The Impact of Population Ageing on Innovation and Productivity Growth in Europe

Research Report 28

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Executive summary

When we try to answer the question **what an ageing workforce will mean for the future European productivity growth**, we have to start with the question about what productivity is. In this report we follow the common convention and use **value added based labour productivity**, the single most frequently computed productivity statistic. Applying growth accounting methods, one can show that the growth rate of labour productivity depends on capital deepening and the growth rate of total factor productivity, the latter often being referred to as a "measure of ignorance". In this report we argue that productivity is a **system attribute** rather than a property in the individual inputs. In particular, since capital and labour are value-weighted aggregates of a great number of fundamentally different humans, objects and services, combined in a great number of ways, there is no unique specification how workforce ageing will influence productivity. Our main argument is that individual productivity cannot be separated from its **social context**. Productivity growth is closely related to investment in research and development that underlies technological growth. Since the **composition of human capital** will determine the growth potential of technology (in particular innovation versus imitation) we discuss the educational composition in the past and its development in the future together with past and future projections of the age composition of the workforce as central explanatory factors of productivity growth.

Reviewing trends in EU aggregate productivity growth over the period 1979-2001 indicates that the EU productivity growth fell behind US growth rates in the second half of the 1990s and at the same time within-EU disparities of productivity growth increased. Productivity growth was highest in **ICT producing** manufacturing and service industries. Productivity growth was lower in both sectors of **ICT using** industries (i.e. the manufacturing and service sector) while **non-ICT sectors** clearly evidenced a downward trend in labour productivity. Since the latter group accounts for about two thirds of economy-wide value added in most countries of the EU, the gains in the former two groups (ICT producing and ICT using) were more than offset by declines in non-ICT industries. Various hypotheses are put forward to explain why the EU has gained less than the US in terms of ICT productivity and why the non-ICT part of the economy has performed much worse as compared to the US. These include regulations in product, labour, and financial markets, lacking efficiency of knowledge production, low capital deepening, low growth rates of total factor productivity, a declining supply of labour, demographics, etc. The focus of our report is to revisit in particular the latter hypothesis (the role of demographics) by performing a study on the relation between productivity and the age and educational composition of the workforce at the plant (Sweden) and firm level (Austria). The **main original contribution of our study is therefore a micro-meso analysis at the firm/plant level** of the relation between productivity and the age and educational composition of the workforce in Sweden and Austria.

We are aware that the micro-meso link through which population ageing will affect productivity is only one among a set of various channels how labour force ageing will affect the economy wide productivity development. At the **macro level**, the link between population ageing and key driving factors of productivity such as technology, research and development, the efficiency of economic systems, etc. constitute important though not fully explored research areas. It is the feedback between the micro and macro level interrelationships and general equilibrium effects that will ultimately determine how population ageing shapes future economic productivity. By offering an in-depth study of the micro-meso level relation of population ageing and economic productivity, our report contributes a step towards such a multi-level analysis in the study of productivity and population ageing.

Since the Lisbon target not only relates to productivity growth but also aims to raise employment rates and to improve labour market performance, our report also summarises **trends in labour force structure** in the past and discusses future projections of productivity growth as they will depend on alternative projections of the labour force. Our study on five OECD countries (France, UK, Germany, Spain and US) clearly indicates that decreases/increases in the crude labour force rate (the total labour force divided by the population of working age) for males/females between 1985 and 2000 were dominated by changes in age-specific labour force participation rates (as opposed to changes in the age distribution of the total population). For males we have shown that mainly changes in labour force participation rates at younger and older ages explain the change in the crude labour force rate. For females, increases in the labour force participation rates at ages between 25 and 55 years account for most of the overall change in the crude labour force rate. Though our study only refers to past changes in labour market indicators and cannot assess the future impact of population ageing on the labour market, our results indicate that there is scope for dampening the effects of labour force ageing and labour force shrinkage through policy interventions aimed at changing labour force participation rates. Of course, **for countries where labour force participation rates for women and men are already high the margin for such behavioural changes is smaller than for countries still faced with low female and male participation rates**. As a recent study by the Commission of Europe shows however, the Lisbon target of an overall employment rate of 70%, a female employment rate of 60% and an employment rate for older people of 50% by 2010 will be hard to fulfil for all countries although some have already achieved one or more of the goals. Regarding the EU-15 as a whole, the largest potential to raise overall employment lies within those countries with lower employment rates and/or larger working age population. Low employment rates in the new member states strengthen the challenge towards the Lisbon target while their larger growth potential may facilitate these aims.

While a static comparative analysis implies that employment and productivity growth are negatively related (arguing that less productive and less skilled people are integrated in the workforce) the long-run effect of boosting employment is argued to be positive, not least from a fiscal perspective since it broadens the tax base.

Before presenting plant and firm level analysis of the age and educational composition on productivity we survey **theoretical and empirical evidence** at the macro and micro level that has discussed the relation between demographic structure and economic productivity. While the relation between age and individual productivity is less clear-cut, there has been recent evidence of a significant relation between changes in the adult population and aggregate productivity at the **macro level**. Based on recent empirical findings which have shown that input accumulation cannot explain the majority of cross-country differences in output per worker and hence total factor productivity (TFP) must account for the differences, various studies have tested whether demographics do exert an influence on TFP. Empirical evidence based on pooled cross-country data over the period 1960-1990 indicates that **workers aged 40-49 have a large positive effect on productivity** (as measured by the Solow residual). A study based on Japanese industries, however, indicates that the positive effect of educated workers older than 40 on technological progress turned from positive in the 1980s to negative in the 1990s. **The higher rate of technological change and capital-biased technological change during the 1990s may have shifted the productivity peak towards younger ages**.

Understanding the age productivity profile at the individual and firm level (i.e. **micro level**) is central to understand retirement incentives at the individual and firm level. Strategies of encouraging older workers to remain longer in the workforce need to be evaluated in tandem with the productivity profile of older workers. It is well known that workers of different ages may have different levels of productivity (as well as capacities of learning), although the exact shape is still highly disputed and strongly dependent on the occupation, technological progress and possible cohort effects that work through schooling levels. Studies that estimate the influence of age on individual productivity are based on different indices, including supervisors' evaluations, piece-rate studies, analyses of **employer-employee datasets**, age-earnings profiles and entrepreneurial activity. Most piece-rate studies, measuring the quantity and quality of the workers' output, and analyses of employer-employee datasets, where companies' productivity is measured, suggest that productivity follows an **inverted U-shaped profile** where significant decreases are found after the age of 50. A problem with most estimates of how productivity varies by age is that older individuals who remain in the workforce are positively selected and have a higher productivity than those leaving the workforce, which might bias the estimates. Although supervisors' evaluations on average show little or no relationship between the assessment score and the age of the employee, subjective opinions may be biased, where for example the management's opinions of older employees may be inflated due to loyalty reasons. Since the relation between individual performance and wages is often distorted, age-earnings profiles cannot replicate the age-productivity profiles. Most commonly the latter profiles peak earlier as the former ones.

