the impact of changing labor-market demands when measuring age-related differences in productivity. In the present study we estimate the productivity potential by weighing age-specific ability levels against the labor-market demand for these abilities.

Basing the estimates on the causes of productivity differences allows us to make an estimate of the impact of structural changes in the labor market. The age–productivity profile is found to vary over time in accordance with changing labor-market needs. Assuming a reasonably strong effect of experience, we estimate that productivity peaks for the 35–44 age group.[12] If the demand for experience falls, the productivity peak shifts toward younger ages. Conversely, if the minimum ability requirement should drop over time, age differences in productivity would decrease.

Our approach does contain simplifications that need to be addressed: simplifications that increase the uncertainty level of the estimates. It is impossible to take all individual job-related abilities into account, and identifying the length of experience needed to reach peak job performance levels entails particularly great uncertainty. The matching procedure is also an approximate method, and several relevant issues, such as those related to disability and health, are not taken into

[12] A productivity peak in the late thirties and early forties is in line with several previous studies, including Davies and Sparrow (1985).

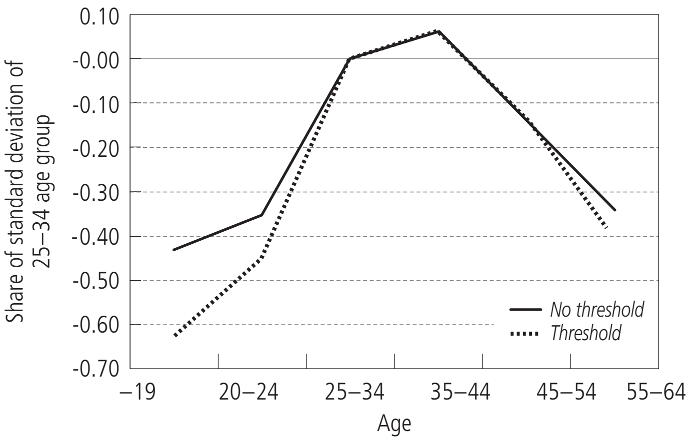

Figure 4.10. Age potential–productivity index, given that ability levels below a threshold affect productivity levels increasingly negatively. Based on Equation 4.6, with $\lambda = -0.3$ and $\phi = 1.5$. Demand structure from 1998.
Source: Own calculations.

account. Actual work potential could be influenced by other factors, such as motivation.

The estimates of the potential productivity profile reflect that job performance on average tends to decrease in the latter half of the working life, given almost any calibration of the equations. The only exception to this is that individuals who have more than a decade of experience still substantially increase their productivity for every additional year of experience, and this effect more than outweighs the decreased functioning of other job-related abilities. Given the available empirical evidence on the effect of experience on productivity, this may seem unlikely.

Age–productivity profiles, where productivity drops from mid–working life, may contrast with current late peaks in the age–earnings slopes. Age–earnings profiles can stem from seniority-based earnings schedules rather than productivity increases over the life cycle. In effect, it will be more costly for the firm to employ older individuals than younger ones. Therefore, population aging decreases firms' profits and creates incentives to abolish the use of seniority-based wage systems. Accelerating technological progress may represent an additional factor that could shift the peak of age–earnings schedules toward younger ages, as it can increase the demand for workers that learn and adjust quickly—abilities that young rather than older individuals tend to have. This may imply a change in the shape of the age–earnings schedules toward the shape of the age–productivity curve, which may lower the relative wages of senior workers.

5

Projections of the Effects of Education Reforms on Norwegian Public Pensions

In this chapter we use a microsimulation model to project the impact on the Norwegian public pension system, up to the year 2100, of a reform that lowers the school-leaving age. The assumptions we make concerning the effects of a shift in the timing and duration of schooling on human capital and fertility and our estimates for the age–productivity curve are, to a large extent, based on the findings from Chapters 2, 3, and 4.

5.1 MOSART

To project the effects of education reforms on the Norwegian public pension system, we apply MOSART, a large-scale dynamic microsimulation model that bases its projections on a representative cross-sectional sample of the Norwegian population. MOSART includes detailed information for every individual in the sample, and it simulates each person's life course. For each passing year, individuals are exposed to risks (transition probabilities) of experiencing a set of events including migration, deaths, births, marriages, divorces, educational activities, retirement, and labor-force participation. Whether an individual experiences an event will depend on his/her personal characteristics. Transition probabilities are based on empirical observations from recent periods.

MOSART takes into account a number of characteristics affecting an individual's status as a contributor to or receiver of public pensions. These characteristics include education, labor-market characteristics, age, marital status, number of children, and a range of other variables. Individual pension rights are based on relevant information, including the number of years worked, age–earnings profile, health, and household status.

Pension payments are financed through a share of the working population's earnings, referred to as the *contribution rate*. Public pension benefits are calculated from labor-market earnings and other characteristics included in the simulation. As aging takes place, a larger share of the population will be entitled to a pension, and the average pension eligibility will increase. The fact that pension benefit levels cannot be adjusted will increase pension expenditure and raise the contribution rate.

The model is designed to give precise estimates of long-term developments in the public pension system in Norway. It is therefore well suited to evaluating specific research questions of the kind we address here, that is, changes in the length of the working life as a result of education reforms. The model uses microlevel units (single individuals and households) as its basic units of analysis, which allows predictions to be made with a high degree of detail. As the simulation is based on individuals rather than aggregated entities, it gives exact projections for each individual's pension status according to the laws and regulations of the Norwegian public pension system (national insurance system). An overview of the model is provided here. A more technical description and an explanation of the model's assumptions can be found in the Appendix.

Making a model more focused, and thereby concentrating on a more limited set of research questions, can provide more detailed insight than an analysis of broader economic parameters. Models that attempt to predict the functioning of a whole economy need to rely on a large number of assumptions and simplifications. This increases the risk of errors at startup, either because the model is wrongly calibrated, or the behavioral functions are falsely specified, or the economic interdependencies are incorrectly postulated.

A microbased model such as MOSART can simulate behavioral shifts and individual-level changes in characteristics and entitlements in a way that would be difficult to achieve with a macrobased model. Micromodel approaches can, with a very high degree of accuracy and detail, capture changes in, for example, productivity levels, labor-force participation rates, and fertility outcomes at the individual level.

On the other hand, our microbased approach means that we cannot take certain macroeconomic phenomena into account. As MOSART is not a general equilibrium model, we cannot, for example, model the effect of changes in the capital stock and real business cycles and their effects on wage levels. Such effects, however, may be of secondary importance for our specific research question. Wage variations will, because of the risk-sharing nature of the Norwegian pension system, be shared by pensioners and income receivers and will not have any first-order effects on many of the most important outcome variables in which we are primarily interested, such as the contribution rate.

The trade-off over time between the gains of a longer working-life, higher fertility, and the costs of lower productivity can be estimated with MOSART. The model provides sufficient demographic detail to reproduce 1) the effects of variation in the timing and outcome of fertility and 2) changes to individual human capital and labor-market behavior resulting from a younger school graduation age.

The choice of Norway as our country of investigation has been made for several reasons. Norway has a relatively generous pay-as-you-go public pension system with high pensions and an extensive coverage of the population. Norway also

Table 5.1. Assumptions of the MOSART projections

Net immigration per year	13,000 persons
Life expectancy at birth	Men 76.3 years, increasing to 84.2 years in 2050, and increasingly linearly thereafter
	Women 81.6 years, increasing to 88.1 years in 2050, and increasingly linearly thereafter
Total fertility rate	1.75 increasing to 1.8 by 2005, and constant thereafter
Average number of years as pupil or student after nine years of primary school	Men 6.6 years Women 8.2 years
Average number of years as disability pensioner	Men 5.6 years Women 7.0 years
Average number of years in the labor force	Men 41.7 years Women 38.2 years
Average labor market earnings	Men 239,000 NOK Women 145,000 NOK
Basic pension unit	50,603 NOK

has a relatively high life expectancy (at birth): 76.3 years for men and 81.6 years for women, which implies that individuals spend a long time as pension receivers (Statistics Norway, 2003a). These facts make demographic aging a substantial challenge to the Norwegian public pension system.

5.1.1 Assumptions

This model is based on a number of assumptions regarding retirement laws, net immigration, fertility, mortality, education, and the skill composition of the labor force. For example, new births and immigrants are added to the population every year, and those who die are removed. Some of the most important of these variables are summarized in *Table 5.1*, and a more detailed description is found in the Appendix.

The demographic variables, including immigration, fertility, and mortality estimates, are to a large extent based on the "medium" scenario from Statistics Norway's population forecasting model (NOS, 2002). The formal retirement age, as well as income and the size of the basic pension unit, come from the current pension laws, while educational transition rates come from Norwegian administrative register data.

The estimates for the pension benefits (which the contribution rate finances) include major pension types covered by the national insurance scheme, which comprises early-retirement schemes, old-age pension systems, widowhood pensions, and disability pensions.

In our projections, expenditure on public education is assumed to remain constant and not to decrease, despite the reduction in the number of years of schooling. This assumption is made for several reasons. To keep the school quality output constant, the intensity of learning per school year may need to be increased, and a greater learning intensity can require more resource use per school year. Moreover, the proposal to compress schooling is more likely to be ratified in a political setting where the employment of education workers is guaranteed (i.e., where no reductions in schooling resources were foreseen).

Childbearing is assumed to influence parental labor supply in accordance with empirical observations of labor-market behavior and Norwegian laws (a couple in Norway is allowed net parental leave of at least 42 weeks). In the simulation model, childbearing will particularly affect the participation of the mother in the labor force, which depends on the age of the youngest child and the total number of children she has.

5.1.2 Transition probabilities

The transition probabilities are shown in *Table 5.2*, which is based on the level and distribution of demographic events. For example, the level and distribution of mortality is determined by sex, age, marital status, educational attainment, and disability status.

5.1.3 The effects of educational reforms on the pension system

Figure 5.1 shows how an individual's life course is simulated in MOSART. The age at school entry is represented by the variable u; s is the school-leaving age; q the age of retirement; and T the age at death. The schooling period is $s - u$; the working life is $q - s$; and retirement is $T - q$.

If a person enters the labor market at a younger age because the graduation age is lowered, then s would decrease and the working life $q - s$ would be extended. This could increase the lifetime income and the amount of taxes that are paid. Extending the working life could, however, also raise the eligibility for pension benefits, as a longer working life can increase pension entitlements. The use of the simulation model MOSART allows the net impact of a longer working life to be estimated by taking into account pension-related effects, such as variations in pension eligibility and lifetime income.

In simulations where the education reform is considered, the first individuals subject to the reform are those born in 1994 who will leave secondary school in 2011. This birth cohort, and all subsequent ones, finishes school two years earlier

Table 5.2. Explanation of estimation periods and covariates for each event

Event	Estimation methods and periods	Covariates
Migration	Based on observations 1990–2001	Sex and age
Mortality	Based on observations 1970–2000	Sex, age, marital status, educational attainment, and disability pension
Fertility	Based on observations 1980–2000	Mother's age, number of children, and age of youngest child
Household status (nuptiality/ divorce)	Observed 1989 rates	Woman's age, children, and marital status
Educational activities	Observed 1999 rates, distribution from 2001	Sex, age and educational activities, and attainment
Entry into disability pension	Logit function 1986–1989, distribution from 2001	Sex, age, marital status, educational attainment, pension status, and labor-force participation
Other transitions in pension status	Observed rates 1986–1989, distribution from 2001	Sex, age, pension status, educational attainment, labor-force participation, widow/widowerhood
Labor-force participation	Logit function, etc., 1985–1988, 1991, distribution from 2001	Sex, age, children, marital status, educational activities and attainment, pension status, and previous year's labor-force participation

than happened previously: one year because of the lower school-entry age and a second year because of the shorter length of primary and secondary education.

If the school reform, by changing the timing and duration of education, influences the amount of learning, this could have consequences for wage and pension levels. The studies presented in Chapter 2 suggest that human capital is unaffected by a compression of schooling, while the younger entry age may imply a 1% lower productivity level.[1] A lower productivity level could, as the pensions are indexed to wages, decrease both income and pensions. Norwegian public pension benefits depend on the current wages of the working population, as the laws regulating pension benefits under the national insurance scheme aim to raise/lower pensions at the same rate as the wage level. This means that marginal variations in productivity levels are unlikely to cause any substantial effects on the contribution rate (the share of the income that workers pay to finance pension benefits).

[1]This finding was based on the female population, and we assume that a similar effect is also valid for the male population.

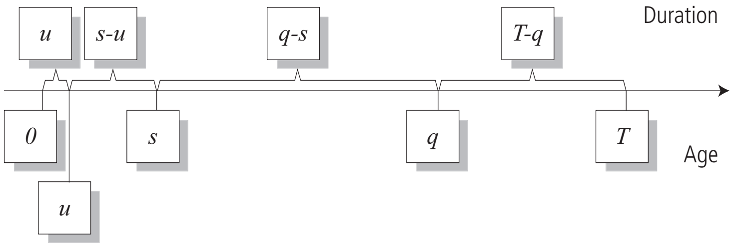

Figure 5.1. Stylized diagram of an individual's life course in the MOSART model. Variable description: u = age at entering school, s = school-leaving age, q = retirement age, T = age at death.

The earlier graduation age of the reform cohort is assumed to cause a parallel shift in the childbearing age or age at labor-market entry (see Sections 2.1 and 3.2 for a discussion of this issue). The spacing of events in adulthood is taken to be of a rigid character, with a shift in the school-leaving age leading to a parallel shift in the timing of subsequent events.

Whether a lower school-leaving age increases childbearing numbers is uncertain. Our study in Chapter 3 does not identify any higher fertility outcome for those who graduate at a younger age. However, our study is based on within-class evidence of individuals with the same social age. A school reform that reduces the school-leaving age would affect the social age of those affected by the reform, as the whole class would graduate at a younger age—and this could have the effect of raising fertility levels.

We base our projections on two fertility scenarios, one where only the timing of fertility changes and one where the outcome of fertility also changes. In the scenarios where the fertility outcome is assumed to be affected, leaving school two years earlier leads to a 6% increase in fertility outcome. This is based on estimates by Kohler *et al.* (2001), who analyze the fertility patterns of monozygotic twins. This research approach allows a wide range of genetic influences on both educational and fertility outcomes to be held constant. For every earlier year of entering parenthood, fertility outcome levels are found to increase by 3%.

The retirement reforms discussed are within the internationally observed limits. Countries such as Iceland or Japan do follow retirement patterns, having a retirement age that is roughly five years later than that of Norway (Blöndahl and Scarpetta, 1998).

5.1.4 Names of variables

Where monetary outcomes are used, we use the values from the year 2001.

Contribution Rate = The Norwegian pension system is essentially a pay-as-you-go system, with taxes on the workforce funding current pensions. The contribution rate—the part of the worker's income that is used to pay for the pensions—is calculated as:

$$\text{Contribution rate} = \frac{\sum \text{Pension benefits}}{\sum \text{Labor-market earnings} + 0.5^{*} \sum \text{Pension benefits}}$$

The pensioners pay lower taxes on their pension benefits because of special tax rules that aim to compensate for lower income, old age, and health problems (see Arneberg and Gravningsmyhr, 1994).

Size of labor force = Population according to age multiplied by age-specific, labor-force participation rates.

Person–years = The number of full person–years worked in the economy per year. A full person–year is counted in Norway as 1,687.5 working hours.

Pensioners = Number of old-age pensioners.

Pension = Average pension benefit for a pensioner. The pension benefit depends on the individual's work history, marital status, and widowhood status.

Population size = Number of individuals in the country.

Total income (in billions) = Sum of the average income for 16–74 year olds. This measurement is sensitive to how productive the cohorts affected by the education reform are.

5.1.5 Description of scenarios

A set of scenarios has been selected to estimate the effects of an education reform and later retirement age on variables related to the public pension system in Norway. The scenarios vary in their assumptions regarding the reform's effects on fertility, human capital levels, and age–productivity profiles. The outcome variables that we investigate include the age, structure, and size of the population. We also look at the effects on the workforce, pensions, and income. Particular emphasis is placed on understanding the extent to which the education reform affects the balance between the working and the retired share of the population, and the impact this has on the contribution rate.

A brief description of the scenarios is given in *Table 5.3*, and a more detailed description follows. S1 refers to the benchmark case, while S2–S4 consider the impact of the education reform on the basis of different assumptions regarding fertility and productivity levels. Scenarios S5–S7 apply to the case where the retirement age increases and labor supply and productivity vary, and S8–S10 consider the combined effects of the education reform and a later retirement age.

Table 5.3. Scenario description

Scenario (S)	Education reform	Younger workers' productivity level	Fertility level	Retirement reform	Older workers' labor supply	Older workers' productivity
S1	No	Not affected	Not affected	No	Not affected	Not affected
S2	Yes, 2 years	Not affected	Not affected	No	Not affected	Not affected
S3	Yes, 2 years	Not affected	Increases	No	Not affected	Not affected
S4	Yes, 2 years	Decreases	Not affected	No	Not affected	Not affected
S5	No	Not affected	Not affected	Yes, 2 years	Not affected	Not affected
S6	No	Not affected	Not affected	Yes, 2 years	Increases	Not affected
S7	No	Not affected	Not affected	Yes, 2 years	Not affected	Decreases
S8	Yes, 2 years	Not affected	Not affected	Yes, 2 years	Not affected	Not affected
S9	Yes, 2 years	Not affected	Increases	Yes, 2 years	Not affected	Not affected
S10	Yes, 3 years	Not affected	Not affected	Yes, 5 years	Not affected	Not affected

Scenario 1: Benchmark scenario—acts as the reference case. It shows the situation where the school-leaving and retirement ages remain constant and no reform is introduced. This scenario is used to compare the effects of an extended working life with the situation where no reforms take place.

Scenario 2: Educational reform, fertility stable—the school-leaving age is lowered by two years in an education reform that lowers the school-entry age by one year and compresses the duration of primary and secondary schooling by another year. The earlier school-leaving age leads to a parallel decrease in labor-market entry and childbearing ages (see Chapters 2 and 3 for a discussion of these issues). There are no effects on the cohort fertility level. The school reform expands the working life and consequently increases the size of the labor force.

Scenario 3: Educational reform, fertility increase—identical to Scenario 2, except that fertility levels are assumed to rise. In accordance with the findings in Kohler *et al.* (2001), the school reform leads to a 6% increase in completed fertility levels. The higher fertility resulting from the education reform will increase the size of the population and lead to a somewhat younger age structure. This will have a cumulative effect on fertility in the long run, as the larger cohorts will also have higher fertility. In effect, the difference between scenarios with and without a fertility effect on the population's size and structure increases over time.

Scenario 4: Educational reform, negative productivity effect—if the earlier education reform adversely affected human capital formation, then a lower productivity level would be expected to be found among those affected by the reform. The lower school-entry age may slightly decrease productivity levels. Assuming that the adverse effect on human capital of lowering the school-entry age from 7 to 6 years (which is the case in the study presented in Section 2.3) is the same as lowering it from 6 to 5 years, we find that wage levels are reduced by 1%. The compression of schooling from 13 to 12 years, on the other hand, in accordance with findings from Section 2.4, does not decrease human capital accumulation.

Scenario 5: Retirement reform—considers the effects of a two-year-later exit from the workforce. The retirement age increases from 2010. Both the risk of entering old-age-pension status and the transition risk to disability pension (which is the highest pensioner status for those below the minimum old-age retirement age) is shifted to two years later. The later entry into retirement status decreases the number of pensioners, increases the number of taxpayers, and consequently lowers the contribution rate.

Scenario 6: Retirement reform, labor supply increases—predicts that the later retirement age will be accompanied by higher labor-force participation rates. The assumptions for this scenario are similar to those of Scenario 5, except that there is an increase among older age groups in the amount of time worked. It is assumed that all individuals aged 45 and above will work more and that they will behave in the labor market as if they were two years younger.

Scenario 7: Retirement reform, older workers less productive—assumes that the relative labor-market performance of older individuals substantially drops and that their wages are reduced as a result (as discussed in Chapter 4). This is reflected by the income characteristics of those above 45 years, whose wages shift as if they were eight years older. This means that the current relatively late age at which wages peak can shift toward earlier ages, resulting in the income levels of senior workers dropping markedly.

Scenario 8: Educational and retirement reform—shows the combined effect of extending the working life at both ends. Individuals enter the labor market two years earlier (because of the education reform) and leave it two years later (because of the increase in the retirement age).

Scenario 9: Educational and retirement reform, fertility increases—identical to Scenario 8, except that there is an increase in fertility levels for the cohorts affected by the education reform.

Scenario 10: Education reform (3 years) and retirement 5 years later—to illustrate the potential capacity of extensions to the working life, we include a scenario with a five-year increase in the age of retirement and an education reform that leads to a school-leaving age that is three years lower. Fertility, labor supply, and productivity levels are assumed to remain constant.

5.2 Projection Results

This section presents the forecasts up to the year 2100 of the dynamic microbased projection model, MOSART. Findings for population characteristics, workers, and the number of pensioners and workers are presented first. Thereafter, forecasts for

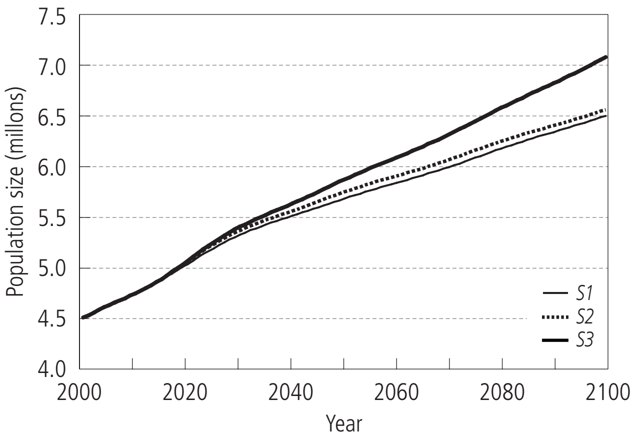

Figure 5.2. Population size of Norway from 2000–2100.
Source: Own calculations.

pension-related variables are shown, including the average pension size and how the contribution rate develops.

5.2.1 Population size

The size of the population is affected by the education reform if the timing of fertility or the fertility outcome changes. Even relatively small changes in fertility levels have large effects on future population sizes. It is estimated that the population will increase substantially by the year 2100, as demonstrated in *Figure 5.2*, although fertility lies below reproductive levels. This is a result of increases in life expectancy and positive net immigration.

If the education reform is implemented, the population will increase to 6,556,000 (S2), while, without the education reform, the population will rise to a level of 6,498,000 in 2100 (S1). Most of the increase in the population size due to the school reform takes place until 2030, as the impact of a younger childbearing age on fertility outcome is strongest for this period (as shown in *Figure 5.3*).

If the education reform increases fertility outcome levels (S3), the population size will increase to 7,072,000. This means that the school reform will increase the size of the population by either 58,000 or 574,000 individuals by 2100, depending on whether the younger school-leaving age affects the timing of fertility or the fertility outcome as well.

These projections are relatively similar to other population projections, such as those of the United Nations (2005). In the UN projections the population will increase to 5,435,000 individuals by 2050 (medium estimate), which is slightly less

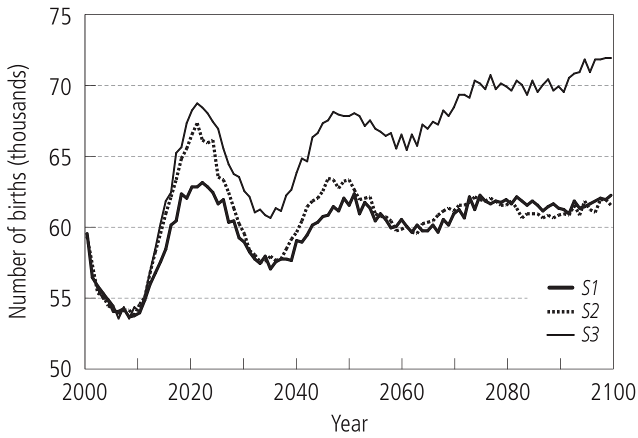

Figure 5.3. Number of births in Norway from 2000–2100.
Source: Own calculations.

than S1 in *Figure 5.2*. The reason why the UN projects a slightly lower population size in Norway is that it assumes lower net immigration and a shorter life expectancy, albeit a slightly higher fertility level.

5.2.2 Age composition of the population

The school reform can affect the size of the population and also the age composition of the population. In *Figure 5.3* the number of births throughout the projected period can be observed. The school reform (S2) leads to a temporary increase in the number of births from 2011 (when those affected by the reform start to graduate from school) relative to the reference case (S1). A few decades after the education reform is implemented, the timing of childbearing has stabilized at younger ages, which means that fertility levels are similar in the two scenarios S1 and S2. However, if fertility levels increase as an effect of the school reform (S3) this would, by 2100, lead to 15.6% more births than in the reference case (S1).

In *Figure 5.4* the age structure of the population is shown. The population is divided into five age categories, 0–19, 20–29, 30–54, 55–74, and 75–120. These age categories would roughly equal the potential number of pre–labor market individuals, young workers, prime-age workers, senior workers, and retirees.

In the reference scenario there is a sharp increase in the number of individuals in the two oldest age categories (S1). The number of prime-age workers (30–54) increases slightly throughout the period, while the two youngest age groups remain relatively constant in size. When the education reform is introduced (S2), this increases the size of the different age groups, starting with the younger cohorts.

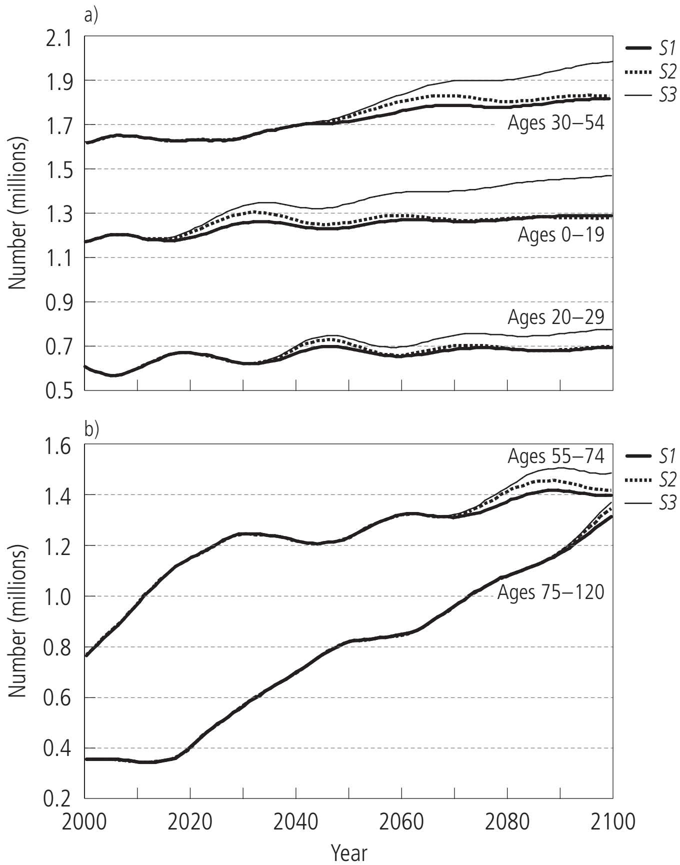

Figure 5.4. Age structure of the population of Norway from 2000–2100.
Source: Own calculations.

The increase in the size of the different age groups is, to a large extent, temporary and is weakened in the years following the implementation of the school reform.

If the education reform raises fertility outcome levels (S3), the size of the different population groups grows cumulatively and the population size increases more over time relative to the reference scenario (S1). Furthermore, the increase in the size of the population takes place first for younger age groups, while the size of the older age groups is affected only toward the end of the simulated period.

5.2.3 Workforce size

The evolution in the size of the workforce is shown in *Figure 5.5*. If no school reform is implemented, the reference scenario predicts that the labor force will increase to a level of 2,805,000 workers (S1) by the year 2100. Implementation of

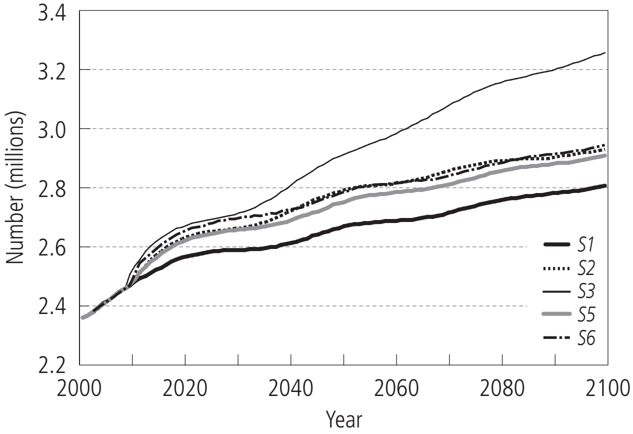

Figure 5.5. Size of the workforce in Norway, 2000–2100.
Source: Own calculations.

the education reform would increase the number of workers to 2,929,000 (S2) in 2100. If fertility levels increase as a result of the education reform (S3), then the workforce size will increase to a level of 3,257,000 individuals in 2100.

This is a slightly higher number than would be caused by retiring two years later, which leads to 2,907,000 workers by 2100 (S5). However, should the retirement reform be accompanied by higher rates of labor supply among older workers (S6), the effect would be similar to that of a younger labor-market entry, and the number of workers would be 2,941,000 in 2100.

5.2.4 Age composition of the workforce

The number of workers in the 16–29 age group will remain relatively constant in the reference scenario and will reach 680,000 by 2100 (S1), as shown in *Figure 5.6*. Increasing the retirement age (S5) has only a very modest effect, as there are only a limited number of old-age pensioners in this young age group (among the few that belong to this category are mainly pensioners on disability allowance).

The education reform, however, considerably increases the number of workers aged 16–29. By 2100 the reform has increased the size of this category to 764,000, assuming constant fertility (S2). If the effect of the school reform is to increase fertility levels, then the number of workers aged 16–29 would be 849,000 by 2100 (S3).

The growth in the size of the 30–54 age group of workers is shown in *Figure 5.7*. In the benchmark case (S1) a modest increase in the number to around 1,551,119 is projected to take place by 2100. Starting earlier in the labor market (S2) and increasing the retirement age when labor supply increases (S6) have about the same

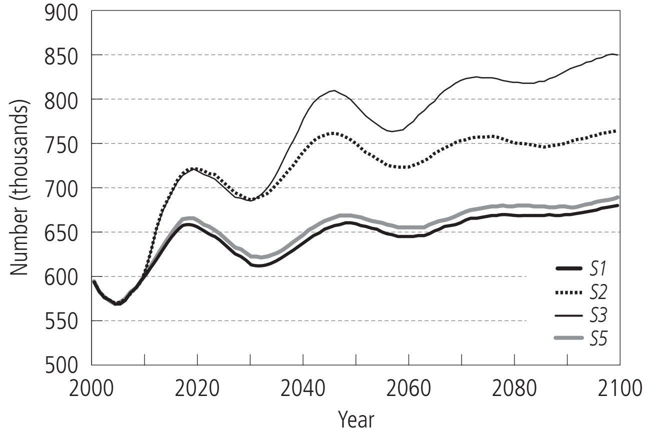

Figure 5.6. Number of workers aged 16–29 in Norway, 2000–2100.
Source: Own calculations.

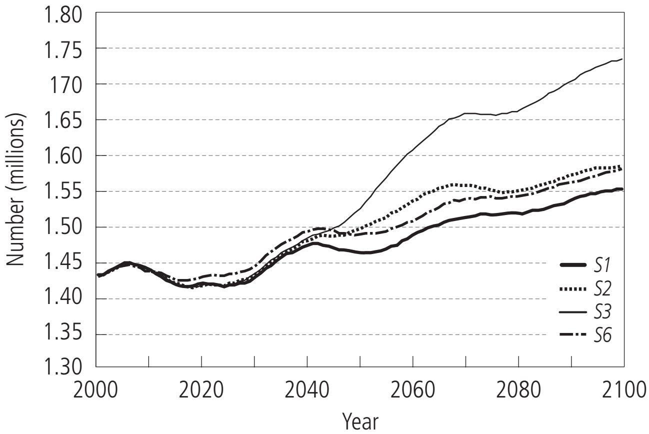

Figure 5.7. Number of workers aged 30–54 years in Norway from 2000–2100.
Source: Own calculations.

effect on the labor force, which increases to around 1,580,000 prime-age workers in 2100. If the education reform leads to an increase in fertility levels (S3), the size of this age category will increase to 1,734,000 workers by the year 2100.

The number of workers in the 55–74 age group increases through population aging, as seen in *Figure 5.8*. The reference scenario predicts that the number of workers will increase to 574,000 by 2100 (S1). The education reform has a very small effect on the number of workers in this category and results in 582,000 individuals by 2100 (S2). However, if the education reform leads to higher fertility

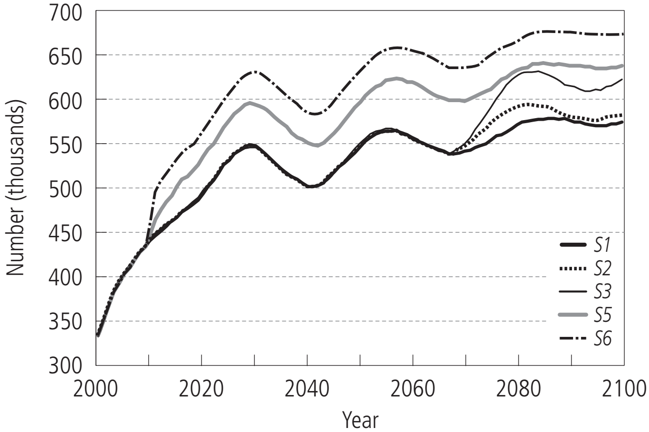

Figure 5.8. Number of workers aged 55–74 years in Norway from 2000–2100. Source: Own calculations.

levels, this would mean an increase in the size of this group to 623,000 individuals by 2100 (S3).

A later retirement age has a strong effect on the number of workers in this age category and would increase the number to 637,000 workers (S5) by 2100. If later retirement is combined with an increase in the labor-force participation rates of older workers, the number of workers in the 55–74 age group increases to 676,000 (S6).

5.2.5 Old-age pensioners

Figure 5.9 portrays the number of old-age pensioners in Norway until 2100. The reference scenario shows an increase from 619,000 pensioners in 2000 to 1,822,000 by 2100 (S1). If the education reform is introduced, the number of pensioners increases to 1,864,000 (S2) by 2100, while a stronger effect is found if fertility increases, when the number of pensioners rises to 1,949,000 (S3).

As we can see, the effect of higher fertility is relevant only from a late stage in the forecasting period, from around the year 2080. If the age of retirement is postponed by two years, the number of pensioners is reduced to 1,691,000 (S5). If retirement increases by five years and the school-leaving age drops by three years, there would be 1,453,000 old-age pensioners in 2100 (S10).

5.2.6 Average pension size

Figure 5.10a and *b* shows the developments in the average size of pensions until 2100. These figures show that there will be a massive increase in the average

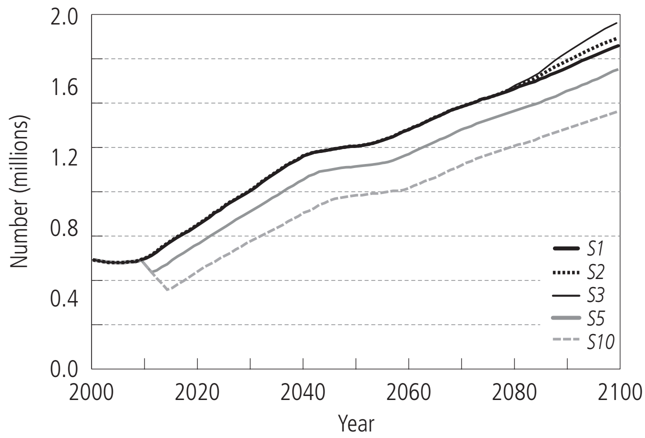

Figure 5.9. Number of pensioners in Norway from 2000–2100.
Source: Own calculations.

pension until 2030 because the pension system "matures," as younger cohorts, with their higher labor-force participation and higher wages, will become entitled to higher pensions. To highlight the differences between the different scenarios, *Figure 5.10b* shows in detail the developments from 2030 to 2100, a time period when pension benefit levels will have stabilized.

In the benchmark case the pension payments stabilize at around 140,000 NOK (S1). If the education reform is implemented, pensions will increase to 141,409 NOK (S2) because the longer working life leads to higher pension entitlements. If the reform decreases human capital and productivity levels, this will lead to a slightly lower pension level of 141,235 NOK (S4) in 2100. If the working life is extended by increasing the retirement age, then pensions will increase to a level of 141,035 NOK (S5) or to 141,293 NOK if the supply of senior workers in the labor market also increases (S6).

5.2.7 Person–years

The number of person–years worked increases in all scenarios, as shown in *Figure 5.11*. The reference scenario predicts that there will be 2,238,000 person–years in 2100 (S1). An education reform increases the number of person–years to 2,411,000 (S2) in 2100. If fertility outcome levels increase, the number of person–years increases to 2,613,000 (S3) in 2100.

If the retirement age increases by two years there will be 2,341,000 individuals by the end of the projection period (S5). If a later retirement is accompanied by higher labor-force participation on the part of older workers, the number of person–years will reach 2,371,000 (S6) in 2100.

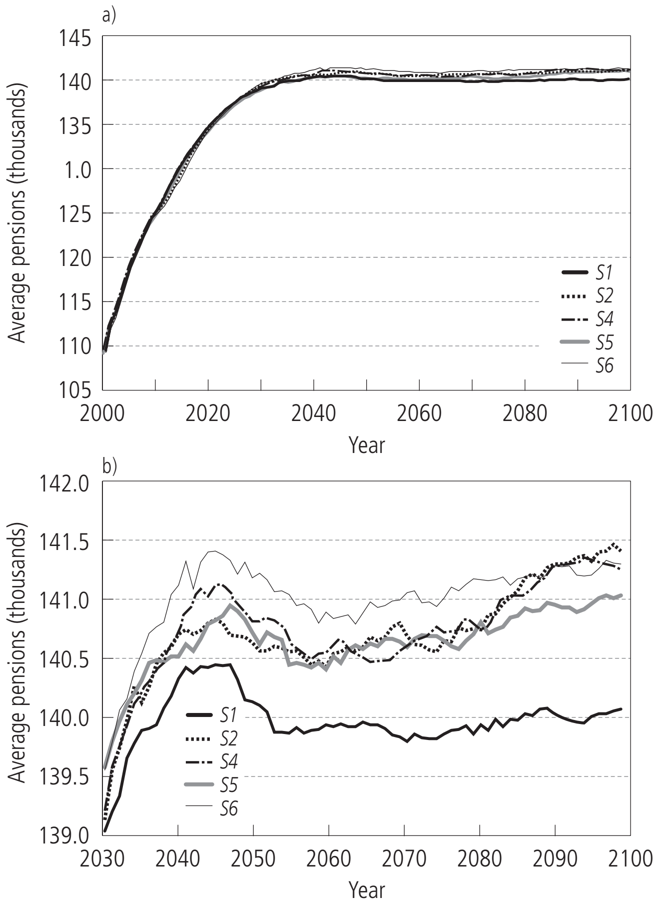

Figure 5.10. Average pensions (in NOK) in Norway from 2000–2100.
Source: Own calculations.

5.2.8 Total income

The total income in the economy increases slowly in the benchmark case to a level of 736 billion NOK (S1) in 2100 (*Figure 5.12*). The education reform increases income to a level of 793 billion NOK (S2). If the reform leads to higher fertility, this results in an increase to around 861 billion NOK per year (S3). If the productivity of the labor-market entrants decreases after an education reform, then the income will increase to only 779 billion NOK (S4).

An increase of two years in the age at retirement produces a total income value of 770 billion NOK (S5). The later retirement age will increase income to a level of 780 billion NOK (S6) if the labor supply increases.

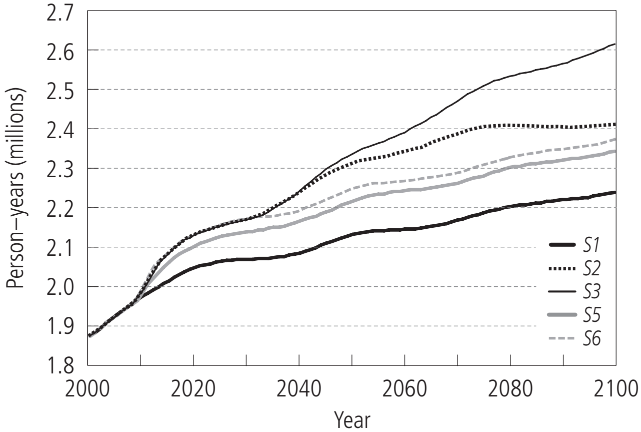

Figure 5.11. Average number of person–years worked in Norway from 2000–2100.
Source: Own calculations.

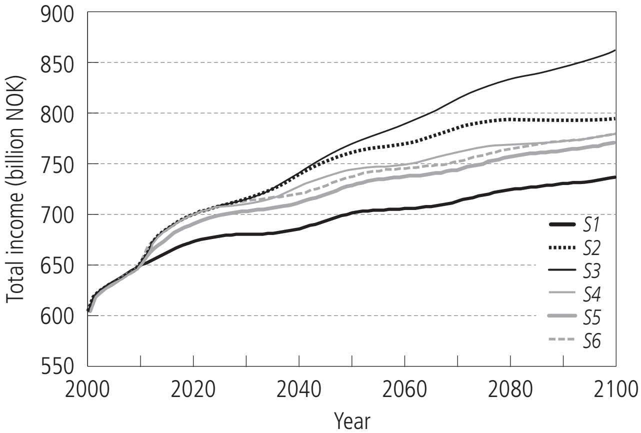

Figure 5.12. Growth of total income in Norway from 2000–2100.
Source: Own calculations.