An important **cause of age-related productivity declines** is likely to be age-specific reductions in **cognitive abilities**. Some abilities, such as perceptual speed, show relatively large decrements already from a young age, while others, like verbal abilities, exhibit only small changes throughout the working life. **Experience** in a firm or plant boosts productivity up to a point beyond which, however, additional tenure has little effect. Older individuals learn at a slower pace and have reductions in their memory and reasoning abilities. In particular, senior workers are likely to have difficulties in adjusting to new ways of working.

Earlier studies tend to neglect the causes of age-related job performance differences and the impact of **changing labour market demands**, when measuring age differences in productivity. In the present report we estimate the productivity potential by weighing age-specific ability levels against the labour market demand for these abilities. Evidence from both employment shifts between industries and changes caused by relative wage levels of unskilled and skilled employees suggests that there has been an increase in the demand for cognitive abilities over a long period of time. Physical strength and bodily co-ordination have lost much of their importance, while analytic, numerical and interpersonal abilities are increasingly in demand. Basing the estimates on the causes of productivity differences allows an assessment of the impact of structural changes in the labour market. The **age-productivity profile** is found to vary over time, in accordance with changing labour market needs. Assuming a reasonably strong effect of experience, we estimate that **productivity peaks for the 35-44 year old age group**. If the demand for experience falls, the productivity peak shifts towards younger ages. Conversely, if the minimum ability requirement should drop over time, age differences in productivity would decrease. The estimations of the productivity profile reflects that job performance on average tends to decrease in the second half of the working life, given almost any calibration of the model. The only exception to this would be if an individual's productivity gains from experience continues for several decades and if this effect more than outweighed the functional decreases with respect to other job-related factors. Given available empirical evidence on how additional work experience affects productivity, this may seem unlikely. Hence, these findings support the theory of delayed payment contracts, where the relatively high wages of older workers create loyalty to the firm and represent a compensation for high productivity earlier in the career.

Continuous increases in life expectancy have raised the concern that the number of years one should spend in the labour market in order to maintain old-age social security need to increase both from an individual as well as social point of view. Understanding how health develops over the life cycle is crucial to understanding individuals' work potential at older ages. **Health effects of age** represent a particularly important issue if frail health makes it difficult to work or if employment represents a health hazard for older individuals. As one grows older, blood circulation deteriorates, maximum oxygen uptake decreases, muscle strength and endurance are lowered, bone mass decreases (particularly among women), hearing and eyesight decline with age and individuals are more likely to fall sick. Older individuals' work capacity can therefore in many occupations be lower, although adjusted working environments, technical aids and ergonomic equipment can improve the situation. Moreover, physical exercise, less smoking and alcohol and a healthier lifestyle with better nutrition would improve the working capacity of older individuals, and presumably this also holds true for younger individuals.

As these various studies on age-productivity differentials show, productivity is a system attribute and cannot be understood in isolation of its social context. However, the hump-shaped pattern of age-productivity differentials seems to be ubiquitous across various studies. To investigate **the relation between age and productivity**, taking into account firm-level-specific factors, we refer to **two matched employer-employee data sets** (a longitudinal one in Sweden and a recently generated cross-sectional one in Austria).

Summing up the micro evidence from **Swedish mining and manufacturing**, we find a hump shape in the age effects on productivity with some indications that the peak of the **hump may lie around the ages 30-49**. We are, however, unable to achieve any final resolution to estimation problems like the specification of functional form, simultaneity between explanatory variables and productivity, and the thorny issue of identifying cohort effects distinguished from age effects. Our results are therefore primarily exploratory ones and subject to revision as research on these issues develop. It is especially puzzling that we have great difficulties in distinguishing any stable and substantial effects from the increasing shares of employees with tertiary education. Our attempt at estimating education-specific age effects do indicate that secondary education is more important than tertiary education for productivity in mining and manufacturing.

Nevertheless **education** quite clearly has substantial effects on productivity and for the purpose of this report indicates that even if an ageing workforce were to become less productive this can very likely be compensated in the long run, 15-40 years into the future, by increasing the education level of the future workforce. The result that productivity is enhanced by large groups of 50-59 year old persons on the **local labour market** level, as well as the weak relation between productivity spread and wage cost spread, are strong indications that labour market mechanisms and flows play an essential role in the determination of productivity at more aggregated levels in the economy. The group of the 50-59 year olds is, according to previous research, also associated with higher unemployment and creation of less vacancies. Our understanding of the dynamics here is still very weak, but differences between the matching of jobs to individual abilities for the young and the old seems crucial for achieving these results. Thus another tentative conclusion with respect to the purpose of the report is that well-functioning **labour markets** may be just as crucial as education for maintaining productivity especially with an ageing workforce. More research is, however, needed at the meso-levels (both regionally, over detailed industries and quite possibly also in the interactions of firms of different sizes) of the economy in order to define what is meant by well-functioning labour markets in this respect. Results on **worker and job flows** for manufacturing establishments with 50 or more employees between 1986/87 to 1995/96 show that many more jobs were created and destroyed than needed to match the net change in employment. This indicates that considerable economic resources are spent on the matching process, and our tentative conclusion is that this would provide an explanation for the phenomenon of “jobless growth”. When the labour force is young there is a high degree of matching going on inducing a very fluid labour market with high rates of job and worker reallocation which stimulates employment growth. However, this high rate of reallocation is costly and tends to dampen the value added growth per employee. Hence an older workforce is more efficiently matched to the available jobs stimulating productivity growth but making employment growth sluggish.