5.2.9 Contribution rate

The development of the contribution rate up to 2100 under a range of different scenarios is shown in *Figure 5.13*. The contribution rate is projected to increase considerably as the population ages and more people enter retirement. The relatively large cohorts born in 1945–1965 increase the numbers of pensioners until around 2030. At the same time, the national insurance scheme matures, which means that those who become pensioners will have acquired more pension rights

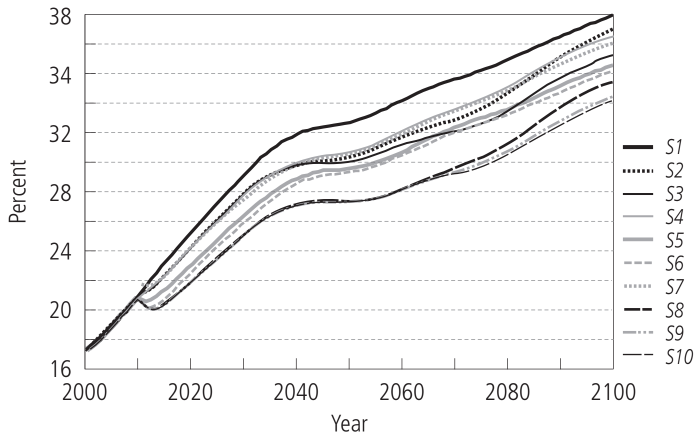

Figure 5.13. Development of the contribution rate for Norway from 2000–2100. Source: Own calculations.

and are entitled to higher pensions. This causes a sharp upward shift in the contribution rate. Continued increases in life expectancy and fertility levels that remain below replacement exacerbate increases in the contribution rate until 2100.

The contribution rate increases to 38% in the benchmark case in 2100 (S1). When an education reform is implemented, the contribution rate increases by less and reaches a level of 36.9% (S2) by 2100. However, the greatest relative impact of the school reform is found in a shorter time horizon, with, for example, in 2040, the reference scenario giving a contribution rate of 30.7% and the school reform scenario a contribution rate of 28.7%. The gap between the reference case and the education reform becomes somewhat narrower toward the end of the period, as the larger cohorts—those born in the years after 2011—retire.

Changes in workers' productivity do not have significant effects on the contribution rate, as pensions are wage-indexed and pension levels adjust to productivity shocks. When the education reform decreases productivity, the contribution rate reaches 36.6% by 2100 (S4).

Given that the school reform leads to an increase in fertility, the contribution rate is substantially lower at the end of the period and reaches a level of 35.4% (S3) in 2100. A retirement-age reform could have a stronger effect on the contribution rate than the school reform. Leaving the workforce two years later leads to a contribution rate of 34.8% (S5) in 2100 or 34.5% (S6) if the labor supply decreases.

The combined effect of increasing the retirement age by two years and bringing forward labor-market entry by two years is also analyzed (S8), and it is found to lead to a contribution rate of 33.8% in 2100. If both the education and the retirement reform are implemented and fertility levels increase, the contribution rate drops to

32.9% (S9). Delaying the retirement age by two years when the older workers are less productive leads to an increase in the contribution rate of 36.2% in 2100 (S7).

In the scenario with a five-year increase in the age of retirement and an education reform that leads to a school-leaving age that is lower by three years, the contribution rate is 32.5% in 2100, given no effects on fertility outcome (S10). This implies that if such a change took place, with the working life being extended at both ends, the contribution would increase by only half as much as that in the reference scenario from 2005 to 2100.

6
Conclusions

In Chapter 1 we argued that if individuals spent more years in the labor market, the sustainability of public pension systems in aging European economies might increase. An extended working life would increase the size of the labor force, ease the burden of a growing dependency ratio, and increase the sustainability of pay-as-you-go pension systems. One possible way of achieving this, which, to date, has not been given much research attention, would be to lower the school-leaving age. We approach this issue by analyzing the effects of an education reform that compresses the length of schooling and lowers the age at school entry, thereby lowering the school-leaving age.

Chapter 2 presented evidence to the effect that shifting the timing and duration of schooling to allow for a younger school-leaving age would be unlikely to cause substantial losses in terms of human capital levels. In Chapter 3, based on birth-month-induced variation in the school-leaving age, we concluded that a younger school-leaving age is likely to lead to an earlier start to childbearing. In Chapter 4 we discussed findings suggesting that workers are most productive at younger ages, thus emphasizing the advantages of rejuvenating the labor force by lowering the age of entry to the labor market. Chapter 5 considered the effect of a lower school-graduation age on the future of Norwegian public pensions, using a microbased projection model. In this chapter, the effects of the lower graduation age are discussed in relation to other policies that have been suggested for strengthening the public pension system.

The school-leaving age in Norway has increased substantially in recent years, as increasing shares of the population attain secondary and/or tertiary education (Statistics Norway, 2004). There are large differences in the number of years required to attain different schooling levels in different countries, and the late school-leaving ages in Norway can, at least in part, be attributed to the long periods of time required to complete different educational levels (UNESCO, 2004). A late entry to the labor market involves social costs in terms of possible adverse effects on public pensions. However, it can also involve individual costs in the form of a shortened working life, fewer years to achieve fertility plans, and a later timing of childbearing that may be suboptimal in terms of the health of mother and child.

The individual and social costs associated with a late school-leaving age raise the question as to whether similar educational standards could be achieved at a younger age. We consider the impact of a reform that lowers the age of graduation by two years, by decreasing the age of school entry from 6 to 5 years and compressing the duration of primary and secondary schooling from 13 to 12 years. The reform is likely to lower the school-leaving age and, at least over time, lower the age of entry to the labor market. According to our estimates of the effects on student performance of marginal variations in the timing and duration of schooling, the human capital effects are likely to be either nonexistent or very small.

To analyze the effects of the reform, we ran projections with MOSART, a large-scale microbased dynamic model designed to forecast the development of the Norwegian public pension system. We find that the reform can have an alleviating effect on the sustainability of the public pension system and could soften the increase in the contribution rate by 1%–2% in comparison with the case where no reform takes place. This implies that the reform could reduce the aging-induced growth in the contribution rate by one-tenth in the period from 2000 to 2100. If fertility were also to increase, the beneficial effect would be about twice as strong.

To sum up, policies that aim to lower the school-leaving age while maintaining educational quality could play a role in expanding and rejuvenating the labor force and may represent an important contribution to the sustainability of the public pension system in Norway.

Appendix

The Dynamic Microsimulation Model, MOSART, and the Norwegian Public Pension System

From the beginning of the twenty-first century, Norway, like most developed countries, has been faced with an aging population. A system for general public pension benefits, the national insurance scheme, was established in Norway in 1967. As new pensioners have been earning pension entitlements for a longer period than current pensioners, the average pension benefit from this scheme will continue to grow until 2035. These two situations—a growing percentage of older people and improved pension benefits—represent a challenge for the future financing of public expenditure. For a proper analysis of these phenomena (especially supplementary pensions, which are calculated from labor-market earnings *each* year throughout the working career), we use an approach based on microdata. This chapter presents a dynamic cross-sectional microsimulation model, MOSART, that can be used to analyze the composition and development of population size, as well as the consequences of these for education levels, labor supply, and public pension benefits. The appendix is partly based on Fredrikssen (1996), which provides a more detailed description of MOSART.

The choice of microsimulation

Orcutt (1957) was the first to suggest microsimulation modeling in social planning, with the idea of representing a socioeconomic system by a sample of decision units, for example, persons or firms. Parameters such as behavior are modeled at the micro level and then aggregated up to total quantities for the economic system, rather than the relationships between aggregated quantities being modeled directly.

In some cases it is easier to model behavior at the micro level, and it may often be inappropriate to model relationships between aggregated quantities because of the heterogeneity between micro units, nonlinearities, and complexity. One example may be a nonproportional tax system (which most tax systems probably are). In this case total taxes will depend, in a somewhat complex manner, on both income level and income distribution. A sound analysis of the effects of changes in tax rules on tax revenue, income distribution, and labor supply may thus require an approach at the micro level. A major distinction between microsimulation models is whether they are *static* or *dynamic*. Static microsimulation models are usually based on a sample of persons with detailed information that comes, for example, from income declaration forms.

The sample is aged by reweighing and indexing all income amounts in such a way that the sample can be perceived as representative of the population in, for example, the next budget year. Two of the usual advantages of static microsimulation are moderate development costs combined with a very detailed representation of the tax and benefits system. However, static microsimulation is of little help in long-term projections and analysis of aspects of the life course, such as pension schemes. In dynamic microsimulation the population is aged by drawing events based on each person's characteristics and implementing the effect of those events on that person's relevant characteristics. It is thus possible and relevant to age a person for his/her full life span and thus make long-term projections following each person over the life course. Dynamic microsimulation covers a large variety of life-cycle models; in this context the MOSART model is based on discrete time and a real sample of a cross-section of the Norwegian population.

Furthermore, all aspects of the population in one year are simulated before the model starts simulating the next year, so-called *cross-sectional* simulation. One disadvantage of (dynamic) microsimulation modeling is the development cost, as none of the major existing applications include a cross-section of persons, firms, and other institutions from a real socioeconomic system. Microsimulation models also require a large sample of decision units to achieve sufficiently small sample errors, and the subsequent computer runtimes may be unacceptable for several purposes.

The first dynamic microsimulation used in socioeconomic policy studies was the DYNASIM model (Orcutt *et al.*, 1976), fathered by the same individual who developed modern microsimulation techniques almost two decades earlier (Orcutt, 1957). At present, there are a number of other dynamic microsimulation models similar to MOSART in existence. These also focus on dynamic projections of population and socioeconomic features. They include Frankfurt (with a focus on Germany), DYNASIM (United States), CORSIM (United States), DPMS (Germany), NEDYMAS (Netherlands), and PENSIM (United Kingdom). [For reviews of the evolution of microbased modeling, see Spielauer (2002); Van Imhoff and Post (1998); and this Appendix].

Only NEDYMAS and MOSART are based on population registers, while the other models apply data from surveys or samples. In DPMS and MOSART, the demographic output is independent of nondemographic modules. MOSART is the only micromodel devoted to linking macrobased population projections and socioeconomic variables.

Moreover, Norway is an interesting country for research purposes because of the availability of centralized personal register systems, where the individual characteristics of those in the pension system are stored centrally and made available for scientific analysis. These individual records are of high quality, both in terms of data coverage and information depth. The data has been carefully examined and analyzed regarding the causal relationships between individual characteristics and the events of which the simulation makes use.

The MOSART model

MOSART is a dynamic microsimulation model using a cross-section of the Norwegian population and a comprehensive set of characteristics. The model starts with a representative sample of the population in a base year and simulates the further life course for each person in this *initial population*. The simulation is carried out by drawing if each person each year makes certain transitions from one state to another, with *transition probabilities* depending on each person's characteristics. Each of these transition probabilities will normally constitute an event and is estimated from observed transitions in a recent period. The MOSART model is based on microdata of a higher quality than data used in other dynamic cross-sectional models at the international level. It includes fewer covariates for some of the transition probabilities, and the theoretical foundation may also be weaker. The model includes fewer characteristics because of our reluctance to include in it characteristics for which genuine microdata are unavailable. The number of subjects in the MOSART model are an average, but some comparable dynamic microsimulation models also include taxes, consumption and savings, and a geographical dimension.

Events included in the simulation are migration, deaths, births, marriages, divorces, educational activities, retirement, and participation in the labor force. Public pension benefits are calculated from labor-market earnings and other characteristics included in the simulation. Newborns and new immigrants are added to the initial population each year. The result of the simulation is a *model population* comprising the life course of each individual. The MOSART model projects the Norwegian population and its characteristics for the coming decades. Before these projections can be made, however, the model user has to make some assumptions as to how the behavior and other factors underlying each event will develop in the future.

The projections can be used in several ways; one interpretation is that the baseline alternative shows the development ahead if "everything continues as it is today." This interpretation assumes that the projections are a prediction of the development ahead, given the underlying assumptions. Policies or other circumstances leading to changes in the underlying assumptions can be analyzed by comparing two or more projections. The MOSART model can also analyze income distribution in the context of the life course. The initial population, the "accounting for" of people, and the transition probabilities show the potential of the MOSART model as a relevant tool for social planning. Several personal characteristics are either stable or easy to predict, for example, gender, age, educational attainment for adults, and pension entitlements that have already been earned. The initial population will therefore contain a great deal of information about the Norwegian population for several decades ahead. The modeling of behavior at the micro level constitutes a population-related accounting system; for example, the number of cohabiting men will automatically equal the number of cohabiting women. A microsimulation model is also a tool for presenting and synthesizing the knowledge contained by a set of transition probabilities about a socioeconomic system.

Initial Population

This version of the MOSART model starts with a 1% random sample of the population in Norway comprising about 40,000 persons. Data include actual information on marriage, birth histories, educational level, and activities, pension status, and pension entitlements under the national insurance scheme. The information is gathered from registers run by the directorate of taxes, the national insurance administration, and Statistics Norway. The sample is stratified according to gender and age, and the sample includes the spouses of all married persons. Ten disjunct 1% samples are available as initial populations for the MOSART model.

Transition Probabilities

A dynamic microsimulation model with discrete time is based on the assumption that each person in each period has certain probabilities of experiencing transitions from one state to another. Each of these transition probabilities will normally constitute an event and will depend on each person's characteristics. The model is then simulated with stochastic drawing, often called the Monte Carlo technique. Usually this means the computer generating a so-called random number with uniform distribution (0.1), and if this random number is smaller than the transition probability, the transition occurs.

The drawing method in the MOSART model is similar, except that the uncertainty generated by stochastic drawing is lower. If the simulation comprises a sufficient number of persons or replications, the model will describe the population or groups of the population and confer the central limit theorem.

The transition probabilities in the MOSART model are estimated mainly by using event-history analysis on actual events in recent periods. Important transition probabilities in the MOSART model are summarized in *Table 5.2* and include covariates and estimation periods and methods. Andreassen *et al.* (1993) and Fredrikssen and Spurkland (1993) give a more detailed description of how the different transition probabilities are estimated.

Underlying Assumptions

Before any projections can be made, the user of the model must make some *underlying assumptions* as to how the transition probabilities will develop in the future. The projections may then be interpreted as a prediction of the expected development, given the underlying assumption. A baseline alternative will typically allow all probabilities to remain at the same level as in the latest year with available data. This may also be interpreted as the expected population changes if "everything continues as it is now." The baseline alternative is often used as a reference track when alternative projections with other underlying assumptions are made. The baseline alternative in this study is summarized in *Table 5.1*. The number of events in the simulation of historical data equals the actual numbers each year for each subject in *Table 5.1*; this is accomplished by adjusting the transition probabilities from *Table 5.2*. The simulated number of events with the drawing method in the MOSART model is the sum of the transition probabilities.

Technical Notes

The MOSART model simulates the whole population each year before starting on the next year. This year-by-year simulation makes it is easy to maintain the relationships between persons in the model population, for example, between spouses. The MOSART model is based on discrete time using the calendar year as the time unit. Our approach is to simulate one event at a time in a fixed order, often called *recursive simulation*. In the example above, this gives 8 binomial logit functions, which is easy to handle. The 8 transitions can also be represented by 8 tables where only the interesting covariates are represented. Simulating one event at a time combined with the year-by-year simulation also makes it easier to adjust the projections against any exogenous constraint on the number of events. If the probabilities are properly conditioned on the results of events drawn previously for the same year, as is the intention, then recursive simulation will, in principle, not affect the result using the identities:

$$P(A, B|X) = P(A|X) \cdot P(B|A, X) = P(B|X) \cdot P(A|B, X) \qquad \text{(A.1)}$$

In Equation A.1, A and B describe changes in two arbitrary characteristics during the calendar year, and X is a vector of personal characteristics at the beginning of the calendar year. The choice between discrete/continuous time and simultaneous/recursive simulation is therefore more important than the equation suggests. When we exclude some covariates or use simple mathematical functions, these are intended simplifications. Moreover, the problems of estimating the proper parameters will also be present in models with discrete time and simultaneous probabilities and in models with continuous time. The order of the events reflects several considerations. For practical reasons, demographic events are simulated to first define each year's population before the other events are simulated. Furthermore, we have considered that, provisionally, some of the transition probabilities are estimated unconditionally. And last, the order reflects our beliefs about the causality between the events, and this eases the interpretation of the conditional probabilities. For example, we find it more natural to say that a person left the labor force because he/she has become a disability pensioner than vice versa. The simulation model is written in the object-oriented language Simula [see Kirkerud (1989) for a presentation of Simula]. Fredrikssen (1995) gives a technical documentation of the model, except for some improvements on the production of the model population. The MOSART model is mainly used in analyses by Statistics Norway and by the Norwegian government in white papers and so forth. Development and maintenance of the model is financed partly through general funding from Statistics Norway and partly through special projects financed by the Norwegian Research Council and the Norwegian government.

Demographic events and population size

The modeling of demographic events and the underlying demographic assumptions of the MOSART model are to a large degree based on the official population projections of Statistics Norway. [See Texmon (1992) and Statistics Norway (1994) for details.]

Migration

One problem relates to the number of Norwegians living abroad and pension entitlements earned in other countries, as MOSART uses net rather than gross migration estimates.

Migration is currently included in the MOSART model only because it renders the development in population size more accurate. Two major simplifications are made. First, the MOSART model includes only net immigration rather than gross immigration and emigration. This means that an exogenous number of "net immigrants" by gender and age are added to the model population each year. Second, net immigrants are mainly assigned the same characteristics as the average Norwegian population. The only exception is educational attainment, which is set to "unknown" for new immigrants, as in the educational registers. This also reflects the actual distribution of educational attainment among "net immigrants." Unknown educational attainment implies a higher risk of disability and lower labor-force participation rates than arise in the average population. In age groups with positive net

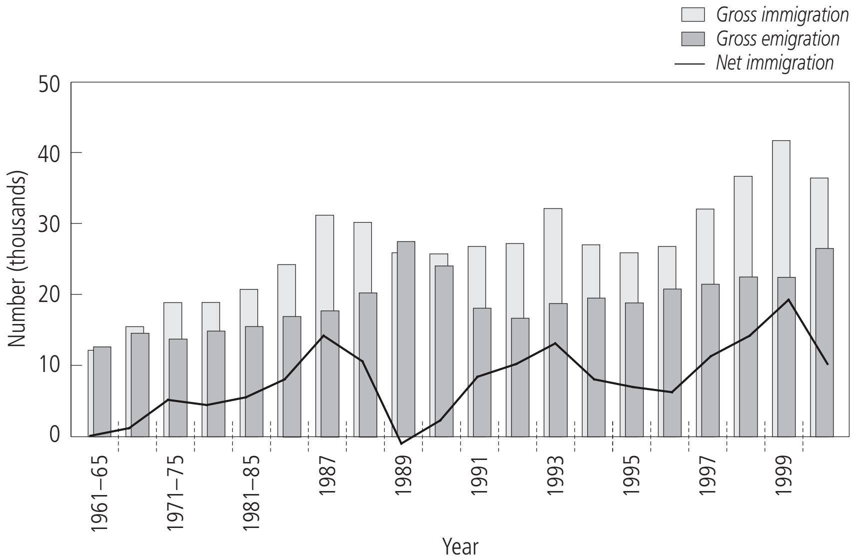

Figure A.1. Migration patterns in Norway, 1961–2000. Five-year averages up to 1985; annual averages thereafter.
Source: Statistics Norway.

emigration, a given number of random persons are removed corresponding to the exogenous level of net immigration.

The evolution of inward and outward migratory patterns over the past 45 years for Norway is reported in *Figure A.1*. An important component of the tendency toward larger positive net immigration are the immigrants from third-world countries in the seventies, and later, refugees and people taking part in family reunifications. The abrupt changes in net immigration since 1985 are caused in part by large fluctuations in unemployment between Norway and Sweden.

Mortality

Mortality depends on gender and age; the baseline mortality rates are adjusted proportionally corresponding to life expectancy at birth each year. The development of life expectancy in Norway from 1960 to 2000 is given in *Figure A.2*. Furthermore, mortality is higher in the simulation for single and disabled people and those with a low level of education. The covariates are roughly estimated from various sources of mortality statistics; they are included because these differences are of significance for pension expenditure. Baseline mortality is simultaneously adjusted to ensure that these covariates do not influence the average mortality by gender and age. If a married person dies, the surviving spouse is made a widow/widower.

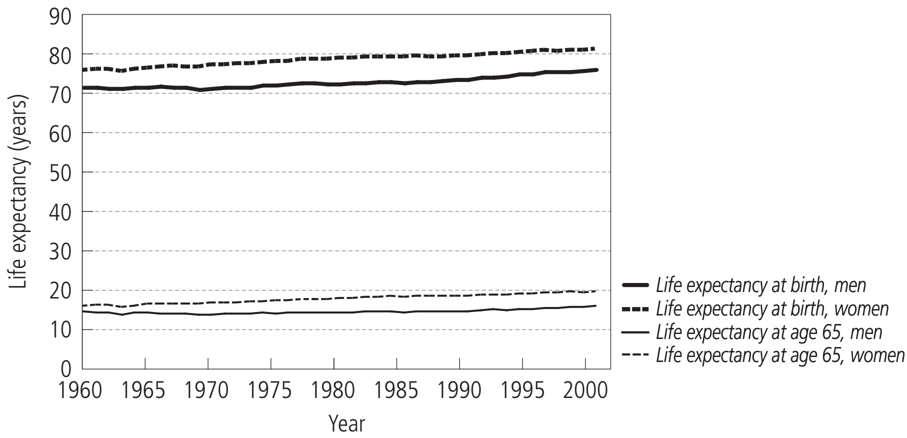

Figure A.2. Norwegian life expectancy for men and women, 1960–2000. Source: Statistics Norway.

Brunborg (1992) discusses mortality in Norway for the last 200 years. From 1890 to 1950, life expectancy increased by 22 years or at an annual growth rate of 0.4 years. Life expectancy has increased less since 1950, especially for men in the first decades after World War II. To date, this increase has mainly been the result of lower mortality below the age of 60, with roughly one-quarter resulting from lower infant mortality.

Fertility

Births are simulated for women with fertility rates from 1989 depending on age, number of children, and the age of the youngest child. Every time a birth occurs, a child is added to the model population. In the simulation of historical data, fertility rates from 1989 are adjusted proportionally each year so that the simulated number of births is equal to the actual level each year. This adjustment is roughly the same as adjusting the fertility rates against the periodic total fertility rate (TFR). The development in TFRs over the last 100 years is reported in Brunborg and Mamelund (1994) and Kravdal (1994). The actual cohort TFRs are estimated from real data for female birth cohorts born before 1940.

"Actual" cohort TFRs for later birth cohorts are estimated from actual data extrapolated with fertility rates from the base year. The large decrease in fertility from the end of the nineteenth century is the so-called demographic transition that most developed countries have experienced, first with lower mortality and then with lower fertility. The evolution of period fertility is given in *Figure A.3*.

The reduction is caused mainly by fewer women giving birth to three children or more, as well as more women having only one child. The actual cohort TFRs are

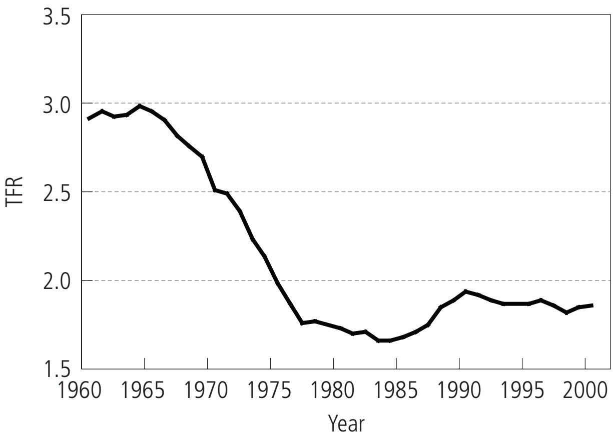

Figure A.3. Norwegian total fertility rate, 1960–2000.
Source: Statistics Norway.

poorly predicted by the simulation of historical data. One explanation may be that decreasing TFRs are caused by lower fertility among women with two children or more, while fertility rates here are adjusted independently of the number of children. This is especially problematic as the current fertility rates show most women stopping at two children. Another explanation may be that periodic variations in fertility have a different impact on contemporary birth cohorts of fertile women, while we adjust all fertility rates in one year by the same factor, independent of age.

The large variations in the annual number of births are an important key to understanding the dynamics of the projections using the MOSART model. One aspect of Norwegian fertility is the low number of births that occurred between World War I and World War II, probably because of economic depression. Contrary to many other developed countries, this will give low or no growth in the number of old persons toward 2010.

Nuptiality

Marital status and choice of spouse are simulated with the focus on women. Marriages are simulated for unmarried women, depending on age and marital status (unmarried, widowed, divorced). If a marriage occurs, the age of a woman's husband is drawn depending on her own age, while an unmarried man of this age is chosen at random. Divorce is simulated for married women; if a divorce occurs, a woman's husband is also divorced. Marriages and divorces are simulated with transition probabilities from Kravdal (1986) for the year 1984 with no adjustments.

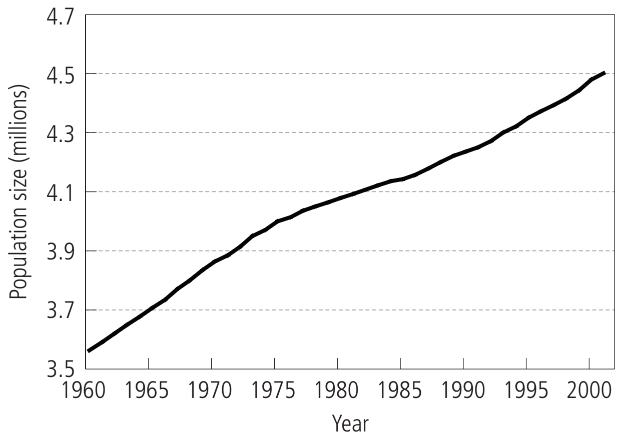

Figure A.4. Norwegian population size, 1960–2001.
Source: Statistics Norway.

Nuptiality has changed since 1984, but the intention is to use marriage as a proxy for the total number of cohabiting couples, and this may have changed less. The simulation of nuptiality will be replaced in 1996 by a simulation of household status and relationships, including marriages and divorces. The focus will be on two-sex couples and their children. Household formation will be implemented in the MOSART model based on a project described in Keilman and Brunborg (1995).

Population Size

The population size will be proportional to the number of net immigrants, and the age composition of the population will be decided by the total fertility rate and, to some degree, by the age distribution of net immigrants. *Figure A.4* displays the population size for the period 1960–2001. Norwegian population growth is outlined in *Figure 5.2*. The growth in population size toward the year 2050 will mainly be among people aged 55 and older. Both larger birth cohorts and lower mortality will contribute to the growth in the number of older persons after 2010.

Education

The MOSART model simulates educational activities and examinations for each person depending on gender, age, and the previous year's educational activity and attainment. The current educational transition probabilities are estimated from all transitions in the Norwegian education system [see Andreassen *et al.* (1993) for details].

It is planned to replace the educational model reported here by educational transition probabilities that also depend on unemployment, relative wages, and capacity in the education system. Education is an important covariate for other events in the MOSART model, such as mortality, disability, and labor-force participation. One aspect of education as a covariate is that most adults keep the same educational attainment throughout their life course. A person with a low or high educational level will therefore have systematically low or high labor-force participation across his/her life course. Measured against the cross-section of the population, the number of additional years of education increased from 2.2 in 1960 to 4.7 in 1987. During 1988, unemployment increased from 2% to almost 5% of the labor force, and this may explain the abrupt increase in the number of pupils and students since 1988. The number of pupils and students according to educational subjects has also become unequal, with a smaller growth in pupils and students in vocational training, technology, and economics.

Projections: The Number of Pupils and Students

The number of pupils and students continues to increase even with a "constant" propensity to study. One explanation may be that we have adjusted gross flows into and out of the education system with a large net inflow. The number of pupils and students must then continue to increase before the gross outflow—as a percentage of the total stock—matches the constant and high gross inflow. Another reason may be that a strongly increasing education level will lead to a higher propensity to study among persons older than 25 years. The efficiency in the education system being low does not imply that the average Norwegian will reach university graduate level. To a large degree, the low efficiency is caused by pupils and students changing subjects rather pursuing the education they set out to pursue.

This may have changed because of recent reforms in the education system. Persons with unknown educational attainment comprise young people who have not yet finished primary school and (new) immigrants. In the MOSART model all young people are assumed to have finished primary school before the age of 17, while 2% finish later (mostly young immigrants). This explains why too many young people have unknown educational attainment in the simulation of historical data.

All "net immigrants" are assigned unknown education as their educational attainment. However, many young immigrants finish primary school after coming to Norway, without being registered as a pupil or student. The MOSART model does not capture this transition, and this explains why too many persons over 30 have unknown education in the simulation of historical data.

Public pension benefits

The national insurance scheme (NIS) was established in 1967 and handles all general public pension benefits in Norway. See Norwegian Ministry of Health and Social Affairs (1995) for an overview. The MOSART model simulates entry into public pension schemes based on old age, disability, widow(er)hood, and early retirement. Disability pensioners are recruited from a wide age group, and the risk of disability has shown large variations during the last decades. The entry into disability is therefore an important transition in the MOSART model. Other transitions in pension status, including exits, are either more rare or related to other events such as age limits or widow(er)hood.

The MOSART model calculates NIS pension benefits for pensioners in the model population based on simulated labor-force participation and other characteristics included in the simulation. Several important benefits are not included in this version of the MOSART model. Persons with severe health problems often participate in a rehabilitation program for several years before drawing a disability pension.

This version of the MOSART model includes labor-force participation but not absence due to unemployment and sickness (at the personal level). In any case, spells of unemployment and sickness are often too short to be handled properly by the time unit used in the MOSART model, that is, the calendar year. Many persons, typically white-collar workers, supplement their NIS pension benefits with other pension schemes, among which are the pension scheme guaranteeing all civil servants a pension benefit including NIS of 66% of the final salary. Pension schemes outside the NIS are not included in this version of the MOSART model.

Disability Pension

Persons with a permanently reduced ability to work due to disease or accident can be granted a disability pension from the national insurance scheme. The ability to work must be reduced by at least 50%. The benefit equals the old-age pension benefit that the person would have received if he/she had continued to work until retirement age. Persons who are not working at present may be granted a disability pension on the basis of domestic work or the anticipation of future jobs. Nevertheless, most disability pensioners were participating in the labor force when the disability occurred.

After one year of sick leave and often an attempt at rehabilitation, the disabled person can apply to the national insurance administration for a disability pension. If the benefit is granted, projections using the MOSART model indicate that more than 95% of the disabled continue to draw disability pensions until retirement age (67 years) or until they die. Until recently the social insurance system in Norway has lacked the general concept of early retirement, and the disability pension may well have served as a flexible retirement age. By the retirement age of 67, 45% of the population were disability pensioners, while survivors' pensions accounted for 7%, implying that 52% of the population were receiving an NIS pension benefit before drawing their old-age pension. Early retirement, however, accounted for only 4% of the population at the age of 66 in 1993. See NOU (1990:17) for a broad discussion on the disability pension in Norway.

Transition Probabilities for Disability Pension

The model draws for all persons aged 16 to 66 who are not already disabled which individuals will draw a disability pension. For those who are already disability pensioners, the model draws the degree of disability and whether they will reenter the labor force. The risk of disability depends on gender, age, year, marital status, educational attainment, and labor-force participation. The covariates are estimated separately for men and women using maximum likelihood over a logit function based on microdata from the period 1986 to 1989:

$$p_{it} = \frac{xp(X\beta_{it} + \delta_t)}{(1 + exp(X_{it}\beta_{it} + \delta_t))} \tag{A.2}$$

The variables in Equation A.2 have the following meanings:
- p_{it} is the probability that person i will enter disability pension in year t;
- X_{it} is a row vector of characteristics for person i in year t;
- β_{it} is a column vector of coefficients for each characteristic;
- δ_t is an adjustment factor/dummy variable for each year t.

Education level is important: those with only a primary-school education have a tenfold-greater risk of drawing disability pension than university graduates. See Fredrikssen and Spurkland (1993) for a more detailed presentation.

Old Age Pension, Survivors' Pension, and Early Retirement

The general retirement age is 67 years in Norway, and the pension benefit is tested against any labor-market earnings the pensioner may have until he/she reaches the age of 70. After 70 the benefit is granted unconditionally, and employees are often obliged to retire at this age, for example, from the public services. The retirement age was reduced from 70 years to the current level of 67 years in 1973. All persons already receiving a pension benefit or who have no labor-market earnings are assumed to have become old-age pensioners when they reach 67 years. The MOSART model draws if employees retire at age of 67 years, and two out of three do this in the simulation.

Toward 2040 the number of old-age pensioners will increase by 80%, with nearly half the increase caused by lower mortality. Early retirement was introduced around 1989 as an agreement between the government and the labor-market organizations, and approximately two-thirds of the labor force are entitled to early retirement at the age of 64. The benefit equals the old-age pension benefit that a person would have received from the NIS if he/she had continued to work until the general retirement age of 67. Less than 25% of those entitled to do so retired before 67 in 1993, but the arrangement is growing in popularity. Widows and (widowers) may be granted a survivor's pension from the NIS until they reach the age of 67 and begin drawing the old-age pension. The benefit includes the late spouse's pension entitlement and is tested against the pensioner's own labor-market earnings.

How Pension Entitlements Are Calculated

Pension benefits from the national insurance scheme are based on the entitlements that each person achieves during his/her working life. These entitlements are guaranteed by the government and cannot be rescinded, although their value can be changed through adjustments to the basic pension unit (see below). Existing pension entitlements will therefore have an impact on the Norwegian economy for decades ahead. A description of how pension entitlements are calculated is given in this section.

Basic Pension Unit

NIS has its own pension measurement unit called the basic pension unit (BPU), with a value of 50,603 NOK in the initial period. The BPU is used to calculate pension entitlements and adjust pension benefits according to inflation and general growth in wealth. The intentions of the current laws regulating NIS are a BPU increasing at the same rate as the wage level. Other rules for calculating entitlements and benefits are held constant, including the special supplement.

Pension benefits

NIS benefits to old-age, disability, and survivor pensioners consist of three elements:

> Pension benefit = basic pension + maximum (special supplement, supplementary pension)

A pensioner married to a pensioner receives a basic pension of 0.75 BPUs, while other pensioners receive 1 BPU. The special supplement was 0.6 BPUs for most pensioners in 1995. The sum of the basic pension and the special supplement is the minimum pension benefit that all pensioners are guaranteed. The supplementary pension is based on previous labor-market earnings, including wages, income as a self-employed person, sick-leave benefits, unemployment benefits, and maternity-leave benefits. Each year, from the age of 17 to 69, a person's labor-market earnings are translated into pension points using the BPU of the year the income was earned. The main rule for calculating the pension point is that labor-market earnings exceeding 1 BPU, the basic pension, are divided by the BPU. Labor-market earnings exceeding 6 BPU are divided by 3 BPU, and labor-market earnings exceeding 12 BPU are ignored, constituting an income ceiling on the earning of pension entitlements. The final pension point is calculated as the average of the 20 largest positive pension points, while pension point years are the number of years with labor-market earnings above 1 BPU. The supplementary pension is calculated using the BPU at the time the pension benefit is received

> Supplementary pension = supplementary pension rate* [minimum (pension-point years, 40) /40]*BPU*final pension point

The supplementary pension rate represents a (marginal) *benefit–wage ratio* with a current value of 42%. The second term, pension-point years divided by 40, represents the *earning-time percentage*. The last term, BPU*final pension point, represents an *income base* and is very approximately the former income level as employee indexed with the growth in the BPU. This approximation is rough because income below 1 BPU and over 6 BPU weighs little or nothing. Equation A.3 shows how pension benefits vary with previous labor-market earnings under certain strict conditions, especially that prices, labor-market earnings, and the BPU are held constant over the career. The equation also represents the case where labor-market earnings and the BPU grow at the same rate and all nominal amounts are wage-deflated. Note that the NIS is progressive, meaning that the ratio of benefits to wages decreases strictly with increasing income level. Average *full-time* earnings were roughly 210,000 NOK in 1993, implying that most persons are unaffected by the income ceiling of 6 and 12 BPUs.

$$\text{Pension point} = \begin{cases} 0 & \text{If: Income} < 1\text{ BPU} \\ (\mathit{Income} - \mathit{BPU/BPU}) & \text{If: } 1\text{ BPU} \leq \text{Income} < 6\text{ BPU} \\ \left[\dfrac{5 + \mathit{Income} - \mathit{BPU}}{3 * \mathit{BPU}}\right] & \text{If: BPU} \leq \text{Income} < 12\text{ BPU} \\ 7 & \text{If: Income} \geq 12\text{ BPU} \end{cases} \tag{A.3}$$

The ratio of the NIS pension benefit to previous labor-market earnings will be 50%–55% with a previous income of 180,000 NOK and 40 pension-point years. After tax the ratio is roughly 60%–65% at this income level, depending on personal tax deductions. The properties of the supplementary pension show the importance of the distribution of labor-market earnings among persons and over the life course.

Other Sources for Pension Entitlements

Disability pensioners are granted a computed pension point for each year of disability until retirement age as a compensation for lost opportunities in terms of earning pension entitlements. The computed pension point is either the average of the pension points over the three years before disability occurred or the average of the best half of all pension points the person may have earned. The latter alternative is omitted in this version of the MOSART model. If disability occurs before the age of 23 years, the disability pensioner is granted a computed pension point of 3.3, as if he/she were born disabled.

Persons with children younger than 7 years or other extensive family-care obligations are granted a pension point of 3.0 each year if their own labor-market earnings yield a lower pension point. The level corresponds roughly to the average pension point for unskilled women working full-time; this family-care pension point was introduced in 1992. Widows (and widowers) can choose between their own supplementary pension and 55% of their own or late spouse's supplementary pension. If the late spouse died before retirement age, the supplementary pension is calculated as if he/she had started to draw disability pension the same year.

Transitional NIS rules were established in 1967 under which only labor-force participation after 1967 yields entitlements to a supplementary pension. People born before 1937 are partly compensated for missing the opportunity of earning full pension entitlements (the same as earning 40 pension-point years). For these birth cohorts, the supplementary pension in Equation A.3 is divided by the maximum possible number of pension-point years instead of the usual 40 years, with a minimum of 20 years, and only for the part of the pension point not exceeding a level of 4.

The NIS was reformed in 1992 to make the system less favorable to those with high incomes. The income limit in Equation A.3, where labor-market earnings are divided by three times the BPU, was reduced from 8 BPUs to 6 BPUs in 1992, though it did not affect pension entitlements already earned. The supplementary pension rate was reduced from 0.45 to 0.42, without affecting entitlements already earned. Pension-point years earned before 1992 are multiplied by 0.45, while the remaining years in Equation A.3 are multiplied by the new rate of 0.42. The reform also affected the future computed pension points of existing disability pensioners.

As mentioned, the national insurance scheme was established in 1967, and it took decades before the system of supplementary pensions matured. The differences in supplementary pension according to gender and birth year excluded inherited entitlements. This figure is based on a projection with a simulated initial population and a projection with the real initial population; the discrepancies between the two projections are discussed later. Both projections use the 1993 perspectives.

The supplementary pensions are decided by entitlements already earned for persons in the real initial population born until 1923. To an increasing degree, supplementary pensions for younger birth cohorts are decided by the simulation, and birth cohorts born after 1972 are purely simulated. The supplementary pensions are larger for younger birth cohorts because these birth cohorts have a longer series of pension points in the NIS. The transition rules give favorable pension benefits to those born after 1917 who have worked every year from 1967 until they are 69 years old, while some years without labor-market earnings can reduce the pension benefits very strongly. Theoretically, persons born in 1937 can achieve full pension entitlements.

Those born in 1950 will, however, be the first birth cohort whose full working career is included in the calculation of supplementary pensions, and the system will continue to mature until then. The aforementioned 1992 reform explains why men born after 1950 will receive smaller supplementary pensions than men born in the forties. The gender differences in wages also decrease in the projection period because of a stronger growth in the education level of women. When average wages per man–year remain constant, the income level decreases by 3% for men. Supplementary pensions continue to grow for women born after 1950, the reason being the large increase in female labor-force participation over the last 25 years.

The short-term variations in the average old-age pension benefits over the last 25 years are caused by adjustments in the BPU and the special supplement. Even when birth cohorts with full entitlements reach retirement age in 2020, the average old-age pension benefits continue to grow until all pensioners have full entitlements.

While the NIS today is far more favorable to male patterns of labor-force participation, the matured NIS is clearly more favorable to women than men compared with an actuarially correct system. When the NIS is fully matured, the average female old-age pensioner will receive a benefit that will be 92% of that of the average male pensioner, even though her labor-market earnings would have been only 67% of his. Several aspects of the NIS contribute to this equalization.

First, the system is progressive in the sense that the benefit/wage ratio decreases with increasing income. A variable income is also favored because the system considers only the 20 best income years and does not give extra credit to working careers that are longer than 40 years. This means that a limited period with reduced income has no direct effect on the pension entitlements, for example, women working part-time during the years they have small children.

Supplementary Pensions for Male Birth Cohorts Born Before 1960

For these birth cohorts the pension entitlements that have already been earned are important, and any discrepancies can be explained by shortcomings in the simulation of labor-market earnings. The difference is roughly 5% for male birth cohorts born around 1930 and 10% for men born around 1945. There are several possible reasons for this. Older persons earn too little in the labor market, while those under 30 earn too much. As labor-market earnings before 1967 are ignored in the NIS, supplementary pensions for the older birth cohorts are reduced. For younger birth cohorts this effect evens out, as the calculations include both the too-high earnings before the age of 30 and the too-low ones after 30.

As only the 20 best pension points are used to calculate the level of the supplementary pension, the supplementary pension level is reduced for all male birth cohorts in the simulations. The two aforementioned errors in the distribution of earnings across age groups/the life course may explain the discrepancies in supplementary pensions for men born between 1910 and 1960. We believe that the effect of this will be for female pensions to be relatively well predicted in the future and for male supplementary pensions to be underpredicted. The latter discrepancy may be of the order of 4% if the distribution of earnings in the future is the same as in the 1967–1993 period, with widow(ers) receiving 55% of the sum of their own and their late spouse's supplementary pension, if this exceeds their own supplementary pension.