To understand the restructuring process more closely which took place in the manufacturing industry during the period from 1986 to 1996 we considered how job and worker flows are distributed among workers in different ages and with different educational levels. We found a **sharp decline in employment for those with lowest education while net employment on average rose for those with a university degree**. Similarly, job creation rates for those with higher education were more than twice as high as for those with only a pre-upper secondary educational level. Job and worker flows by age groups indicate that employment among the oldest workers fell rather dramatically during the whole period and almost no jobs were created for oldest workers. Although a direct comparison to American data is marred by definition problems, the available evidence indicates that levels of reallocation of jobs are similar to the Swedish data we analysed, while worker reallocation is likely to be higher in the American economy. There are at least two possible interpretations of this. One is the conventional Eurosclerosis hypothesis that regulations and insider power makes European labour market less flexible. However, the local labour market age effects on productivity and the similarity of reallocation levels suggest another possibility. The Swedish labour market may be more efficient than the American in allocating youngsters to their most productive employment. High churning rates may be good for productivity if they lead to better matches, but there is also the possibility that the benefit of this is offset by excessive adjustment costs. While this remains only an interesting conjecture within the scope of this study it seems a most worthwhile focus of future research.

The cross-sectional firm level analysis for **Austrian mining and manufacturing** enterprises showed—just like for Sweden—that productivity dispersion is much wider than wage dispersion and it is almost impossible to see any relation between firm productivity and wage level. Regression of value added per worker on age and gender shares indicates a hump-shaped pattern for the age variable, i.e. firms in which the share of younger or older workers is higher, have a lower productivity compared to firms where the share of the middle age group is higher. By adding firm-specific factors like the size and age of the firm, etc. we still find a hump-shaped pattern of the age profile. Peak productivity is still found in the 30-49 year old age group. However, once we include the occupational structure and the part-time share of workers in firms as additional control variables, the hump-shaped pattern of age on productivity is dampened suggesting that age effects may be working through these variables since they are clearly correlated. Splitting the sample into two subsamples of **small** (less than 50 employees) versus **large firms** (50 or more employees) yields different conclusions than found for Sweden. For small-sized firms the results on the age pattern and other covariates are similar as for the whole sample. By contrast, age variables become all but insignificant in the sample containing only large firms. This means that no clear pattern of age can be observed in large firms. From these results it seems that in Austria the theory that larger-sized firms are more flexible to adjust the age structure of workers is not valid to the same degree as in Sweden. The results could rather indicate that large-sized firms can afford a workers council which protects employees' rights and worker flows are consequently more restricted. Another reason could be that large-sized firms, because of their market power, are not that much forced to minimise costs by optimising the age structure of their staff compared to small-sized firms. To test whether age structure effects are different between industries who belong to different categories of **ICT industries**, we perform separate regressions for the manufacturing sector distinguishing between ICT producing, ICT using and the rest of industries. We find no age pattern on productivity for ICT producing industries, a weak age pattern for ICT using industries and a hump-shaped age profile for all remaining industries. These results lend support to the hypothesis that other factors of production (e.g., ICT capital) are more important than the age structure of employees for ICT producing firms.

Based on our analysis of plant data for the Swedish manufacturing (which showed that both age structure and educational structure of the workforce have statistically significant effects on the productivity), we conduct a **prospective analysis** on workforce change and productivity in the last part of the report. The analysis is carried out in two steps. First, the model is calibrated on an out-of-sample data set of 14 EU countries. Then, for the 2005-2040 period, the model is combined with population projections, educational assumptions and assumptions of activity rates in order to produce scenarios for the EU-25 economies. It is important to note the limitations of this exercise. The projections do not account for any behavioural policy responses to the age effects, nor do they account for other factors affecting productivity growth such as technological change. The projections therefore must be interpreted as an assessment of how productivity would develop in the absence of any other changes than the projected population, labour force and education changes that are assumed. Our analysis does include, however, the important feedback of labour force participation rates and educational attainment for the long-run economic development. Put differently, an increase in educational level may compensate a decline in productivity more likely the longer people work and therefore the longer returns of education will last.

Our conclusion from the first calibration step is that the model we have developed using plant-level data on the relation between labour force structure and productivity can be used to reproduce movements in GDP at the aggregate level that are caused by variations in age structure and education levels. This provides us with a mechanism whereby assumptions about future changes in the structure of the active labour force can be transformed into different scenarios for GDP, GDP per worker, and GDP per capita scenarios. Our projection results indicate that the average prospects for **productivity growth** are not bad for the next 15 years. After 2025, though, there is a potential risk for stagnation if current participation rates and current education enrolment rates remain constant. Rising enrolment rates alone are not enough to secure long-run growth in GDP per capita since the high growth rate of the non-working age population dominates. Only by increasing labour force participation rates can negative effects on productivity growth of the ageing workforce be avoided. On average our results indicate that between 2005 and 2025 projected growth rates of labour productivity may rise from slightly below one per cent to over two per cent by raising participation rates to the best-practice level. To maintain growth after that requires raising education rates also to the best-practice levels. The effect will be even stronger on per capita income growth since also the number of employed in relation to the total population will increase in addition to rising productivity levels. Depending on current participation rates and educational attainment rates, and on differences in age structure, the national trends will differ. For instance, in **Sweden** the increase in educational levels will help to increase GDP per capita during the next years but this may not be enough for continued increase. Labour force participation rates are already high in Sweden and the growth potential that operates through increased labour force participation is therefore more difficult to achieve for Sweden. Note, however, that according to the model the negative trend in Sweden is not due to an ageing workforce but to the rejuvenation that will take place as the baby boomers from the 1940s retire. On the other extreme, **Austria** has a very high educational level but labour force participation rates of older workers are among the lowest in the EU. The growth potential with respect to labour market reforms aimed at increasing the participation rates is therefore high for Austria. For **Italy**, both policies (increasing educational levels and labour force participation) are timely and would help to increase GDP per capita over the next decades.

While many questions are still unanswered this study points out some clear directions for future policy in this area. **First**, it confirms the common belief that **raised education**

levels are important for maintaining growth in ageing economies, but it also indicates that for reasonable levels of education to be attained the delay in productivity effects is quite substantial, as in most cases appreciable effects do not occur until twenty years after such efforts have been initiated. In many countries **labour force participation rates** are historically low and could be raised which would offer a much faster road to increased productivity growth.