Indexing of the basic pension unit changes in the value of the BPU will, in effect, represent the indexing of all existing pension entitlements in the NIS from the point in time at which the entitlements were earned. If the BPU and wages increase at the same rate, people in the labor force and existing NIS pensioners will see their entitlement grow at roughly the same rate. Pensioners with only minimum pension benefits may be compensated through an increase in the special supplement. Although the value of the minimum pension benefit increased relative to wages per man–year until 1980, it has changed little relative to the wage level since then.

At the same time, the special supplement time will increase to compensate those pensioners who receive minimum pension benefits; thus, in the long run, the maximum supplementary pension will be worth less than the special supplement.

By 2090 no supplementary pensions will exceed the value of the special supplement, and the average old-age pension benefits will be the average minimum pension benefit, at that time 57,000 NOK. Until recently, most pensioners have received only the minimum pension benefit and therefore had little interest in the BPU as long as the special supplements increased sufficiently. This is changing, and interest in the BPU on the part of pensioners and labor-market organizations is increasing. The high and unstable inflation during the period 1970–1981 may also have complicated the indexing of the BPU. The final pension points are calculated from the 40 rather than the 20 best income years, with no transitional rules. A real reform cannot affect entitlements that have already been earned, and with proper transitional rules the full effect would not have taken place until the year 2060 [see Fredrikssen and Koren (1993) for examples].

Labor-force participation

Labor-force participation is simulated in two steps in the MOSART model. First, the number of persons in the labor force and person–years are projected based on definitions and data from Statistics Norway's Labor-Force Sample Surveys. Second, each person's earnings are simulated in such a way that the number of income recipients and their earnings are consistent with the labor force projected above. The difference between the labor force and the number of those receiving income is caused by the first being a yearly average and the latter also including all those who have worked only for parts of the year. Each of the two steps is described in the next two sections, while Fredrikssen and Spurkland (1993) also describe the estimated parameters.

Labor-Force Projections

The MOSART model projects the labor force and number of person–years by adding each person's calculated labor-force participation rate (LFPR) and expected working hours. The LFPR and working hours are estimated from the labor-force sample surveys from 1991 and depend on gender, age, children, marital status, educational activities, educational attainment, and pension status. The LFPR and working hours calculated for each person do not, however, depend on their previous year's participation in the labor-force. The projections show only the effect on the labor force of changes in population size and composition. In the projections the estimated LFPRs and working hours are adjusted to the respective level and then held constant.

The effects of educational activities and a disability pension on the LFPR and working hours are estimated by combining the labor-force sample survey with administrative registers. The labor-force sample survey in Norway has only conditional questions about educational activity or disability; it therefore overlooks the fact that a person working (part-time) may also be a student or disability pensioner. After combining the two sources, we find that disability pensioners have an average LFPR of 16%, while pupils and students have an average LFPR of 39%.

The effect on the labor force of one more person taking the disability pension is the difference in LFPR before and after the disability occurred, roughly 65 percentage points in the MOSART model. For example, if the risk of taking the disability pension increases, then 100 more disability pensioners reduce the labor force by approximately 65 people. The same figure for pupils and students is 40 people in the short term and none in the long term because people with greater educational attainment remain in the work force for longer.

Labor-Force Participation Rates

Historic figures and projections regarding employment in Norway from 1960 to 2020 are given in *Figure A.5a* and *Figure A.5b*, which show the development in the number of hours worked and the employment rate. For men there is a strong decrease in the number of hours worked, while for females the number of hours worked increased slightly in the first half of the period, which leads to a gender convergence. Moreover, employment rates increased for women from 1960 to 1990, while men's employment rates fell somewhat in the same period. Female participation in the labor force increased in spite of changes in educational activities and the disability pension. The gender differences in LFPRs have decreased dramatically, but they are still bigger in Norway than in the other Nordic countries. The LFPRs in the projections increase because the age composition of the population changes and the education level increases. The education level increases more for women than for men, and this explains the decrease in gender difference in the projections.

Labor Supply

The projection of the future labor force is described in *Figure 1.6*. The strong increase in the 1970s resulted from the increase in female labor-force participation, already mentioned. The year 1987 was a peak year both in terms of the number of people entering the labor force and the LFPRs. The problems in the labor market since 1988 have especially affected people aged 16–24, leading to LFPRs that are 12 percentage points lower and a corresponding increase in the propensity to study. The labor force increases by 200,000 people toward 2020 with the year 2000 perspectives (see *Table 1.6*); two-thirds of the increase is due to there being more people in the 25–66 age group, and the rest is explained by an increasing level of education.

The education level will be higher among women than among men, and nursing and teaching will especially contribute to this. Gender differences, however, remain, with caring professions dominated by women and vocational training and technology dominated by men. Within secondary school the percentage of three-year courses (skilled labor) will increase at the expense of the percentage of one-year courses (basic education).

Labor-Market Earnings

The simulation of labor-market earnings is divided into two substeps. The first step simulates if or not a person receives labor-market earnings, and the second

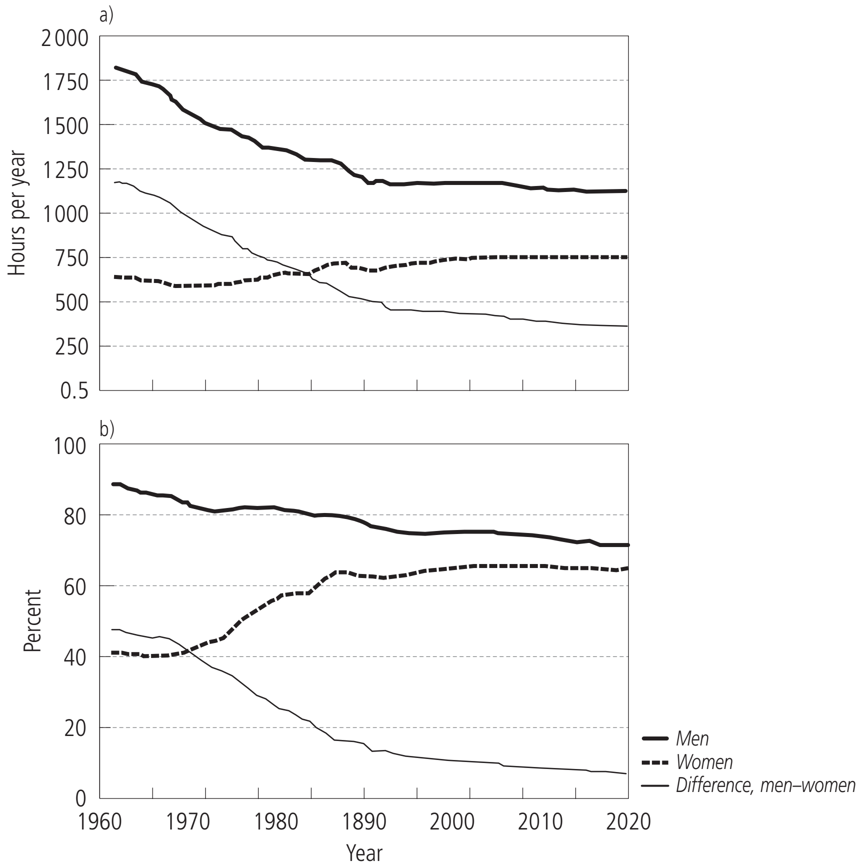

Figure A.5. Hours worked (a) and employment rate (b), 1960–2020.
Source: Statistics Norway.

step decides how large this income is. Labor-market earnings comprise wages, self-employed income, sick-leave benefits, unemployment benefits, and maternity-leave benefits. The probabilities of receiving labor-market earnings depend on the same characteristics as the LFPRs, for instance gender, age, children, marital status, educational activities, educational attainment, and pension status. Labor-market earnings also depend on previous years' earnings, and in this sense the simulation describes gross flows into and out of the labor force. The probabilities are estimated using maximum likelihood over a logit function with microdata for the period 1985–1988:

$$p_{it} = \frac{exp(X_{it}\beta + \delta_t)}{(1 + exp(X_{it}\beta + \delta_t))} \tag{A.4}$$

where:
- p_{it} is the probability that person i will enter disability pension in year t;
- X_{it} is a row vector of characteristics for person i in year t;
- β is a column vector of coefficients for each characteristic; and
- δ_t is an adjustment factor/dummy variable for each year t.

The probabilities in Equation A.4 are adjusted each year by changing the "constant" term δ_t such that the number of recipients of labor-market earnings in the simulation is consistent with the projected labor force. Each person is assigned a probability r_i of being in the labor force if he/she is a wage earner, and this probability can be interpreted as the percentage of the year this person is working. For most people, r_i is 100%, while pupils, students, disability pensioners, and those beginning or quitting work during the year have lower percentages. Consistency is achieved when the projected labor-force year $t = \sum_i p_{it} r_i$. The value of δ_t is found by an iteration over a first-order Taylor polynomial with pit as a function of δ_t. With the drawing method in the MOSART model, the simulated number of income recipients also equals the adjusted number. If the model draws that a person is earning, the income level is simulated by:

$$Y_{it} = exp(X_{it}\alpha + \varepsilon_{it} + \gamma_t) \qquad \text{(A.5)}$$

where:
- Y_{it} is labor-market earnings for person i in year t;
- X_{it} is a row vector of characteristics for person i in year t;
- α is a column vector with covariates for each characteristic;
- ε_{it} is a residual for person i in year t;
- γ_t is an adjustment factor/dummy variable for each year t.

The level of labor-market earnings depends on the same characteristics as the probability of receiving labor-market earnings, and the covariates in α are estimated using GLS on microdata for the period 1985–1988. An exponential function is chosen to avoid nonpositive income amounts. Total labor-market earnings are restricted to equal the product of the projected person–years M_t and an exogenous wage W_t per man–year:

$$\sum_i Y_{it} = M_t W_t \qquad \text{(A.6)}$$

The adjustment factor in Equation A.6 is found by first calculating the income for each income recipient without γ_t:

$$\gamma_t = \ln \frac{M_t^* W_t}{\sum_i Y_{it}^{\textit{without}\,\gamma}} \qquad \text{(A.7)}$$

The labor-market earnings for each income recipient are then adjusted by multiplying by the exponent of γ_t . The estimation of α in Equation A.5 includes a so-called disturbance term, which is included in the simulation by the personal residuals ε_{it} . The intention is to capture variations in labor-market earnings not explained by the model $X_{it}\alpha$. In the real initial population, the residuals ε_{it} are calculated for each person from the difference between the actual labor-market earnings in 1988 and the expected income by Equation A.7. Residuals ε_{it} are drawn for new persons and persons without stable labor-market earnings using the observed distribution of the disturbance term from the estimation of the equation. Each person keeps the same residual ε_{it} throughout his/her entire career in the baseline alternative.

Contribution rates

A major purpose of the MOSART model is to carry out analyses of the economic consequences of an aging population or, more precisely, how taxes will increase as a result of increasing public expenditure related to old persons. This version of the MOSART model excludes important parts of this expenditure, for example, health care for old persons.

Furthermore, the tax rules are represented in a very simple way as the MOSART model lacks important income components and excludes behavioral responses to changes in the tax level. However, we believe that these analyses are of interest as a large variety of sensitivity analyses are presented. An analysis of the tax system and public pension benefits requires a clarification of how public pension benefits are financed and how pensioners are taxed. For simplicity, we assume that current public pension benefits are financed through current taxes, the so-called pay-as-you-go system or PAYG. Pensioners also have special tax rules to compensate for lower income, old age, and health problems [see Arneberg and Gravningsmyhr (1994) for details]. The question here is how this tax gap will develop in the future. A reasonable approach may be that income after tax increases at the same rate for each pensioner as for wage earners. This can be achieved through adjustments to the special tax rules for pensioners and the special supplement. The basic pension unit is, however, an inappropriate means of adjusting income after tax for pensioners, as it will affect the earning of pension entitlements. In the absence of a more sophisticated representation of the tax rules, we assume that pensioners pay half as much tax as wage earners. The average tax rate due to public pension benefits, the *contribution rate*, is then calculated by:

$$\text{Contribution Rate} = \frac{\sum \text{Pension benefits}}{\sum \text{Labor-market earnings} + 0.5 * \sum_i \text{Pension benefits}} \qquad \text{(A.8)}$$

Mean constrained drawing method

The main drawing method in the MOSART model is described in this Appendix, while Fredrikssen (1996) gives a more detailed discussion of the method and its effects and suggests how to solve the practical problems. The drawing method in the MOSART model does not complicate computer programs, and computer runtimes increase by less than 1% in this version of the MOSART model. Standard deviations on projection results induced by stochastic drawing are 70%–90% lower as compared with the random number method (see below).

The Problems of Stochastic Drawing

Dynamic microsimulation models are generally solved by stochastic drawing, often called the Monte Carlo technique. In the *random number* method the computer generates so-called random numbers with uniform distribution (0.1), and if the random number is smaller than the probability, the event occurs. This stochastic drawing generates an extra uncertainty in the projections often called Monte Carlo Variability (MCV). The MCV is measured in this study by relative empirical standard deviation across replicated simulations, where the only difference is the sequence of random numbers.

The MCV is unnecessary for most social-planning purposes and is often used as an important critique of microsimulation. In the MOSART model we have found the MCV with the random number method to be troublesome when two projections with different underlying assumptions are being compared. The MCV with the random number method is also troublesome when year-to-year growth rates are being estimated and for long-run projections.

The idea of the drawing method in the MOSART model is to constrain the simulated number of events to its expectation value without changing each person's probability of experiencing the event. With exogenous probabilities, the expectation value of the model is the sum of the transition probabilities. This constraining is easy when probabilities are (group-wise) homogeneous and, for example, used when a stratified sample comprises a given number of people from each stratum. The drawing method in the MOSART model handles heterogeneous binomial probabilities.

Some Related Methods

With a limited knowledge of statistical literature, we cannot exclude the existence of any similar and better method of reducing MCV than offered in Equation A.15. However, the related methods discussed below do not offer any method that is able to both handle *heterogeneous* binomial probabilities, be unbiased, be easy to implement in a computer program, and require hardly any computer resources.

Orcutt *et al.* (1986) is a major contribution on microsimulation in social planning, and the introduction by Orcutt (1986) includes a discussion of variance reduction methods. We have also found useful the discussion in a preliminary version of Beckering (1995), a dissertation including one paper on variance reduction methods in microsimulation models. The discussion in Orcutt (1986) and Beckering (1995) is related to the drawing method in the MOSART model.

The brute method is to increase the sample or use the average across replicated simulations. This implies that any interesting methods of reducing MCV must be efficient in the sense that they do not complicate the computer programs too much or overly increase the computer runtimes. However, a four-times-larger sample normally reduces the standard deviation to only one-half.

The next idea is to present the sum of the transition probabilities as the simulation result, which gives the expectation value of the simulation. This method is used in the MOSART model in the projection of labor-force years and person–years. However, the method is insufficient in a model with multiple periods because the number of possible paths for each person will be too large. The process of aging the population must draw what happens into the next period. If the MCV related to the number of births and persons who survive is large, this will also affect the sum of the probabilities in subsequent periods.

Two simulations can be executed with the same sequence of random numbers, known as the method of *common random numbers*. This reduces the MCV on the difference between the two simulations, as only people with changed probabilities can experience different events in the two simulations. Unfortunately, the method requires the sequence of possible events to be the same, which, in general, is not true in dynamic microsimulation. What events may occur in one period depend heavily on other events in earlier periods, especially births and deaths. In this version of the MOSART model, pension benefits do not affect any *transition* probabilities. An analysis where only rules for calculating pension benefits are changed can be carried out with the method of common random numbers in the MOSART model.

Orcutt (1986) focuses on a method called *alignment*, and implementations of the method can be found in Caldwell (1996) and Galen (1995). First, all persons are assigned a personal random number, and the unadjusted number of events are counted as the number of persons with probabilities larger than the assigned random number. The discrepancy between the unadjusted number of events and the expected number is used to calculate an alignment factor, and this may require sorting or an iteration process. In the second round, all probabilities are multiplied by the alignment factor, and if the adjusted probability is larger than the assigned random number an event occurs:

An event occurs if $p_i * f_i > r_i$, where:

- p_i is the probability that person i will experience the event;

- r_i is the random number with uniform distribution (0.1) assigned to person i;
- f_i is the alignment factor for person i.

The task between the first and second round is to find the proper value of the alignment factor f_i that will result in the expected number of events. The alignment method is similar to the drawing method in the MOSART model in the sense that alignment can be used to constrain the number of events to the expectation value of the simulation when probabilities are binomial and heterogeneous. However, the alignment method requires the simulation model to run through the population at least twice and perhaps more if the alignment factor f_i is difficult to calculate. This means that the alignment method complicates computer programs and increases computer runtimes more than the drawing method in the MOSART model.

More seriously, the alignment technique introduces a (small) bias that may be visualized by a simple example. A person with a probability p_i should on average experience p_i events per drawing. If p_i is 1, the average number of events should also be 1. However, on some occasions, a small alignment factor f_i and a large assigned random number r_i will prevent persons with p_i equal to 1 from experiencing the event. Furthermore, the number of events per drawing will never exceed 1, and the average number of events with the alignment method will therefore be less than 1 for persons with p_i equal to 1.

The alignment method can also be used to *adjust* the probabilities so that the simulation is consistent with any reasonable exogenous constraint on the number of events. See Beckering (1995) and Galen (1995) for a discussion. In the MOSART model an adjustment against an exogenous number different from the sum of the (unadjusted) probabilities requires the probabilities to be adjusted before the simulation, which may reduce the advantages of the drawing method in the MOSART model.

Beckering (1995) claims that most of the remaining methods require the transition probabilities to be identical within a limited number of subpopulations, which we call group-wise homogeneous probabilities. Beckering (1995) also suggests and tests a new drawing method based on sorting that handles multinomial probabilities but, according to the author, the method is "not easy to implement in a computer program."

The Idea of the Drawing Method in the MOSART Model

Each person i is assumed to have a probability p_i of experiencing the event. The population is then divided into drawing groups within each of which the sum of the transition probabilities is exactly 1. The practical problems of making drawing groups and of rounding is addressed later. The model then draws for each conditionally on the events of the *previous* persons in the drawing group:

$$p_1^{adjusted} = \begin{cases} p_i/(1 - \sum_{j<i} p_j) & \text{if no event has occured in this drawing group, yet} \\ 0 & \text{if an event has occured in this drawing group} \end{cases} \quad \text{(A.9)}$$

where:
- i is the person subject to drawing;
- $j < i$ are all persons in the drawing group that have already been exposed.

The drawing is executed by comparing the adjusted probability with a random number with uniform distribution (0.1) generated by the computer. If the random number is smaller than the adjusted probability, the event occurs for person i. The probability r_i of person i experiencing an event (described in Equation A.9) can be written as:

$$r_i = E(p_i^{adjusted}) = (p_i/(1 - \sum_{j<i} p_j)) \cdot q_i + 0 \cdot (1 - q_i) \quad \text{(A.10)}$$

In Equation A.10 the following assumptions hold:
- q_i is the probability of no event before person i;
- $(1 - q_i)$ is the probability of an event before person i.

Two persons within the same drawing group cannot experience an event, and the probability $(1 - q_i)$ of any of them experiencing an event is the sum of the probability of each of them experiencing the event. Using Equation A.11 this gives:

$$1 - q_i = \sum_{j<i} r_j \quad \text{(A.11)}$$

Equation A.10 can now be simplified by substituting Equation A.11 into Equation A.10:

$$r_i = (p_i/(1 - \sum_{j<i} p_j)) \cdot (1 - \sum_{j<i} r_j) \quad \text{(A.12)}$$

It is now easy to show by iteration that the probability r_i in Equation A.12 is equal to the probability p_i:

$$\begin{array}{ll} r_i & = (p_i/(1-0)) \cdot (1-0) = p_1 \\ r_2 & = (p_2/(1-p_1)) \cdot (1-r_1) = (p_2/(1-p_1)) \cdot (1-p_1) = p_2 \\ r_3 & = (p_3/(1-p_1-p_2)) \cdot (1-r_1-r_2) \\ & = (p_2/(1-p_1-p_2)) \cdot (1-p_1-p_2) = p_3 \\ \ldots & \\ r_i & = (p_i/(1-\sum_{j<i} p_j)) \cdot (1-\sum_{j<i} r_j = (p_i/(1-\sum_{j<i} p_j)) \cdot (1-\sum_{j<i} p_j) = p_i \end{array} \quad \text{(A.13)}$$

The method described in Equation A.13 does not therefore alter each person's probability of experiencing an event in this simple example. The last person within a drawing group must experience the event if no-one else in this group has, as the probabilities add up to 1:

$$p_{last}^{adjusted} = p_{last}/(1 - \sum_{j<last} p_{last}) = p_{last}/(1 - (1 - p_{last})) = p_{last}/p_{last} = 1 \qquad \text{(A.14)}$$

In Equation A.14, each drawing group will therefore end up with one and only one event, which is also the expected number of events within each drawing group. With the correct number within each drawing group, the number of events for the total population is also correct.

Practical Solutions of Making Drawing Groups and Rounding

The drawing groups are formed by one person being simulated at a time and each new person being added to the current drawing group. At the end of a drawing group a rounding problem occurs, or more precisely the probabilities do not generally add up to exactly 1. The transition probability of this last person is "divided" between the drawing group that is to be closed and the new drawing group, by adjusting Equation A.9.

$$p_1^{adjusted} = \begin{cases} Max(1, p_i/(1 - \sum_{j<i} p_j) & \text{If event had occured in the present drawing group before person } i \\ p_i^{new}/(1 - p_i^{old}) & \text{If an event had happened in the present drawing group before person } i \text{ and } \sum_j p_j \geq 1 \\ 0 & \text{If an event had happened in the present drawing group before person } i \text{ and } \sum_j p_j < 1 \end{cases} \qquad \text{(A.15)}$$

where:
- j are all members in the present drawing group
- $p_i^{old} = 1 - \sum_{j<i} p_j$
- $p_i^{new} = p_i - p_i^{old}$

If $(\sum_j pj \geq 1)$ open a new drawing group and include in it the probability p_i^{new} as the first probability and also any event by $\frac{p_i^{new}}{(1-p_i^{old})}$.

If the sum of the probabilities is less than one, the expected number of events in Equation A.15 is the same as in Equation A.13, or else the expected number of events in Equation A.15 can be written as:

$$
\begin{aligned}
&E(p_i^{adjusted} | \sum_j p_j \geq 1) \\
&= s\,^*E(Max(1, p_i/(1 - \sum_{j<i} p_j))) + (1-s)^* E(p_i^{new}/(1 - p_i^{old}) \\
&= (1 - \sum_{j<i} p_j)^* 1 + (\sum_{j<i} p_j)^* p_i^{new}/(1 - p_i^{old}) \\
&= p_i^{old} + p_i^{new} = p_i
\end{aligned} \tag{A.16}
$$

where:

- s is the probability of no events before person i in the present drawing group.

The expected number of events in the new drawing group for the person crossing two drawing groups is p_i^{new}, and this probability is also included in the new drawing group. One sequence of drawing groups is used for different groups of the population for each event to make each drawing group as homogeneous as possible.

This eliminates the uncertainty not only about the total number of simulated events but also about the number of events within each group of the population. This also contributes to reducing the uncertainty caused by which probabilities will "survive" to the next period.

Testing

One test is performed by comparing the percentage of persons becoming disability pensioners sorted by the probability of experiencing this event. We find that the observed percentages fit the underlying probabilities and that the method is not biased toward small or large probabilities. Moreover, a simple model is presented with one event, with 100 persons with transition probabilities randomly and uniformly distributed (0.1). Replicated simulations across this simple model indicate that the probability of experiencing the event is the same as the used probability, independent of the size of the probability or the ordering of persons.

The drawing method in Equation A.15 introduces a strong negative correlation of experiencing an event among members of the same drawing group. Where independence between the drawings is required, care must be taken to avoid two persons entering the same drawing group. This may be two persons from the same household, or if a drawing group crosses two years, the same person being included twice.

Computer Resources

The MOSART model is programmed in the object-oriented language *Simula* [see Kirkerud (1989) for details]. The object orientation simplifies the implementation of the drawing procedure in Equation A.15. The drawing procedure is defined as a class including the necessary counting variables; each type of event is assigned its own drawing object, and the procedure is invoked by writing:

If name-of-drawing-object.event(probability) then ......

The counting variables are hidden within the object and properly updated. The drawing "procedure" with the random number method requires approximately the same amount of source code:

If *probability* $>$ Uniform$(0, 1, u)$ then ......

Classification of education

Below is a description of how education is classified in the MOSART model. The level of education is measured by the minimum number of years a full-time pupil or student normally takes to finish his/her education. The primary school level is set at 9 years, irrespective of the actual length. Secondary school comprises those aged 10–12; higher education 13–19; graduate level 17–18; post-graduate education 19. The levels at which each educational subject can be studied/finishes are shown in brackets. See Andreassen *et al.* (1993) for how the classification of education in the MOSART model corresponds to the official classification of education in Statistics Norway (1989). See Vassenden (1993) for a description of the educational registers used in the MOSART model.

Unknown Education

The education registers lack information on approximately 100,000 adults, mainly people who failed to report their own educational attainment in the population census.

Primary School

All people with only primary school are assigned an educational level of 9 years.

Secondary School

Secondary school comprises the three first years after primary school. Students in higher education are mainly recruited from academic-track schools, but in reality most subjects give access to higher education. Approximately 10% of academic-track-school candidates participate in *various basic courses* (before they enter higher education). Academic-track school (10–12, 12), administration and economics (10–12, 10–12), vocational training (10–12, 10–12), various basic courses; domestic science, military subjects (not including compulsory military service), *folkehøyskole* (10, 10), other (10–12, 10–12).

Higher Education

Higher education comprises all education beyond secondary school and requires a secondary school education providing entitlement to higher education, for example, academic-track schooling. Technology (13–19, 13–17+19), administration and economics (13–16, 13–16), nursing (13–16, 15+16), teaching (13–18, 13–16+18), preliminary tests (13, 13), humanities (13–19, 13–19), social sciences (13–19, 13–19), natural sciences (13–19, 13–19), law (15–19, 15+17+19), medicine (13–19, 18+19), dentistry (13–19, 17+19), other (13–19, 13–19).

References

Aakvik, A., Salvanes, K.G., and Vaage, K., 2003, *Measuring Heterogeneity in the Returns to Education in Norway Using Educational Reforms*, Discussion Paper 4088, Centre for Economic Policy Research, London, UK, October.

Abowd, J., and Kramarz, F., 1999, The analysis of labor markets using matched employer–employee data, in O. Ashenfelter and D. Card, eds., *Handbook of Labor Economics*, Elsevier Science Publishers, Amsterdam, The Netherlands, pp. 2630–2672.

Ahituv, A., and Joseph, Z., 2000, *Technical Progress and Early Retirement*, Discussion Paper 2614, Centre for Economic Policy Research, London, UK, November.

Alberts, D.M., Griffith, E., and Morrison, F.J., 1997, Nature–nurture in the classroom: Entrance age, school readiness, and learning in children, *Developmental Psychology*, 33(2): 254–262.

Alton, A., and Massey, A., 1998, Date of birth and achievement in GCSE and GCE A-level, *Educational Research*, 40(1): 105–109.

Anderson, J.W., Johnstone B.M., and Remley D.T., 1999, Breastfeeding and cognitive development: A meta-analysis, *American Journal of Clinical Nutrition*, 70(4): 525–553.

Andersson, G., 1999, Childbearing trends in Sweden, 1961–1997, *European Journal of Population*, 15: 1–24.

Andersson, G., 2002, Fertility developments in Norway and Sweden since the early 1960s, *Demographic Research*, 6(4): 65–86.

Andersson, B., Holmlund, B., and Lindh, T., 2002, *Labor Productivity, Age and Education in Swedish Mining and Manufacturing 1985–1997*, (mimeo of preliminary results), Uppsala, Sweden.

Andreassen, L., Andreassen, T., Fredrikssen, D., Spurkland, G., and Vogt, Y., 1993, *Framskriving av Arbeidsstyrke og Utdanning, Mikrosimuleringsmodellen MOSART* [Projections of Labour Force and Education, the Dynamic Microsimulation Model MOSART], Reports 93/6, Statistics Norway, Oslo, Norway [in Norwegian].

Angrist, J., and Krueger, A.B., 1991, Does compulsory school attendance affect schooling and earnings? *Quarterly Journal of Economics*, 106(4): 979–1014 (November).

Angrist, J., and Lavy, V., 2002, New evidence on classroom computers and pupil learning, *Economic Journal*, 112(482): 735–765.

Arneberg, M.W., and Gravningsmyhr, H.A., 1994, *Pensjonistbeskatningen—Kostnader og fordelingsvirkninger* [Taxation of pensioners—Costs and distribution effects]. Økonomiske analyser 7/94, Statistics Norway, Oslo, Norway [in Norwegian].

Arrow, K., 1973, Higher education as a filter, *Journal of Public Economics*, 2(3): 193–216.

Ashenfelter, O., and Rouse, C., 1998, Income, schooling and ability: Evidence from a new sample of identical twins, *Quarterly Journal of Economics*, 113(1): 253–284.

Atkinson, R., Atkinson, R., Smith, E., and Bem, D., 1993, *Introduction to Psychology*, Harcourt Brace and Company, Orlando, FLA, USA.

Autor, D., Levy, H.F., and Murnane, R.J., 2003, The skill content of recent technological change. An empirical exploration, *Quarterly Journal of Economics*, 118(4): 1279–1333.

Avolio, B., and Waldman, D., 1994, Variations in cognitive, perceptual, and psychomotor abilities across the working life span: Examining the effects of race, sex, experience, education, and occupational type, *Psychology and Aging*, 9(3): 430–442.

Avramov, D., and Maskova, M., 2003, *Active Ageing in Europe*, Population Studies No. 41(1), Council of Europe Publications, Strasbourg, France.

Ball, K., Berch, D.B., Helmers, K.F., Jobe, J.B., Leveck, M.D., Marsiske, M., Morris, J.N., Rebok, G.W., Smith, D.M., Tennstedt, S.L., Unverzagt, F.W., and Willis S.L., 2002, Effects of cognitive training interventions with older adults, *Journal of the American Medical Association*, 288(18): 2271–2281.

Baltes, P.B., and Lindenberger, U., 1997, Emergence of a powerful connection between sensory and cognitive functions across the adult life span. A new window to the study of cognitive aging? *Psychology and Aging*, 12(1): 12–21.

Barrett, G.V., and Depinet R.L., 1991, A reconsideration of testing for competence rather than for intelligence, *American Psychologist*, 46(10): 1012–1024.

Barro, R., 1999, Human capital and growth in cross-country regressions, *Swedish Economic Policy Review*, 6(2): 237–277.

Barro, R.J., and Lee, J.-W., 2000, *International Data on Education Attainment: Updates and Implications*, NBER Working Paper Series 7911, National Bureau of Economic Research, MA, USA.

Bartel, A.P., and Sicherman, N., 1993, Technological change and retirement decisions of older workers, *Journal of Labor Economics*, 11(1): 162–183.

Bauer, T., Lofstrom, M., and Zimmermann, K.F., 2000, Immigration policy, assimilation of immigrants and natives' sentiments towards immigrants: Evidence from 12 OECD countries, *Swedish Economic Policy Review*, 7: 11–53.

Beckering, J.M., 1995, *A Sorting Method for Variance Reduction in Microsimulation Models: A Microsimulation Model to Analyze Income Tax Individualization*, Tilburg University Press, Tilburg, The Netherlands.

Bentolila, S., and Ichino, A., 2000, *Unemployment and Consumption. Are Job Losses Less Painful Near the Mediterranean?* CESifo Discussion Paper 2539, Munich, Germany.

Bergmann, A., and Mertens, A., 2002, *Job Stability Trends, Layoffs and Quits—An Empirical Analysis for West Germany*, (mimeo), Max Planck Institute for Human Development, Berlin, Germany.

Billari, F., Manfredi, P., and Valentini, A., 2000, Macro-demographic effects of the transition to adulthood: Multistate stable population theory and an application to Italy, *Mathematical Population Studies*, 9(1): 33–63.

Birch, E., Garfield, S., Hoffman, D., Uauy, R., and Birch, D., 2000, A randomized controlled trial of early dietary supply of long-chain polyunsaturated fatty acids and mental development in term infants, *Developmental Medicine & Child Neurology*, 42(3): 174–181.

Bishop, J.H., 1991, Achievement, test scores, and relative wages, in M. Kosters, ed., *Workers and Their Wages*, AEI Press, Washington, D.C., USA, pp.146–186.

Blossfeld, H.-P., and De Rose, A., 1992, Educational expansion and the changes in entry into marriage and motherhood. The experience of Italian women, *Genus*, 48: 73–89.

Blossfeld, H.-P., and Huinink, J., 1991, Human capital investments or norms of role transition? How women's schooling and career affect the process of family formation, *American Journal of Sociology*, 97: 143–168.

Blossfeld, H.-P., and Rohwer, G., 1995, *Techniques of Event History Modeling. New Approaches to Causal Analysis*, Lawrence Erlbaum Associates, Hillsdale, NJ, USA.

Blöndahl, S., and Scarpetta, S., 1998, *The Retirement Decision in the OECD Countries*, Economics Department Working Paper No. 202, Organisation for Economic Cooperation and Development, Paris, France.

Blum, J.E., Jarvik, L.F., and Clark, E.T., 1970, Rate of change on selective tests of intelligence. A twenty-year longitudinal study of aging, *Journal of Gerontology*, 25: 171–176.

Bobak, M., and Gjonca, A., 2001, The seasonality of live births is strongly influenced by socio-economic factors, *Human Reproduction*, 16(7): 1512–1517.

Boissiere, M., Knight, J.B., and Sabot, R.H., 1985, Earnings, schooling, ability and cognitive skills, *American Economic Review*, 75: 1016–1030.

Bologna Declaration, 1999, See http://www.bologna-berlin2003.de/pdf/bologna_declaration.pdf

Boot, H.M., 1995, How skilled were Lancashire cotton factory workers in 1833? *Economic History Review*, 2: 283–303.

Bouchard, T., Lykken, T., McGue, M., Segal, N., and Tellegen, A., 1990, Sources of human psychological differences: The Minnesota study of twins reared apart, *Science*, 250(4978): 223–228.

Bound, J., and Jaeger D.A., 1996, *On the Validity of Season of Birth as an Instrument in Wage Equations: A Comment on Angrist and Krueger's "Does Compulsory School Attendance Affect Schooling and Earnings?"* NBER Working Paper Series 5835, National Bureau of Economic Research, MA, USA.

Börsch-Supan, A., 2002, *Mehr Zuwanderung? Zur Rolle des Auslands bei der Stabilisierung der Gesetzlichen Rentenversicherung in Deutschland* [More Immigration? Concerning the Role of Other Countries in Stabilizing Public Pension Insurance in Germany], Mannheim Economics of Aging (MEA) Working Paper 22-2, Mannheim, Germany [in German].

Braathe, H.J., and Ongstad, S., 2001, Egalitarianism meets ideologies of mathematical education—Instances from Norwegian curricula and classrooms, *Zentralblatt für Didaktik der Mathematik*, 33(5): 1–11.

Brunborg, H., 1992, Dødelighet [Mortality], in O. Ljones, B. Moen, and L. Østby, eds., *Mennesker og Modeller* [Human Beings and Modelers], Social and Economic Studies 78, Statistics Norway, Oslo, Norway [in Norwegian].

Brunborg, H., and Mamelund, S.-E., 1994, *Kohort-og periodefruktbarhet i Norge 1980–1993* [Cohort and Period Fertility for Norway 1980–1993], Report No. 94/27, Statistics Norway, Oslo, Norway [in Norwegian].

Bundesamt für Statistik, 1999, *Bildung und Wissenschaft: Öffentliche Bildungsausgaben 1990–1997* [Education and Science: Public Educational Expenditure 1990–1997], Statistik der Schweiz 15, Neuchâtel, Switzerland [in German].

Bunk, S., 2000, Cognition and aging. A rare colony of old macaques gives clues to age impairment, *The Scientist*, 14: 18–19.

Burgess, S., and Rees, H., 1996, Job tenure in Britain, 1975–92, *The Economic Journal*, 106: 334–344.

Caldwell, S.B., 1996, Health, wealth, pensions, and life paths. The Corsim dynamic microsimulation model, in A. Harding, ed., *Micro-simulation and Public Policy*, North-Holland, Elsevier Science Publishers, Amsterdam, The Netherlands, pp. 505–521.

Card, D., 1999, The causal effect of education on earnings, in O. Ashenfelter and D. Card, eds., *Handbook of Labor Economics*, North-Holland, Elsevier Science Publishers, Amsterdam, The Netherlands, Chapter 30.

Ceci, 1991, S.J., How much does schooling influence general intelligence and its cognitive components? A reassessment of the evidence, *Developmental Psychology*, 27(5): 703–722.

Chatterji, M., Seaman, P., and Singell Jr., L., 2003, *A test of the signalling hypothesis*, Oxford Economic Papers, 55: 191–215.

Clark, R.E., York, A., and Anker, R., 1999, Economic development and labor force participation of older persons, *Population Research and Policy Review*, 18: 411–432.

College Board, 2002, *Average SAT Scores of Entering College Classes, 1967–2002*. See http://www.collegeboard.com/prod_downloads/about/news_info/cbsenior/yr2002/pdf /table2.pdf (Last accessed August 2005).

Colonia-Willner, R., 1998, Practical intelligence at work: Relationship between aging and cognitive efficiency among managers in a bank environment, *Psychology and Aging*, 13(1): 45–57.

Corijn, M., 1996, *Transition into Adulthood in Flanders. Results from the FFS*, NIDI/CBGS Publications, The Hague, The Netherlands.

Crépon, B., Deniau, N., and Perez-Duarte, S., 2002, *Wages, Productivity and Worker Characteristics. A French Perspective*, (mimeo), Institut National de la Statistique et des Etudes Economiques (INSEE), Paris, France.

Currie, J., and Thomas, D., 1999, *Early Test Scores, Socioeconomic Status and Future Outcomes*, NBER Working Paper Series 6943, National Bureau of Economic Research, MA, USA.

Dalton, G.W., and Thompson, P.H., 1971, Accelerating obsolescence of older engineers, *Harvard Business Review*, 49(5): 57–67.

Davies, D.R. and Sparrow, P.R., 1985, Age and work behavior, in N. Charness, ed., *Aging and Human Performance*, John Wiley and Sons, London, UK, pp. 293–332.

Davis, B.G., Trimble, C.S., and Vincent, D.R., 1980, Does age of entrance affect school achievement? *The Elementary School Journal*, 80: 133–143.

Deary, I.J., Whalley, L.J., Lemmon, H., Crawford J.R., and Starr, J.M., 2000, The stability of individual differences in mental ability from childhood to old age. Follow-up of the 1932 Scottish mental survey, *Intelligence*, 28(1): 49–55.

Deaton, A., 1997, *The Analysis of Household Surveys: A Microeconometric Approach to Development Policy*, The Johns Hopkins University Press, Baltimore, MD, USA.

Devlin, B., Daniels, M., and Roeder, K., 1997, The heritability of IQ, *Nature*, 388: 468–471.

Dickens, W., and Flynn, J., 2001, Heritability estimates versus large environmental effects: The IQ paradox resolved, *Psychological Review*, 108(2): 346–369.

Doblhammer, G., and Vaupel, J.W., 2001, Life span depends on month of birth, *Proceedings of the National Academy of Sciences*, 98(5): 2934–2939.

Dolton, P.J., and Vignoles, A.F., 2000, The pay-off to mathematics A-level, in C. Tikly and A. Wolf, eds., *The Maths We Need Now*, The Institute of Education, London, UK, pp. 52–73.

Easterlin, R.A., 1978, What will 1984 be like? Socioeconomic implications of recent twists in age structure, *Demography*, 15: 397–432.

ECON, 1996, *Innvandring og offentlig økonomi* [Immigration and Public Economics], Report 46/96, ECON Report 10047 to the Norwegian Department of Local Government and Labour, Oslo, Norway [in Norwegian].

EDK, 2003, Swiss Conference of Cantonal Ministers of Education. See www.edk.ch (Last accessed 20 October 2003).

Education Commission of the States, 1994, *Compulsory School Age Requirements*, Department of Education, Washington, D.C., USA, March.

Ekberg, J., and Andersson, L., 1995, *Innvandring, Sysselsättning och Ekonomiska Effekter* [Immigration, Employment, and Economic Effects], Report to Expertgruppen for studier i offentlig ekonomi, 68, Swedish Treasury Department, Stockholm, Sweden [in Swedish].

Ekhaugen, T., 2005, *Immigrants on Welfare: Assimilation and Benefit Substitution*, Memorandum 18/2005, Frisch Centre for Economic Research, Oslo, Norway. See www.oekonomi.uio.no/memo/memopdf/memo1805.pdf (Last accessed September 2005).

Ericsson, K.A., and Lehmann, A.C., 1996, Expert and exceptional performance: Evidence of maximal adaption to task constraints, *Annual Review of Psychology*, 47: 273–305.

Ermisch, J., and Francesconi, M., 2001, Family structure and children's achievements, *Journal of Population Economics*, 14(2): 249–270.

Eurydice, 2000, *Key Data on Education in Europe 1999/2000*, European Commission Brussels, Belgium.

Eva, K., 2002, The aging physician: Changes in cognitive processing and their impact on medical practice, *Academic Medicine*, 77(10 Suppl.): 1–6.

Fallows, J., 1980, The tests and the brightest, *The Atlantic Monthly*, 245(2): 37–48.

Flynn, J.R., 1987, Massive IQ gains in 14 nations: What IQ tests really measure, *Psychological Bulletin*, 101: 171–191.

Frazis, H., 2002, Human capital, signaling, and the pattern of returns to education, *Oxford Economic Papers*, 54: 298–320.

Fredrikssen, D., 1995, MOSART—Teknisk Dokumentasjon [MOSART—Technical Documentation], *Notater* 95(5), Statistics Norway, Oslo, Norway [in Norwegian].

Fredrikssen, D., 1996, *Projections of Population, Education, Labour Supply and Public Pension Benefits—Analyses with the Dynamic Micro-simulation Model MOSART*. Statistics Norway, Social and Economic Studies 101, Oslo, Norway.

Fredrikssen, D., and Koren, C., 1993, Kvinners forsørgelsesmønster og folketrygden [Female labor-force participation and the national insurance scheme], *Økonomiske Analyser*, 8/93, Statistics Norway, Oslo, Norway [in Norwegian].