Second, the study shows that productivity growth is a more complex phenomenon than just adding up the individual capacity of the available labour supply. Individual productivity age profiles vary with the technological context and content of the work. Industrial restructuring and reallocation of labour within the current social context is quite likely to be quantitatively much more important than the age composition of labour per se. Matching properties of the labour market that depends to a very high degree on idiosyncrasies of national labour market institutions most likely are important in order to explain differences between the Swedish and Austrian results. The Swedish results indicating positive ageing effects at the local labour market level also indicate that such properties may be directly crucial for the explanation of "jobless growth" and, combined with macro evidence, indicate that ageing may enhance productivity growth at the national level in spite of individual productivity peaking at middle age.

While there are many questions left to resolve by future research these results indicate that **heterogeneity within the EU** is pervasive with respect to what measures different member states need to take in order to ensure future productivity growth. **In this perspective the achievement of common targets along the Lisbon agenda will clearly depend on the implementation of nationally specific policies that are tailored to the specific institutional and demographic circumstances of the individual countries**.

In summary, however, the **results of this study indicate that the problem of an ageing workforce may have been somewhat exaggerated**. The effects of ageing per se are not particularly strong and can be ameliorated by largely rather modest changes in labour force participation and raised education levels. For some countries this may be more difficult than for others, especially when policy at the same time must deal with the fiscal problems associated with rising dependency burdens. A sober assessment from this study is, however, that the latter problem is likely to overshadow the problem of an ageing workforce. Thus the problem of how to organise increasing redistribution within an ageing population seems more pressing than how to deal with an ageing workforce, even though success in the latter aspect will make the former problem easier to deal with.

If, as this study indicates, reallocation of jobs and workers across industries, firms, plants and places are crucial to the productivity performance of the population in ageing economies, then serious issues are raised with respect to current EU policies for social, industrial and regional protection. Alleviating the problems caused by declining industries or regions by subsidies preventing such reallocation may then carry a very high cost for the future sustainability of European welfare. Lock-in mechanisms in the labour market designed for social security today may undermine the social security of the future. From our results we can only raise this issue and not prescribe how to avoid it. Due to a lack of data on previous labour flows, the workings of these reallocation mechanisms are still uncharted research territory, where knowledge is scarce and opinions are many.

Comparative research in this area is still underdeveloped but attracting more and more attention. Our study demonstrates that a better understanding of the matching processes at the labour market is crucial for the formulation of sustainable industrial and labour market policies.

1 Introduction

To achieve the **Lisbon objective** of making Europe the **most competitive and dynamic knowledge-based economy in the world by 2010**, the single most important goal is an increase in productivity since Europe has already fallen behind the US due to its low utilisation of labour and its lack of innovative capacity. As productivity becomes ever more important the need to understand the driving forces behind productivity growth becomes critical. Innovation, both public and private, international knowledge spillover, human capital development, entrepreneurship and information, and communication technology, constitute the major drivers of productivity growth in Europe. However, there is only limited knowledge about the relations between these factors and the **age structure of the workforce**. Are older workers less willing to adopt new technologies? Is innovation and new firm entry hampered if there are fewer younger workers? Obviously labour market institutions together with changes in the demand structure of an economy will determine the impact of the changing age composition of the labour force on productivity and economic growth, and there are also forces that may compensate for the adverse effects associated with a slower inflow of younger workers. For instance, increasing competition within Europe may induce many firms to spur up their innovation, while investments in on-the-job training could make the ageing workforce more apt to adopt new technologies. However, there are other equilibrium effects that may very well reinforce the slowdown in productivity growth associated with the changing age structure. Of particular concern in this context is the development of the economic structure towards service industries that have lower productivity growth. This trend may be strengthened by an ageing population, since the demand for services is typically higher among older cohorts.

Clearly **educational attainment**, health of the population, public infrastructure and tax policies are all drivers of productivity as well. An ageing population may constitute a major burden on these drivers since older people are less educated, less healthy and demand more transfers. Strategies counteracting those forces are high on the agenda and as we will argue in this report, new opportunities for restructuring the labour market, welfare systems and educational systems may originate as Europe has to face these challenges.

An important factor often related to decreasing productivity at the aggregate level is the different **employment pattern of older and younger workers**. Older workers are less likely to become unemployed, but once unemployed there is a lower probability of finding work again. Older workers change jobs less often and are less geographically mobile. Their enrolment numbers in general and firm-specific education are lower as well. While part of these differences are driven by age-related differences in skills, preferences and income, an important explanation can be found in organisational structures and more generally human resource management. E.g., the growth of pension schemes has created incentives for early retirement and shifts in the industrial structure of employment have reduced the demand for the skills that older workers possess.

In this report we offer an **in-depth analysis of what an ageing workforce will mean for the future European productivity growth**. The first three chapters of the report review measures of productivity (Section 2), trends in productivity (Section 3) and trends in labour force structure (Section 4). The main original contribution of our study is a **micro-meso analysis at the firm/plant level**[1] **of the relation between productivity and the age and educational composition of the workforce in Sweden and Austria** (Section 6). This is set within the framework of a comprehensive survey of both macro and micro studies, relating to aggregate productivity as well as to individual productivity (Section 5). Based on our analysis of plant data for the Swedish manufacturing industry, we conduct a prospective analysis on workforce change and productivity in the last part of the report (Section 7).

1 The enterprise (firm) corresponds to a legal entity that forms an organisational unit and has a certain freedom of decision in particular regarding the use of the current funds it accrues. An enterprise carries out one or more activities at one or more locations. The plant (local unit) of employment is a part of an enterprise that is situated in a fixed location (e.g., sales outlet, office, warehouse, workshop). In this location or from this location, economic activities are carried out for which—with exceptions—one or more persons work (possibly also part-time) on behalf of one and the same enterprise.

2 Measuring productivity

When we try to answer the question of what an ageing workforce will mean for future European productivity growth, we actually have to start by asking what productivity actually is. We often use this concept in a rather loose sense, as a generally good thing, but when we want to be more specific there are actually a host of difficult questions that arise. In this chapter we shortly review measures of productivity and key economic factors that explain productivity differentials across countries. (The following summary is based on Weil 2005, Part III; Schreyer and Pilat 2001; and OECD 2001).

Productivity describes the relation between "output and the inputs that are required to generate that output" (Schreyer and Pilat 2001, p.128). As illustrated in Weil (2005, p.184 ff) an economy may increase its output by either increasing the production factors or by using input factors more effectively.