Fredrikssen, D., and Spurkland, G., 1993, Framskriving av alders- og uføretrygd fra folketrygden ved hjelp av mikrosimulerings-modellen MOSART [Projections of old age and disability pension benefits from the national insurance scheme using the dynamic microsimulation model MOSART], *Reports*, 93/7, Statistics Norway, Oslo, Norway [in Norwegian].

Fronstin, P., Greenberg, D., and Robins, P., 2001, Parental disruption and the labour market performance of children when they reach adulthood, *Journal of Population Economics*, 14(1): 137–172.

Galen, J. van, 1995, *MICROS, a Microsimulation Model on Household Incomes: Structure, Development and Applications*, Paper presented at the Fourth Nordic Microsimulation Conference, Oslo, Norway.

GEM Consortium, 2004, National Team Reports. See www.gemconsortium.org/category_list.asp?cid=164 (Last accessed 21 April 2005).

Goldin, C., and Katz, L.F., 2002, The power of the pill: Oral contraceptives and women's career and marriage, *Journal of Political Economy*, 110(4): 730–770.

Golini, A., 2004, Demographic trends, aging and labour: The work of the young elderly: Is there willingness and possibility? Two Italian surveys among people and firms, *Manuscript*, Rome University, Rome, Italy.

Gonzalez, E., Smith, T., and Sibberns, H., 1998, *User Guide for the TIMSS International Database—Final Year of Secondary School (population 3)*, TIMSS International Study Center, Boston College, Chestnut Hill, MA, USA.

Gottfredson, L.S., 1998, The general intelligence factor, *Scientific American Presents*, 9(51): 24–29.

Grant, J., Hoorens, S., Sivadasan, S., van het Loo, M., DaVanzo, J., Hale, L., Gibson, S., and Butz, W., 2004, *Low Fertility and Population Ageing. Causes, Consequences, and Policy Options*, Rand Corporation, Santa Monica, CA, USA.

Gredler, G.R., 1984, Transition classes: A viable alternative for the at-risk child? *Psychology in the Schools*, 21: 463–470.

Grogger, J.T., and Eide, E., 1993, Changes in college skills and the rise in the college wage premium, *Journal of Human Resources*, 30(2): 280–310.

Gruber, J., 2000. *Is Making Divorce Easier Bad for Children? The Long Run Implications of Unilateral Divorce*, NBER Working Paper Series, 7968, National Bureau of Economic Research, Cambridge, MA, USA.

Gruber, J., and Wise, D., 2001, *An International Perspective on Policies for an Ageing Society*, NBER Working Paper Series, 8103, National Bureau of Economic Research, Cambridge, MA, USA.

Gustafsson, S., 2001, Optimal age at motherhood. Theoretical and empirical considerations on postponement of maternity in Europe, *Journal of Population Economics*, 14: 225–247.

Halpern, D., 2000, *Sex Differences in Cognitive Abilities*, Lawrence Erlbaum Associates, London, UK.

Haltiwanger, J.C., Lane, J.I., and Spletzer, J.R., 1999, Productivity differences across employers. The roles of employer size, age and human capital, *American Economic Review*, Papers and Proceedings 89(2): 94–98.

Hansen, K., Heckman, J., and Mullen, K., 2004, The Effect of Schooling and Ability on Achievement Test Scores, Journal of Econometrics, 121(1–2):39–98.

Hanushek, E., 1997, Assessing the effects of school resources on student performance: An update, *Educational Evaluation and Policy Analysis*, 19(2): 141–164.

Hanushek, E.A., and Kimko, D., 2000, Schooling, labor-force quality, and the growth of nations, *American Economic Review*, 90(5): 1184–1208.

Hanushek, E., and Luque, J., 2003, Efficiency and equity in schools around the world, *Economics of Education Review*, 20(5): 481–502.

Harmon, C., Walker, I., and Westergård-Nielsen, N., 2001, *Education and Earnings in Europe—A Cross Country Analysis of Returns to Education*, Edward Elgar Publishing, Cheltenham, UK.

Harris, M., and Homstrom, B., 1982, A theory of wage dynamics, *Review of Economic Studies*, 49: 316–333.

Hartigan, J., and Wigdor, A.K., 1989, *Fairness in Employment Testing*, National Academies Press, Washington, D.C., USA.

Hægeland, T., and Klette, T.J., 1999, Do higher wages reflect higher productivity? Education, gender and experience premiums in a matched plant-worker data set, in J.C. Haltiwanger, J.R. Spletzer, J. Theeuwes, and K. Troske, eds., *The Creation and Analysis of Employer-Employee Matched Data*, Elsevier Science Publishing Company, The Netherlands, pp. 231–261.

Hellerstein, J.K., and Neumark, D., 1995, Are earnings profiles steeper than productivity profiles? Evidence from Israeli firm-level data, *Journal of Human Resources*, 30(1): 89–112.

Hellerstein, J., and Neumark, D., 2004, *Production Function and Wage Equation Estimation with Heterogeneous Labor: Evidence from a New Matched Employer–Employee Data Set*, NBER Working Paper Series, National Bureau of Economic Research, MA, USA.

Hellerstein, J.K., Neumark, D., and Troske, K.R., 1996, *Wages, Productivity and Worker Characteristics: Evidence from Plant Level Production Function and Wage Equations*, NBER Working Paper Series, 5626, National Bureau of Economic Research, Cambridge, MA, USA.

Hellerstein, J.K., Neumark, D., and Troske, K.R., 1999, Wages, productivity and worker characteristics: Evidence from plant level production function and wage equations, *Journal of Labor Economics*, 17: 409–446.

Hoem, B., 2000, Entry into motherhood in Sweden: The influence of economic factors on the rise and fall in fertility, 1986–1997, *Demographic Research*, 2(4).

Hogan, D., 1978, The effects of demographic factors, Family background and early job achievement on age at marriage, *Demography*, 15: 161–175.

Horn, J.L., and Cattell, R., 1966, Refinement and test of the theory of fluid and crystallized intelligence, *Journal of Educational Psychology*, 57: 253–270.

Horn, J.L., and Cattell, R., 1967, Age differences in fluid and crystallized intelligence, *Acta Psychologica*, 26: 107–129.

Hoyer, W.J., and Lincourt, A.E., 1998, Aging and the development of learning, in M.A. Stadler, ed., *Handbook of implicit learning*, Sage Publications, London, UK, pp. 445–470.

Høigård, E., and Ruge, H., 1947, *Den Norske Skoles Historie: En Oversikt* [The History of the Norwegian School: An Overview], Cappelen, Oslo, Norway [in Norwegian].

Hungerford, T., and Solon, G., 1987, Sheepskin effects in the returns to education, *Review of Economics and Statistics*, 69(1): 175–177

Hutchens, R., 1989, Seniority, wages and productivity: A turbulent decade, *Journal of Economic Perspectives*, 3(4): 49–64.

IEA, 2000. *International Mathematics Report*, International Association for the Evaluation of Educational Achievement, Boston, MA, USA.

Ilmakunnas, P., Maliranta, M., and Vainiomäki, J., 1999, *The Role of Employer and Employee Characteristics for Plant Productivity*, Working Paper of the Helsinki School of Economics and Business Administration, Helsinki, Finland, p. 223.

International Adult Literacy Survey, 2001, *Literacy, Numeracy and Labour Market Outcomes in Canada*, Statistics Canada, Ottawa, Canada.

Jackson, W.A., 1998, *Political Economy of Population Ageing*, Edward Elgar Publishing, Cheltenham, UK.

Jaeger, D., and Page, M., 1996, Degrees matter: New evidence on sheepskin effects in the returns to education, *Review of Economics and Statistics*, 78(4): 733–739.

Jenkins, A., 2001, Companies' use of psychometric testing and the changing demand for skills: A review of the literature, *Centre for the Economics of Education Discussion Paper*, CEEDP0012, London School of Economics, London, UK. Download at http://cee.lse.ac.uk/cee%20dps/CEEDP12.pdf (Last accessed July 2005).

Jimeno, J., and Rodriguez-Palenzuela, D., 2002, Youth unemployment in the OECD: Demographic shifts, labour market institutions, and macroeconomic shocks, *European Central Bank Working Paper*, 155, ECB, Frankfurt, Germany.

Jones, M.M., and Mandeville, G.K., 1990, The effect of age at school entry on reading achievement scores among South Carolina students, *Remedial and Special Education*, 11: 56–62.

Jørgensen, T., 1997, Utdanning i Norge [Education in Norway], *Statistical Analyses* 19, Statistics Norway [in Norwegian].

Juhn, C., Murphy, K.M., and Pierce, B., 1993, Wage inequality and the rise in returns to skill, *Journal of Political Economy*, 101(3): 410–442.

Jürges, H., Schneider, K., and Büchel, F., 2003, *The Effect of Central Exit Examinations on Student Achievement: Quasi-Experimental Evidence from TIMSS Germany*, CESifo Working Paper, 939, May.

Katz, L., and Murphy, K., 1992, Changes in relative wages, 1963–1987: Supply and demand factors, *Quarterly Journal of Economics*, 107(1): 35–78.

Keilman, N., and Brunborg, H., 1995, *Household Projections for Norway 1990–2020, Part 1: Macrosimulations*, Reports 95/21, Statistics Norway, Oslo, Norway.

Kirkerud, B., 1989, *Object-Oriented Programming with Simula*, Addison-Wesley, Boston, MA, USA.

Kjærnsli, M., and Lie, S., 2002, TIMSS science results seen from a Nordic perspective, in D.F. Robitaille and A.E. Beaton, eds., *Secondary Analysis of the TIMSS Data*, Kluwer Academic Publishers, Dordrecht, The Netherlands, pp.193–208

Kohler, H.P., Skytthe, A., and Christensen, K., 2001, *The Age at First Birth and Completed Fertility Reconsidered: Findings from a Sample of Identical Twins*, Working Paper 2001-006, Max Planck Institute for Demographic Research, Rostock, Germany.

Kohler, H.P., Billari, F.B, and Ortega, J.A., 2002, The emergence of lowest-low fertility in Europe during the 1990s, *Population and Development Review*, 28(4): 641–680.

Kravdal, Ø., 1986, *Framskriving av Befolkningen etter Kjønn, Alder og Ekteskapelig Status, 1985–2050* [Population Projections by Gender, Age, and Marital Status 1985–2050], Reports 86/27, Statistics Norway, Oslo, Norway [in Norwegian].

Kravdal, Ø., 1994, *Sociodemographic Studies of Fertility and Divorce in Norway with Emphasis on the Importance of Economic Factors*, Social and Economic Studies 90, Statistics Norway, Oslo, Norway.

Kunzel, N.R., Hezlett, S.A., and Ones, D.S., 2004, Academic Performance, career potential, creativity, and job performance: Can one construct predict them all? *Journal of Personality and Social Psychology*, 86(1): 148–161.

Kutscher, R.E. and Walker, J.F., 1960, Comparative job performance of office workers by age, *Monthly Labor Review*, 83(1): 39–43.

Langer, P., Kalk, J.M., and Searls, D.T., 1984, Age of admission and trends in achievement: A comparison of Blacks and Caucasians, *American Educational Research Journal*, 21: 61–67.

Layard, R., Nickell, S., and Jackman, R., 1991, *Unemployment: Macroeconomic Performance and the Labor Market*, Oxford University Press, Oxford, UK.

Lazear, E.P., 1979, Why is there mandatory retirement? *Journal of Political Economy*, 87(6): 1261–1284.

Lazear, E.P., 1988, *Adjusting to an Aging Labor Force*, NBER Working Paper Series, 2802, National Bureau of Economic Research, Cambridge, MA, USA.

Lazear, E.P., and Moore R., 1984, Incentives, productivity, and labor contracts, *The Quarterly Journal of Economics*, 99(2): 275–296.

Lee, R., and Miller, T., 1997, The future fiscal impacts of current immigrants, in J. Smith and B. Edmonston, eds., *The New Americans: Economic, Demographic, and Fiscal Effect of Immigration*, National Academies Press, Washington, D.C., USA, pp. 297–362.

Lehman, H.C., 1953, *Age and Achievement*, American Philosophical Society, Princeton University Press, Princeton, NJ, USA.

Lektorbladet, 2003, *Når kvalitet betyr nedskjæring* [When quality means budget cuts], *Lektorbladet*, 2 (2) [in Norwegian].

Lenzen, D., 2003, *Bildung Neu Denken!* [Rethink Education!], Leske & Budrich, Opladen, Germany [in German].

Lesgold, A., 1984, Acquiring expertise, in J. Anderson and S. Kosslyn, eds., *Tutorials in Learning and Memory: Essays in Honor of Gordon Bower*, Freeman, New York, USA, pp.31–60.

Levin, H.M., 1995, Work and Education, in M. Carnoy, ed., *Encyclopedia of Economics of Education*, Pergamon Press, Oxford, UK, pp.10–20.

Lindh, T., and Malmberg, B., 1999, Age structure and growth in the OECD, *Journal of Population Economics*, 12(3): 431–449.

Loehlin J.C., Horn, J.M., and Willerman, L., 1997, Heredity, Environment and IQ in the Texas Adoption Study, in R.J. Sternberg and E.L. Grigorenko, eds., *Heredity and Environment*, Cambridge University Press, Cambridge, UK, pp.105–125.

Lucas, A., Morley, R., Cole, T.J., Lister G., and Leeson-Payne, C., 1992, Breast milk and subsequent intelligence quotient in children born pre-term, *The Lancet*, 339(8788): 261–264.

Luttmer, E., 2001, Group loyalty and the taste for redistribution, *Journal of Political Economy*, 109(3): 500–528.

Lutz, W., and Scherbov, S., 2003, Can Immigration Compensate for Europe's Low Fertility? Interim Report IR-02-052, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Lutz, W., and Skirbekk, V., 2004, *How Would Tempo Policies Work? Exploring the Effect of School Reforms on Period Fertility in Europe*, Paper presented at the Annual Meeting of the Population Association of America, Boston, MA, USA, 1–3 April.

Lutz, W., and Skirbekk, V., 2005, Policies addressing the tempo effect in low fertility countries, *Population and Development Review*, 31(4), December.

Maitland, S.B., Intrieri, R.C., Schaie, K.W., and Willis, S.L., 2000, Gender differences and changes in cognitive abilities across the adult life span, *Aging, Neuropsychology, and Cognition*, 7(1): 32–53.

Malmberg, B., and Lindh, T., 2002, *Population Change and Economic Growth in the Western World, 1850–1990*, Paper presented at the 3rd Max Planck Institute Workshop on Demographic Macroeconomic Modeling, held in Rostock, Germany, September.

Marini, M.M., 1984, The order of events in the transition to adulthood, *Sociology of Education*, 57: 63–84.

Mark, J.A., 1957, Comparative job performance by age, *Monthly Labor Review*, 80: 1467–1471.

Martin, L.G., and Ogawa, N., 1988, The effect of cohort size on relative wages in Japan, in R. Lee, W. Arthur, and G. Rodgers, eds., *Economics of Changing Age Distributions in Developed Countries*, International Studies in Demography, Clarendon Press, Oxford, UK, pp. 59–75.

McEvoy, G.M., and Cascio, W.F., 1989, Cumulative evidence of the relationship between employee age and job performance, *Journal of Applied Psychology*, 74(1): 11–17.

McGue, M., and Bouchard, T., 1998, Genetic and environmental influences on human behavioral differences, *Annual Review of Neuroscience*, 21: 1–24.

McGue, M., Bouchard Jr., T.J., Iacona W.G., and Lykken D.T., 1993, Behavioral genetics of cognitive ability: A life span perspective, in R. Plomin and G.E. McClearn, eds., *Nature, Nurture and Psychology*, American Psychological Association Press, Washington, D.C., USA, pp. 59–76.

Medoff, J.L., and Abraham, K.G., 1980, Experience, performance, and earnings, *Quarterly Journal of Economics*, 95(4): 703–736.

Medoff, J.L., and Abraham, K.G., 1981, Are those paid more really more productive? The case of experience, *Journal of Human Resources*, 16(2): 186–216.

Meghir, C., and Palme, M., 2003, *The Effect of a Social Experiment in Education*, Institute for Fiscal Studies Working Paper W03/05, London, UK.

Miller, G.F., 1999, Sexual Selection for Cultural Displays, in R. Dunbar, C. Knight, and C. Power, eds., *The Evolution of Culture*, Edinburgh University Press, Edinburgh, UK,

Mincer, J., 1974, *Schooling Experience and Earnings*, Columbia University Press, New York, USA.

Mincer, J., 1980, Human Capital and Earnings, in A.B. Atkinson., ed., *Wealth, Income and Inequality*, second edition, Oxford University Press, Oxford, UK. pp. 71–91.

Minois, N. and Le Bourg, E., 1997, Hypergravity and aging in drosophila melonagaster. Conditioned suppression and habituation of the proboscis extension response, *Aging, Experimental and Clinical Research*, 9(4): 1–11.

Mitra, A., 2002, Mathematics skill and male–female wages, *Journal of Socio-Economics* 31(5): 443–456

Moulton, B., 1990, An illustration of a pitfall in estimating the effects of aggregate variables on micro unit, *The Review of Economics and Statistics*, 72(2): 334–338.

Mullis, I., Martin, M., Beaton, A., Gonzalez, E., Kelly, D., and Smith, T., 1998, *Mathematics and Science Achievement in the Final Year of Secondary School*, IEA's Third International Mathematics and Science Study (TIMSS), TIMSS International Study Center, Boston College, Chestnut Hill, MA, USA.

Murnane, R.J., Willett, J.B., and Levy, F., 1995, The growing importance of cognitive skills in wage determination, *Review of Economics and Statistics*, 77(2): 251–266.

Murnane, R.J., Willett, J.B., Duhaldeborde, Y., and Tyler J.H., 2000, How important are the cognitive skills of teenagers in predicting subsequent earnings? *Journal of Policy Analysis and Management*, 19(4): 547–568.

Myerson, J., Hale, S., Wagstaff, D., Ponn L.W., and Smith, G.A., 1990, The information loss model: A mathematical theory of age-related slowing, *Psychological Review*, 97(4): 475–486.

Neiss, M., Rowe, D.C., and Rodgers, J.L., 2002, Does education mediate the relationship between IQ and age of first birth? A behavioral genetic analysis, *Journal of Biosocial Science*, 34: 259–275.

Neisser, U., Bood, G., Bouchard, T.J., Broykin, A.W., Brody, N., Ceci, S.J., Halpern, D.F., Loehlin, J.C., Perloff, R., Sternberg R.J., and Urbina, S., 1996, Intelligence: Knowns and unknowns, *American Psychologist*, 51: 77–101

Nigg, J.T., and Goldsmith, H.H., 1994, Genetics of personality disorders: Perspectives from personality and psychopathology research, *Psychological Bulletin*, 115: 346–380.

Nishimura, K.G., Minetaki, K., Shirai, M., and Kurokawa, F., 2002, *Effects of Information Technology and Aging Work Force on Labor Demand and Technological Progress in Japanese Industries: 1980–1998*, Discussion Paper CIRJE-F-145, Faculty of Economics, University of Tokyo, Japan.

Nonaka, K., Nakamura, I., Shimura M., and Miura T., 1987, Secondary sex ratio and the month of a mother's birth—A hypothesis of sex-ratio-decreasing factors, *Progress in Biometeorology*, 5:51–60.

Norwegian Ministry of Health and Social Affairs, 1995, *The Norwegian Social Insurance Scheme: A Survey*, Publications of the Norwegian Ministry of Health and Social Affairs, Oslo, Norway.

NOS, 2002, *Framskriving av folkemengden 1999–2050, Nasjonale og regionale tall* [Population Projections 1999–2050: National and Regional Figures], Statistics Norway, Oslo-Kongsvinger [in Norwegian].

NOU, 1990:17, *Uførepensjon* [Disability Pension], Norwegian Official Reports, Ministry of Health and Social Affairs, Oslo, Norway [in Norwegian].

NOU, 1991:28, *Mot Bedre Vitende? Effektiviseringsmuligheter i Offentlig Sektor* [Against Better Knowledge. Efficiency Opportunities in the Public Sector], Norwegian publicly commissioned paper, NOU, Oslo, Norway [in Norwegian].

NOU, 2000:14, *Frihet med Ansvar* [Freedom with Responsibility], Norwegian publicly commissioned paper, NOU, Oslo, Norway [in Norwegian].

NOU, 2000:21, *En Strategi for Sysselsetting og Verdiskaping* [A Strategy for Increasing Employment and Productivity], Norwegian publicly commissioned paper, NOU, Oslo, Norway [in Norwegian].

NOU, 2002:10, *Førsteklasses fra Første Klasse. Forslag til Rammeverk for et Nasjonalt Kvalitetsvurderingssystem av Norsk Grunnopplæring* [First Class from First Grade. Suggestion for a Framework to Nationally Evaluate Norwegian Primary and Secondary School], Norwegian publicly commissioned paper, Utdannings- og Forskningsdepartementet, NOU, Oslo, Norway [in Norwegian].

NOU, 2003:16, *I Første Rekke* [In the First Row], Norwegian publicly commissioned paper, Utdannings- og Forskningsdepartementet, NOU, Oslo, Norway [in Norwegian].