Productivity measures can either be **single-factor productivity** measures (where output is related to one input only) or alternatively **multi-factor productivity** measures (where output is related to a set of inputs). With respect to output measure, one may distinguish between gross output (production value) or valued added (see Table 2.1 as taken from Schreyer and Pilat 2001, p.129). Value added is gross output corrected for purchases of intermediate inputs. In our study we follow the common convention and use **value added based labour productivity**; the single most frequently computed productivity statistic.

Table 2.1:
Overview of main productivity measures

	Type of input measure			
Type of output measure	Labour	Capital	Capital and labour	Capital, labour and intermediate inputs (energy, materials, services)
Gross output	Labour productivity (based on gross output)	Capital productivity (based on gross output)	Capital-labour MFP (based on gross output)	KLEMS multi-factor productivity
Value added	Labour productivity (based on value added)	Capital productivity (based on value added)	Capital-labour MFP (based on value added)	-
	Single-factor productivity measures		Multi-factor productivity (MFP) measures	

Source: Schreyer and Pilat (2001), p. 129

Depending on whether the level or growth rate of productivity is studied, economists either apply "development accounting" or "growth accounting" techniques (Weil, 2005, p.186 ff). In principle, the measure of productivity for both methods is the residual (multi-factor productivity) of output that remains after accounting for changes in input factors. In formal terms, if Q is deflated value added (at a specific producer unit such as a firm, an industry, a sector or an entire economy) and if we consider only labour L and capital K as inputs, the **growth accounting equation** becomes

$$\frac{d\ln Q}{dt} = s_L \frac{d\ln L}{dt} + s_K \frac{d\ln K}{dt} + \frac{d\ln A}{dt}$$

where A captures multi-factor productivity and s_L, s_K are the share of labour and capital in total costs. **Labour productivity growth** is expressed as the difference in value added and labour force growth:

$$\frac{d\ln Q}{dt} - \frac{d\ln L}{dt} = (1-s_L)(\frac{d\ln K}{dt} - \frac{d\ln L}{dt}) + \frac{d\ln A}{dt} \qquad (2.1)$$

From equation (2.1) it becomes clear that labour productivity growth depends on capital deepening and the growth rate of total factor productivity. However, from this decomposition we cannot explain productivity differences, nor answer why productivity grows at different speed across different countries. In the literature the measure of A as derived in (2.1) is therefore often called a "**measure of ignorance**".

Several caveats arise when measuring productivity which include for instance: the distinction between new products versus the increase in quality, the measurement of labour input, the importance of skill composition of the labour force, the difficulty to correctly measure capital, etc.

As we will argue in this report (see Lindh 2005), **productivity is really a system attribute** rather than a property in the individual inputs, and in particular it may be quite misleading to speak only of individual productivity and age productivity profiles. As we shall show in the case studies for Sweden and Austria in Chapter 6—at the plant level (for Sweden) and the firm level (for Austria)—the measured labour productivity for the older part of the workforce will tend to be lower simply because the matching process in the labour market leads to the fact that older workers will work predominantly in older plants, using older capital associated with older technologies. Moreover, as pointed out by Börsch-Supan (personal communication), individual comparisons of productivity are marred by a selection bias, since a typical career means that the best workers in general change their type of work once or more often, so when comparing young workers with older workers doing the same type of work we are bound to see a selection bias.

Moreover, our data also indicate that much of the action in productivity growth at the plant level is driven by the relation between **inflow of new plants and outflow of old plants**, making selection bias operative at this level as well. Hence we also have to consider the scale of the system when we talk about productivity. There are important differences whether we talk about the plant level, the industry level, the national or the global level, since their relative advantages and how we organise trade and factor flows will also be important for the actually observed productivity.

To summarise, both capital and labour are value-weighted aggregates of a great number of fundamentally different humans, objects and services, which in practice are combined in a great number of ways in order to produce an ever vaster array of goods and immaterial services. Marginal products and price setting determines what is actually produced. Under ideal circumstances competitive markets will equalise marginal products and prices but in the real world there is a host of **imperfections, missing markets and incomplete information** making more or less persistent deviations from this ideal a fact of life. In the context of age-specific productivity the existence of seniority wage schedules where actual wages deviate deliberately from the marginal productivity is one of the difficulties that we have no clear solution for.

The consequences of all this fuzziness and heterogeneity is that we can have no hope of achieving a detailed true specification which would allow us to logically deduce what will happen as the workforce is ageing. **Individual productivity cannot be separated from its social context**.

Components of productivity

Besides measuring productivity, growth economists are mainly interested in the components that drive productivity growth (Weil 2005). A central role in this discussion is taken up by **technology**, i.e., the knowledge about how factors of production should be combined for output production. **Research and development** are the key investments to encourage technology. In turn, the amount of investment will depend on the size and duration of the competitive advantage gained by the entity (firm, industry, …) which invests in technology development. Since the implementation of a new technology may—by way of creative destruction—hurt some firms or single workers (profits may decrease, unemployment may rise), such technological implementation may even be blocked. Whether and how an ageing population may be an influence on technological growth is an empirical question and not yet fully understood (Nishimura 2002). A further important aspect is whether **innovation** (creating a new technology) or **imitation** (copying an existing technology) is the driving force of technological growth. The age structure of the labour force may determine these processes. In particular, as recently argued in Vandenbussche et al. (2005) the composition of human capital will determine the growth potential of an economy near the technological frontier. Since innovation is more skill-intensive, a younger population, i.e., a population of more recent human capital vintage, may therefore be positively related to technological improvement. Additionally, as the structure of the economy in an ageing population will change in favour of the service industries, it will be important "whether technological progress will spill over from the goods-producing sectors, where it has historically been fastest, into the production of services, where technological progress has thus far been slow." (Weil 2005, p.265) Productivity differences cannot be explained solely by differences in technologies. An important source of differences in productivity is the effectiveness with which factors of production and technology are combined to produce output, i.e., **efficiency** is a key explanatory variable for productivity differentials. As argued in Weil (2005) differences in efficiency explain a larger part of differences in productivity than differences in technology. Population ageing may be related to those inefficiencies through misallocation of factors (labour or capital) among sectors, underemployment of resources (idle capital), etc.

3 Trends in productivity

In this section we summarise trends in EU productivity (1979-2001) and its main driving factors during the last decades. We refer to recent publications by the European Commission (Denis, McMorrow and Röger 2004; O'Mahony and van Ark 2003) in the subsequent discussion.

3.1 EU productivity trends at the aggregate level

The definition which will be used in the following is **labour productivity growth** as measured by the growth in value added at constant prices minus the growth in hours worked. This indicator is closely associated with increases in the standard of living.

While EU and US living standards were growing at similar rates during 1980-1995, EU productivity growth fell behind US growth rates in the second half of the 1990s. At the same time, intra-EU disparities in productivity growth increased.

At the **sectoral level** the EU experienced reduced growth of labour productivity in the fields of manufacturing, distribution and business services as well as relatively low growth in financial services[2]. Differences exist within these sectors and over time. Especially wholesale trade, retail trade and auxiliary financial services in ICT (= information and communications technology) using sectors and office machinery and electronic manufacturing in ICT producing sectors have experienced a relatively weak development. In general, remarkably high or low growth rates are more often found in smaller[3] industries, while larger industries are marked by productivity growth rates in a moderate range of ± 4%-points.

According to the **industry taxonomy** (Appendix A[4]) suggested in O'Mahony and van Ark (2003) the highest annual growth rates of productivity over the periods 1979-1990, 1990-1995 and 1995-2001 occurred in the **ICT producing/manufacturing** sector, followed by **ICT producing/services** (Table 3.1). Productivity growth rates were lower in both sectors of **ICT using industries**. A clear downward trend of labour productivity is apparent in the **non-ICT sectors** which account for about two thirds of the economy-wide value added in most countries of the EU-15. Overall, the gains in ICT using and producing industries were more than offset by the declines in productivity in the non-ICT industries of the EU economy.

A comparison **of labour productivity growth rates across EU-15** in the two periods 1990-1995 and 1995-2001 indicates that Ireland and Germany experienced the largest growth in ICT producing sectors. Over the same time period, Belgium, Greece, Spain, France, Italy

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2 Comparisons refer to the United States. GDP figures within basic calculations are deflated by US (hedonic) price indices for the ICT industries.

3 The size of an industry is measured by its employment share in the aggregate employment.

4 The ICT-3 classification refers to the groups ICT Producing, ICT Using, Non-ICT while the ICT-7 classification distinguishes between manufacturing and services within each ICT category and includes also an additional group termed Non-ICT other.

and Finland also increased their growth in ICT producing, whereas productivity decreased in the UK. Accelerating growth in the ICT using sector for some countries such as Denmark, Greece, Spain, Ireland, Netherlands, Portugal, Finland and the UK was more than compensated by decreasing growth in the large countries Germany, France and Italy, so that the EU-15 show slightly decreasing labour productivity growth in ICT using sectors for 1990-2001. The deceleration of productivity growth was most pronounced in the non-ICT. Only in four of the EU-15 countries (Greece, Portugal, Ireland and Sweden) labour productivity growth in these sectors did not decrease.

Overall, the lower growth rate of labour productivity in the EU results from low capital deepening and low growth rates of total factor productivity. Moreover, the amount of labour has declined in the EU due to lower labour force participation rates and a reduction in number of hours worked per employee. To what extent these developments are the results of rigid institutional frameworks, too heavy tax loads, etc. versus individual decisions is a key research focus in explaining low productivity growth rates in the EU. For instance, a common argument is that higher tax rates on labour decrease the supply of labour an individual offers and indirectly also decreases the incentive in human capital investment.

Table 3.1:
Annual labour productivity growth of ICT producing, ICT using and non-ICT industries

	1979-1990	1990-1995	1995-2001
Total economy	2.2	2.3	1.7
ICT producing industries	7.2	5.9	7.5
ICT producing manufacturing	12.5	8.4	11.9
ICT producing services	4.4	4.8	5.9
ICT using industries	2.2	2.0	1.9
ICT using manufacturing	2.4	2.4	1.8
ICT using services	2.1	1.8	1.8
Non-ICT industries	1.8	2.1	1.0
Non-ICT manufacturing	3.0	3.6	1.6
Non-ICT services	0.6	1.2	0.5
Non-ICT other	3.4	3.2	2.1

Source: O’Mahony and van Ark (2003), Table III.3, p. 78 (modified)

O’Mahony and van Ark (2003) present also two further taxonomies: one that distinguishes industries by **skill group** and the other by **source of innovation**. Productivity growth in EU countries is high in industries using (high-) intermediate skills. The results based on the innovation taxonomy are similar to the ICT taxonomy.

Various hypotheses have been put forward in the literature to explain (a) why the EU has gained less than the US in terms of ICT and (b) why the non-ICT part of the economy has performed much worse as compared to the US. These include among others: regulations at the product level, labour (e.g., employment protection legislation) and financial markets, the degree of openness of economies, the efficiency of knowledge production (R&D, education), determinants of physical investment levels, and demographics.

Decomposition of EU-15 labour productivity growth by country

Because of their large share of total EU employment Germany, France, the UK and Italy (and to a lesser extent Spain) contribute the largest parts of labour productivity growth within the EU-15 (Table 3.2). In the **ICT producing sector** the smaller countries Ireland, Netherlands and Finland clearly increased their influence on total EU development, while the growth pattern was non-monotonous over time for France, Germany and Italy, and the UK increased its contribution slightly.

The overall decline in labour productivity growth in the **ICT using sectors** for the EU as a whole (2.23% in 1979-1990, 2.09% in 1990-1995, 1.88% in 1995-2001) was mainly due to the bad performance of Germany, France and Italy, although the UK and Spain added some positive contributions.

Non-ICT industries, representing 60% of overall employment within the EU and containing mostly traditional industries, showed sharply declining labour productivity growth in all four large countries: Germany, which shows the most negative development, France, Italy and the UK.

Some of the declining contribution of Germany may be due to its declining share in EU employment, whereas Spain increased its relative employment share.

Growth accounting

Growth accounting methods can be applied to decompose labour productivity growth into contributions from factor inputs such as labour, labour quality, ICT capital, non-ICT capital—weighted by their input shares—and total factor productivity (TFP) (see O'Mahony and van Ark, p.92ff). These methods have been applied to decompose labour productivity **for four EU countries: France, Germany, Netherlands and UK** and separately for the three sets of the ICT taxonomy for the periods 1990-95 and 1995-2000.