Odelstingsinnstilling 2001, *Innstilling Fra Familie-, Kultur- og Administrasjonskomiteen om Lov om Endringer i Barnelova, Forskotteringsloven og i Enkelte Andre Lover (Nye Regler for Beregning av Barnebidrag m.m.)* [Family, Culture, and Administrative Committee on Child Laws, Advance Laws and other Laws (Including New Rules for Calculation of Child Allowance)], Innst.O. 127 (2000–2001) [in Norwegian].

OECD, 1998, *Work Force Ageing: Consequences and Policy Responses, Maintaining Prosperity in an Ageing Society: The OECD Study on the Policy Implications of Ageing*, Working Paper AWP 4.1, Organisation for Economic Co-operation and Development, Paris, France.

OECD, 1999, *Thematic Review of the Transition from Initial Education to Working Life*, Final Comparative Report, Directorate for Education, Employment, Labour and Social Affairs, Education Committee, DEELA/ED (99) 11, Organisation for Economic Co-operation and Development, Paris, France.

OECD, 2000, *From Initial Education to Working Life. Making Transition Work*, Organisation for Economic Co-operation and Development, Paris, France.

OECD, 2001, The OECD Programme for International Student Assessment (PISA), Organisation for Economic Co-operation and Development, Paris, France.

OECD, 2002, Increasing employment: The role of later retirement, in *Economic Outlook* (72), Organisation for Economic Co-operation and Development, Paris, France, December.

OECD, 2003a, *Employment Outlook. Towards More and Better Jobs*, Organisation for Economic Co-operation and Development, Paris, France.

OECD, 2003b, *Low Fertility Rates in OECD countries: Facts and Policy Responses*, Social, Employment and Migration Working Papers, 15, Organisation for Economic Co-operation and Development, Paris, France.

OECD, 2003c, *Education at a Glance*, Organisation for Economic Co-operation and Development, Paris, France.

Oosterbeek, H., and Webbink, D., 2003, *Who Gains from Increasing Compulsory Education?* Paper given at the Conference of the European Association of Labour Economists (EALE), held in Seville, Spain.

Orcutt, G., 1957, A new type of socio-economic system, *Review of Economics and Statistics*, 39: 116–123.

Orcutt, G.H., Caldwell, S., Wertheimer, R.R., Franklin, S., Hendricks, G., Peabody, G., Smith, J., and Zedlewski, S., 1976, *Policy Exploration Through Microanalytic Simulation*, The Urban Institute, Washington, D.C., USA.

Orcutt, G.H., 1986, Views on microanalytic simulation modeling in G.H. Orcutt, J. Merz, and H. Quinke, eds., *Microanalytic Simulation Models to Support Social and Financial Policy*, Elsevier Science Publishers, North-Holland, Amsterdam, The Netherlands, pp. 9–29.

Orcutt, G.H., Merz J., and Quinke, H., eds., 1986, *Microanalytic Simulation Models to Support Social and Financial Policy*, Elsevier Science Publishers, North-Holland, Amsterdam, The Netherlands.

Oster, S.M., and Hamermesh, D.S., 1998, Aging and productivity among economists, *The Review of Economics and Statistics*, 80(1): 154–156.

Park, D.C., Nisbett, R.E., and Hedden, T., 1999, Culture, cognition, and aging, *Journal of Gerontology*, 54B: 75–84.

Park, J., 1999, Estimation of sheepskin effects using the old and the new measures of educational attainment in the current population survey, *Economic Letters*, 62: 237–240.

Pedersen, N., Plomin, R., Nesselroade, J.R., McClearn, G.E., 1992, A quantitative genetic analysis of cognitive abilities during the second half of the life span, *Psychological Science*, 3: 346–353.

Phelps, R., and Shanteau, J., 1978, Livestock judges: How much information can an expert use? *Organizational Behavior and Human Performance*, 19(4): 209–219.

Pischke, J., 2003, *The Impact of Length of the School Year on Student Performance and Earnings: Evidence from the German Short School Year*, NBER Working Paper Series 5835, National Bureau of Economic Research, MA, USA.

Planas, J., 1999, School-to-work transition in Spain, in D. Stern and D. Wagner, eds., *International Perspectives on the School-To-Work Transition*, Hampton Press, NJ, USA, pp. 413–422.

Plomin, R., and Petrill, S.A., 1997, Genetics and intelligence: What's new? *Intelligence*, 24: 53–77.

Plug, E.J.S., 2001, Season of Birth, Schooling and Earnings, *Journal of Economic Psychology*, 22: 641–660.

Plug, E., and Vijerberg, W., 2003, Schooling, family background, and adoption: Is it nature or is it nurture? *Journal of Political Economy*, 111(3): 611–641.

Psacharopoulos, G., 1994, Returns to investment in education: A global update, *World Development*, 22(9): 1325–1343.

Psacharopoulos, G., and Layard, R., 1974, The screening hypothesis and the returns to education, *Journal of Political Economy*, 82(5): 985–998.

Raaum, O., and Aabo, T.E., 2000, The effect of schooling on earnings: Evidence on the role of family background from a large sample of Norwegian twins, *Nordic Journal of Political Economy*, 26(2): 95–113.

Raskin, E., 1936, Comparison of scientific and literary ability: A biographical study of eminent scientists and letters of the nineteenth century, *Journal of Abnormal and Social Psychology*, 31: 20–35.

Remery, C., Schippers, H.K., Ekamper, J., and Ekamper, P., 2003, Managing an aging workforce and a tight labor market: Views held by Dutch employers, *Population Research and Policy Review*, 22: 21–40.

Retherford, R.D., and Sewell, W.H., 1989, How intelligence affects fertility, *Intelligence*, 13: 169–185.

Riksförsakringsverket, 2002, *Föräldrapenning–Vägledningar* [Maternity Benefit Guidance], National Social Insurance Board, Stockholm, Sweden [in Swedish].

Rindfuss, R., Bumpass, L., and St. John, C., 1980, Education and fertility: Implications for the roles women occupy, *American Sociological Review*, 45: 431–447.

Rodgers, J.L., 1999, Massive IQ gains. Methodological artifacts, or both? *Intelligence*, 26(4): 337–356.

Rosenzweig, M.R., and Wolpin, K.I., 2000, Natural "natural experiments" in Economics, *Journal of Economic Literature*, 38: 827–874.

Rubin, D.K., and Perloff, J.M., 1993, Who works for piece rates and why, *American Journal Of Agricultural Economics*, 627: 1036–1043.

Rybash, J.M., Hoyer, W., and Roodin, P.A., 1986, *Adult Cognition and Ageing*, Pergamon Press, New York, USA.

Salthouse, T., 1984, Effects of age and skills in typing, *Journal of Experimental Psychology*, 113: 345–371.

Salthouse, T., and Maurer, T.J., 1996, Aging, job performance and career development, in J.E. Birren and K.W. Schaie, eds., *Handbook of the Psychology of Aging*, fourth edition, Academic Press, San Diego, CA, USA, pp. 353–364.

Schaie, K.W., 1994, The course of adult intellectual development, *American Psychologist*, 49: 304–313.

Schaie, K.W., 1996, *Intellectual Development in Adulthood. The Seattle Longitudinal Study*, Cambridge University Press, New York, USA.

Schaie, K.W., and Willis, S.L., 1986a, Training the elderly on the ability factors of spatial orientation and inductive reasoning, *Psychology and Aging*, 1(3): 239–247.

Schaie, K.W., and Willis, S.L., 1986b, Can decline in intellectual functioning be reversed? *Developmental Psychology*, 22(2): 223–232.

Schmidt, F.L., and Hunter, J.E., 1998, The validity and utility of selection methods in personnel psychology: Practical and theoretical implications of 85 years of research findings, *Psychological Bulletin*, 124(2): 262–274.

Schmidt, F.L., and Hunter, J.E., 2004, General mental ability in the world of work: Occupational attainment and job performance, *Journal of Personality and Social Psychology*, 86(1), 162–173.

Schwartzman, A.E., Gold, D., Andres, D., Arbuckle, T.Y., and Chaikelson, J., 1987, Stability of intelligence. A 40 year follow-up, *Canadian Journal of Psychology*, 41: 244–256.

Sham, P.C., O'Callaghan, E., Takei, N., Murray, G.K., Hare, E.H., and Murray, T.M., 1992, Schizophrenia following prenatal exposure to influenza epidemics between 1930 and 1960, *British Journal of Psychiatry*, 160: 461–466.

Sharp, C., 1995, What's age got to do with it? A study of patterns of school entry and the impact of season of birth on school attainment, *Educational Research*, 37(3): 251–265.

Shepard, L.A., and Smith, M.L., 1986, Synthesis of research on school readiness and kindergarten retention, *Educational Leadership*, 44: 78–86.

Shimer, R., 2001, The impact of young workers on the aggregate labor market, *Quarterly Journal of Economics*, 116: 969–1007.

Simon, R., and Lynch, J.P., 1999, A comparative assessment of public opinion towards immigrants and immigration policies, *International Migration Review*, 33(2): 455–467.

Skirbekk, V., 2004, Age and individual productivity: A literature survey, in G. Feichtinger, ed., *Vienna Yearbook of Population Research*, Verlag der Österreichischen Akademie der Wissenschaften, Vienna, Austria.

Skirbekk, V., 2006, Does school duration affect student performance? Findings from canton-based variation in Swiss educational length, *Swiss Journal of Economics and Statistics*, 142(1).

Skirbekk, V., Kohler, H.-P., and Prskawetz, A., 2003, *Completing Education and the Timing of Births and Marriage: Findings From a Birth-Month Experiment in Sweden*, Working Paper WP-2003-017, Max Planck Institute for Demographic Research, Rostock, Germany.

Skirbekk, V., Kohler, H.-P., and Prskawetz, A., 2004a, Birth month, school graduation and the timing of births and marriages, *Demography*, 41(3): 547–568.

Skirbekk, V., Kohler, H.-P., and Prskawetz, A., 2004b, The marginal effect of school leaving age on demographic events. A contribution to the discussion on causality, in S. Gustafsson and A. Kalwij, eds., *Education and Postponement of Maternity*, Kluwer Publications, Amsterdam, The Netherlands.

Smeeding, T., 2004, *Income Distribution and Social Expenditure: Health, Education, and Cash*, Presentation at the Annual Meeting of the Population Association of America, held in Boston, MA, USA, 1–3 April.

Smith, A.D., 1996, Memory, in J.E. Birren and K.W. Schaie, eds., *Handbook of the Psychology of Aging*, fourth edition, Academic Press, San Diego, CA, USA, pp. 236–247.

Smith, H.L., 1990, Specification problems in experimental and nonexperimental social research, *Sociological Methodology*, 20: 59–91.

Smithers, A.G., and Cooper H.J., 1984, Social class and season of birth, *Journal of Social Psychology*, 124: 79–84.

Snijders, T., and Bosker, R.J., 1999, *Multilevel Analysis. An Introduction to Basic and Advanced Multilevel Modeling*, Sage Publications, London, UK.

Spence, M., 1973, Job market signalling, *Quarterly Journal of Economics*, 87: 355–374.

Spielauer, M., 2002, *Dynamic Microsimulation of Health Care Demand, Health Care Finance and the Economic Impact of Health Behavior. Part II: Survey and Review*, Interim Report IR-02-036, International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Spitz, A., 2004, *Are Skill Requirements in the Workplace Rising? Stylized Facts and Evidence on Skill-Based Technological Change*, ZEW Discussion Paper No. 04-33, Mannheim, Germany.

Stanfors, M., 2003, *Education, Labor Force Participation and Changing Fertility Patterns. A Study of Women and Socioeconomic Change in Twentieth Century Sweden*, Lund Studies in Economic History 22, Almqvist and Wiksell International, Sweden.

StataCorp, 2001, *Stata Statistical Software: Release 7.0.*, StataCorp LP, College Station, TX, USA.

Statistics Austria, 2003, *Volkszählung 2001—Entscheidungsgrundlagen für unsere Zukunft* [Population Census 2001—Decision Basis for our Future], Presentation by E. Kutzenberger, Statistics Austria, Vienna, Austria, 5 May [in German].

Statistics Norway, 1989, *Norwegian Standard Classification of Education, Revised 1989*, Standards for Norwegian Statistics, Oslo, Norway.

Statistics Norway, 1994, *Population Projections 1993–2050, National and Regional Figures*, Official Statistics of Norway, NOS C 176, Oslo, Norway.

Statistics Norway, 2003, Holdning til innvandrere og Innvandring. Spørsmål i SSBs omnibus undersøkelse august/september 2003 [Attitudes to immigrants and immigration. Question in Statistics Norway's omnibus survey August/September 2003] *Notater* 2003, 87, Oslo, Norway [in Norwegian].

Statistics Norway, 2004, *Stadig flere med høyere utdanning* [The number of highly educated increases further] Official Statistics of Norway, Oslo, Norway [in Norwegian]. See http://www.ssb.no/emner/04/01/utniv/arkiv/ (Last accessed September 2005).

Statistics Sweden, 1998, *Barnafödande och sysselättning. Upp- och nedgången i fruktsamheten 1985-1997* [Childbearing and Employment. The Increase and the Decrease in Fertility 1985–1997], Statistics Sweden, Stockholm, Sweden [in Swedish].

Statistics Sweden, 2000, *Befolkningsstatistik del 4 för 1999* [Population Statistics, Part 4 for 1999], Statistics Sweden, Stockholm, Sweden [in Swedish].

Statistisk Tidsskrift, 1962, *Elevernas Ålder Höstterminen, 1960* [Age Distribution of Pupils in Different Sections of the Educational System, 1960], Statistics Sweden, Stockholm, Sweden [in Swedish].

Statistiska Meddelanden 1964, *Elevernas Ålder Höstterminen, 1963* [Age Distribution of Pupils, 1963], Statistics Sweden, Stockholm, Sweden [in Swedish].

Statistiska Meddelanden 1968, *Elevernas Ålder Höstterminen, 1966* [Age Distribution of Pupils, 1966], Statistics Sweden, Stockholm, Sweden [in Swedish].

Statistiska Meddelanden 1970, *Elevernas Ålder Höstterminen, 1969* [Age Distribution of Pupils, 1969], Statistics Sweden, Stockholm, Sweden [in Swedish].

Steinerskolen, 2003, Steinerskolen—En Introduksjon [The Steiner School–An Introduction] http://www.vestfold.steinerskolen.no/introduksjon/SBintroduksjon.pdf (Last accessed 30 January 2004).

Stephan, P.E., and Levin, S.G., 1988, Measures of Scientific Output and the Age–Productivity Relationship, in A. Van Raan, ed., *Handbook of Quantitative Studies of Science and Technology*, Elsevier Science Publishers, Amsterdam, The Netherlands, pp. 31–80.

Stiglitz, J.E., 1975, The theory of screening, education and the distribution of income, *American Economic Review*, 65: 283–300.

Storesletten, K., 2000, Sustaining fiscal policy through immigration, *Journal of Political Economy*, 108(21): 300–323.

Storesletten, K., 2003, Fiscal implications of immigration—A net present value calculation, *Scandinavian Journal of Economics*, 105(3): 487–506.

Streissguth, A., Barr, H.M., Sampson, P.D., Darby, B.L., and Marin, D.C., 1989, IQ at age 4 in relation to maternal alcohol use and smoking during pregnancy, *Developmental Psychology*, 25(1): 3–11.

Teasdale, T.W., and Owen, D., 1984, Heritability and family environment in intelligence and education level—A sibling study, *Nature*, 309: 620–622.

Teltsch, T. and Breznitz, Z., 1988, The effect of school entrance age on academic achievement and social–emotional adjustment of children, *Journal of Genetic Psychology*, 149(4): 471–483.

Teulings, C., and Van Rens, T., 2002, *Education, Growth and Income Inequality*, Discussion Paper 3, Tinbergen Institute, The Netherlands.

Texmon, I., 1992, Norske befolkningsframskrivinger 1969–1985 [Norwegian population projections 1969–1985] in O. Ljones, B. Moen, and L. Østby, eds., *Mennesker og Modeller—Livsløp og Kryssløp* [Men, Models, and Life Courses], Social and Economic Studies 78, Statistics Norway, Oslo, Norway [in Norwegian].

Thompson, A.H., Barnsley, R., and Stebelsky, G., 1991, Born to play ball: The relative age effect and major league basketball, *Sociology of Sport Journal*, 8: 146–151.

Trygdetaten, 2003, *Ytelser ved Svangerskap, Fødsel og Adopsjon* [Benefits for Pregnancy, Births and Adoption], Information Brochure, Folketrygden [National Office for Social Insurance], Oslo, Norway [in Norwegian].

Tuddenham, R.D., 1948, Soldier intelligence in World Wars I and II, *American Psychologist*, 3: 54–56.

Turner D., Giorno, G., De Serres, A., Vourc'h, A., and Richardson, P., 1998, *The Macroeconomic Implications of Ageing in a Global Context*, OECD Working Paper 63, Economics Department, Organisation for Economic Co-operation and Development, Paris, France.

Tyler, J.H., Murnane, R.J., and Willett, J.B., 2000, Do the cognitive skills of school dropouts matter in the labor market? *Journal of Human Resources*, 35(4): 748–754.

Uauy, R., and Peirano, P., 1999, Breast is best: Human milk is the optimal food for brain development, *American Journal of Clinical Nutrition*, 70: 433–434.

UNESCO, 1999, *Statistical Yearbook*, Bernan Press, Lanham, MD, USA.

UNESCO, 2003, *Global Education Digest 2003: Comparing Education Statistics Across the World*. United Nations Educational, Scientific and Cultural Organization, New York, USA. See http://portal.unesco.org/uis/TEMPLATE/pdf/ged/GED_EN.pdf (Last accessed 13 March 2004).

UNESCO, 2004, *Length, Starting, and Ending Age of Compulsory Education*, United Nations Education, Scientific and Cultural Organization, Institute for Statistics, New York, USA. See http://stats.uis.unesco.org/eng/TableViewer/Wdsview/dispviewp.asp?ReportId=30 (Last accessed 15 March 2004).

United Nations, 2005, *World Population Prospects: The 2004 Revision*, United Nations, Population Division, New York, USA.

Uphoff, J.K., and Gilmore, J., 1985, Pupil age at school entrance—How many are ready for success? *Educational Leadership*, 43: 86–90.

U.S. Department of Health, 1965, *State Law on Compulsory Attendance*, Department of Health, Education and Welfare, Office of Education, Washington, D.C., USA.

U.S. Department of Labor, 1957, Comparative job performance by age. Large plants in the men's footwear and household furniture industries, *Monthly Labor Review*, 80: 1468–1471.

U.S. Department of Labor, 1972, *Handbook for Analyzing Jobs*, Manpower Administration, Department of Labor, Washington D.C., USA.

Utdannings- og Forskningsdepartementet, 2003, Clemet avklarer skoleløpets lengde: Vil Beholde 13 Års Grunnopplæring [Clemet determines school duration. Will keep 13 years of primary and secondary school], Press release 065-03, 27 August. See www.dep.no/ufd/norsk/aktuelt/pressem/045071-070129/index-dok000-b-n-a.html [in Norwegian]. (Last accessed 13 March 2004).

Van Imhoff, E., and Post, W., 1998, Microsimulation Methods for Population Projection, *Population: An English Selection*, 10(1): 97–138.

Vassenden, E., 1993, *Befolkningens Høyeste Fullførte Utdanning, Revidert Dokumentasjon* [Education Statistics, Revised Documentation], Notater 93/15, Statistics Norway, Oslo, Norway [in Norwegian].

Verhaegen, P., and Salthouse, T.A., 1997, Meta-analyses of age-cognition relations in adulthood. Estimates of linear and nonlinear age effects and structural models, *Psychological Bulletin*, 122(3): 231–249.

Ver Ploeg, M., 2002, Children from disrupted families as adults: Family structure, college attendance and college completion, *Economics of Education Review*, 21(2): 171–184.

Warr, P., 1994, Age and employment, in H. Triandis, M. Dunnette and L. Hough, eds., *Handbook of Industrial and Organizational Psychology*, second edition, Consulting Psychologist Press, Palo Alto, CA, USA, pp. 485–550.

Wechsler, D., 1997, *Manual for the Wechsler Adult Intelligence Scale-III*, Psychological Corporation, New York, USA.

Weiss, A., 1995, Human capital vs. signalling explanations of wages, *Journal of Economic Perspectives*, 9(4): 133–154

Westoff, C.F., and Ryder, N.B., 1977, *The Contraceptive Revolution*, Princeton University Press, Princeton, NJ, USA.

Willis, S.L., and Baltes, P.B., 1980, Intelligence in adulthood and aging: Contemporary issues, in L.W. Poon, ed., *Aging in the 1980s*, American Psychological Association Press, Washington D.C., USA, pp. 260–272.

Wilson, R.S., 1983, The Louisville twin study: Developmental synchronics in behavior. *Child Development*, 54: 298–316.

Winship, C., and Korenman, S., 1997, Does staying in school make you smarter? The effect of education on IQ in the bell curve, in B. Devlin, S.E. Fienberg, D.P. Resnick, and K. Roeder, eds., *Intelligence, Genes, and Success*, Springer-Verlag, New York, USA, pp. 215–235.

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