Table 3.2:
Contributions of member states to EU-15 aggregate annual labour productivity growth

	ICT producing			ICT using			Non-ICT using		
	1979-1990	1990-1995	1995-2001	1979-1990	1990-1995	1995-2001	1979-1990	1990-1995	1995-2001
Belgium	0.13	0.09	0.17	0.08	0.12	-0.05	0.08	0.07	0.06
Denmark	0.11	0.13	0.06	0.03	0.01	0.04	0.03	0.05	0.01
Germany	2.41	1.21	2.05	0.53	0.67	0.30	0.47	0.64	-0.01
Greece	0.01	0.03	0.07	0.01	0.01	0.06	0.01	0.03	0.04
Spain	0.26	0.31	0.33	0.10	0.03	0.17	0.21	0.20	0.23
France	1.69	0.94	1.07	0.56	0.13	0.13	0.23	0.28	0.17
Ireland	0.09	0.16	0.50	0.02	0.03	0.07	0.02	0.04	0.07
Italy	0.68	0.78	0.67	0.28	0.48	0.29	0.23	0.27	0.06
Luxembourg	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01
Netherlands	0.28	0.19	0.34	0.14	0.15	0.14	0.13	0.11	0.07
Austria	0.18	0.14	0.07	0.09	0.09	0.06	0.05	0.08	0.02
Portugal	0.03	0.07	0.05	0.02	0.02	0.03	0.02	0.02	0.04
Finland	0.11	0.10	0.23	0.04	-0.02	0.03	0.05	-0.01	0.03
Sweden	0.22	0.20	0.09	0.04	0.05	0.05	0.06	0.01	0.06
UK	1.14	1.58	1.78	0.27	0.29	0.56	0.26	0.32	0.16
EU-15	7.37	5.97	7.51	2.23	2.09	1.88	1.84	2.12	1.02

Source: O'Mahony and van Ark (2003), Table III.10, pp. 91f.

For **ICT producing industries** the contribution of TFP to labour productivity growth dominates. In **ICT using industries** labour quality becomes more important, but its contribution to overall productivity growth declines over time. Moreover ICT capital deepening is rising over time and non-ICT capital relinquishes a great part of its influence. The contribution of TFP is comparably low, but slightly rising. Non-ICT capital deepening plays a larger role than ICT capital deepening in **non-ICT industries** but declines sharply from the first to the second period. Similarly, the contribution of labour quality has been shrinking. Again, TFP has the biggest input to labour productivity, but nevertheless declines.

Taking a look at **TFP growth** over time across various industries[5] in the EU-4 as a whole, acceleration is focussed on ICT producing/manufacturing, i.e., electrical, electronic and office equipment and instruments, as well as communications and deregulated sectors, such as utilities and transport, as well as financial services.

The general drop in importance of **capital deepening** relative to the US is not significant for non-ICT capital in Germany, France, and the Netherlands in 1990 and 1995. **Non-ICT industries** include high capital-intensive manufacturing industries, where—following post-war behaviour—capital has been substituted for high-cost labour. Since wages have been rising only moderately within the EU from 1995 on, this may have led to the circumstance that capital has rarely been substituted for labour, which in turn led to an underdevelopment of labour productivity growth. This issue may present the source for negative long-run consequences on growth.

High-skilled workers, which might have induced the earlier adoption of ICT in the US, increased strongest in the ICT producing sector for the UK, France, Germany and the Netherlands. Likewise, all four EU countries raised their shares of graduates in the ICT using sector, whereas only the UK did so for the Non-ICT industries.

Higher-intermediate skilled workers (= highly skilled craftsmen, higher education below degree level) increased in number as well—especially in ICT producing and using sectors—whereas the share of lower-intermediate skills and persons with no formal qualification declined.

3.2 EU productivity trends at the company level

O'Mahony and van Ark (2003, chapter V) also present productivity trends at the company level. The focus of their analysis is on whether the **firm size** and the **extent of R&D investment** determine the adjustment of firms to technological change.

According to economic theory and to empirical evidence, firms that operate in ICT-intensive sectors, i.e., high-technology environment, are more likely to benefit from spillover effects and therefore augment their productivity.

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5 A unique database, the **Industry Labour Productivity Database** at the Groningen Growth & Development Centre, provides details for 1979 through 2001 on output, hours worked and labour productivity for all 15 EU countries and the US, covering 56 industries and additionally including data series for capital inputs and labour force skills for the US and four EU countries (France, Germany, Netherlands, UK).

Due to the lack of information on skills and ICT at the firm level, company and industry information have been merged. Matching the companies to the different taxonomies makes it possible to discover firms which show the same characteristics although they belong to different industries. According to the **ICT-3 taxonomy, among the EU-15 countries about 50% of the companies belong to the non-ICT group, while 34% belong to the ICT using sectors, and 17 % to the ICT producing ones.** With respect to the skills taxonomy the EU has a smaller share of its firms in the high intermediate and high skills sectors as compared to the US.

By comparing the evolution of labour productivity at company level during the period 1992-1995 with the period 1996-2001, one can verify if performance at company level is similar to the one at the aggregate level. In fact, between these two periods labour productivity growth decreased from (a weighted average rate of) 0.94% to 0.71%. Productivity decline occurred in the service (from 1.2% to 1.0%) as well as the manufacturing sectors (from 0.77% to 0.47%). These levels correspond well with the aggregate figures.

Influence of R&D and firm size

Following economic theory, R&D influences productivity positively through two channels: firstly via the firm's own investment (directly) and secondly via spillover effects (indirectly). Smaller firms are more flexible in adapting technological changes, while larger firms have the financial potential for internal R&D. The interaction of firm size and R&D is therefore of importance.

The study by O'Mahony and van Ark indicates that over the whole time period (1992-2001), **R&D reporting firms were more productive** than their non-R&D reporting counterparts. With regard to firm size, **the smaller a firm the larger its productivity growth**. This development was most evident in the service sector. Considering a connection of R&D investments and firm size, the largest R&D differential in services appears in the intermediate group, while in manufacturing the largest productivity growth gap belongs to the smallest firms. Conclusively, R&D reporting firms are the most productive ones, which can be found in the intermediate-sized firms of the service sector.

Econometric analysis

To specify the **relation between R&D and productivity** a log-linear Cobb-Douglas production function has been implemented in O'Mahony and van Ark (2003) with employment, fixed capital, R&D investments as the set of explanatory variables as well as a post-1995 time dummy interacting with the variables, allowing for the influence of size and spillover effects. Results indicate that employment elasticities are higher in R&D reporting companies in services and manufacturing, whereas capital elasticities are higher only in R&D reporting firms in the service sector. An **R&D return of 20%** is shown to hold for the UK, France and Germany.

The post-95 dummy shows a significantly negative impact on productivity within the EU-15 in the manufacturing sector. Within the service sector the coefficient on the interaction of the time dummy and R&D investment is significantly positive probably due to the increasing use of ICT. Hence, the negative post-1995 trend might be reversed in the future.

While there are no regularities of **firm size** in manufacturing, productivity is obviously positively correlated to smaller and intermediate firm size in the service sector with an additional advantage for intermediate-sized firms—aside from R&D. Introducing further interaction shows how the returns to different production factors vary with firm size. In manufacturing the returns to R&D investments are especially high for larger firms with more than 1000 employees. The interaction coefficients are not significant in the service sector, but overall productivity growth remains highest in intermediate-sized firms.

Concerning the taxonomy dummies one may state that firms in **ICT producing industries** have a productivity gain of about 4%, and these are even higher for ICT producing/services than for ICT producing/manufacturing.

Companies operating in **high-skill manufacturing** gain about 3% productivity growth compared to those in low-skill manufacturing. Taking R&D into account, positive spillover effects mainly occur for ICT producing (manufacturing) firms and ICT producing services.

Firm dynamics

The literature has evidenced that a great part of productivity growth is generated by factors outside the firm like **dynamics of entry and exit of firms**. For instance, the turnover rate of firms in the business sector lies between 15% and 20% for most countries.

Moreover, survival of new firms is positively related to age (learning) and size (accumulation of basic competitive assets or skills) but their growth is negatively related to these factors—at least for small and young companies. About 40% of entering firms in the UK fold up within their first or second year. Afterwards, the probability to survive five more years is about 60% to 70%. Survival beyond the seventh year is experienced by only 40% to 50% of total entering firms.

For OECD countries it is evident that for short-term periods within-firm growth contributes most to aggregate productivity growth as well as it is significant during expansion. In years of recession the contribution of between-firm growth, i.e., the turnover, exceeds. Entering firms are more productive than exiting firms, but less productive than an average firm. While within-firm growth contributes to labour productivity in the long run as well, the turnover mainly contributes to multifactor productivity growth.

In manufacturing increasing shares of highly productive plants and decreasing shares of low productive firms are very important for productivity growth. Moreover, new firms usually invest more into new technologies and organisational changes, while incumbents substitute capital for labour and therefore raise labour productivity.

Entry and exit contribute an even bigger part to aggregate productivity growth in the service sector than in manufacturing.

Since innovation may act as a product differentiation and therefore present a barrier to survival and to entry, high technology manufacturing and ICT-related industries are characterised by a higher turnover than average. While the influence of entering the market exceeds in ICT industries, since new firms adopt the most recent technologies, it is within-firm growth and the exit of firms for mature industries.

Within the EU, the UK and Finland have the highest turnover rates, while only Germany and Italy have lower rates than the US. However, the EU obviously has a disadvantage in financing possibilities for entrepreneurs with small or innovative projects and reduced administrative costs to entering the markets, which could be sources for a higher degree of experimentation among entering firms, higher post-entry employment growth and more rapid expansion.

Policy implications are that the focus should not only lie on stimulating within-firm growth, but also to eliminate restrictions on firm entries and exits and to encourage “creative destruction”. As summarised in O’Mahony and van Ark (2003, p. 2020), “More restrictive product and labour markets in many European countries may discourage entry and posterior growth of new firms, reduce innovative efforts, technology spillovers, and competitive pressures, which affects negatively productivity growth (…) In the US however, the administrative start-up costs and labour adjustment cost are relatively low, what stimulates the entrepreneurs to start on a small scale and if successful grow to reach the minimum efficient scale”. As further argued, this process is highly important in innovative sectors where newly entering firms adopt the newest technology and thereby positively contribute to technological progress and economic growth at the aggregate level.

Conclusions

Reviewing trends in EU aggregate productivity growth over the periods 1979-1990, 1990-1995 and 1995-2001 indicates that the EU productivity growth fell behind US growth rates in the second half of the 1990s and at the same time within-EU disparities of productivity growth increased. Productivity growth was highest in **ICT producing** manufacturing and service industries. Productivity growth was lower in both sectors (manufacturing and services) of **ICT using** industries while **non-ICT sectors** evidenced a clear downward trend of labour productivity. Since the latter group accounts for about two thirds of economy-wide value added in most countries of the EU, gains in the former two groups (ICT producing and ICT using) were more than offset by declines in non-ICT industries. Various hypotheses are put forward to explain why the EU has gained less than the US in terms of ICT and why the non-ICT part of the economy has performed much worse as compared to the US. These include product-, labour- and financial market regulations, efficiency of knowledge production, low capital deepening, low growth rates of total factor productivity, a declining supply of labour, demographics, etc. Moreover as various studies indicated R&D is positively related to productivity and R&D returns in the manufacturing are higher for larger firms. In contrast, the size of a firm is negatively associated with productivity in the service sector. Since firm dynamics, i.e., exit and entry of firms, play a key role for productivity dynamics, elimination of restrictions to creative destruction, encouraging innovative efforts, reduction of start-up costs and labour adjustment costs should be fostered.

4 Trends in labour force structure

Parallel to increasing productivity growth, the Lisbon target has a strong focus to raise **employment rates** and to improve labour market performance. Since both targets go hand in hand, we shortly review the trends in labour force structure in selected countries in the past (Prskawetz et al. 2004) and summarise current labour force structure and prospects (Commission of the European Communities 2005, chapter 3).

4.1 The role of direct and indirect demographic structure on labour force indicators

There is a growing literature that investigates the **impact of demographic changes** on labour force indicators. Besides the compositional effect that works through the age structure this literature is concerned about the direct effect that operates via a change of age-specific rates. As Johnson (2002), p. 113, notes "... demography is not the only, or even the most important, factor influencing the relative size and structure of the labour force." p.114: "Furthermore, behavioural factors which determine age- and sex-specific participation rates are more important than the population age structure in determining economy-wide employment shares." **Changes in age-specific rates** may be caused by individual factors as well as institutional and macroeconomic variations, which include shifts in the demand as well as supply of labour (e.g., economic swings, delayed labour market entry due to prolonged education, early retirement exits). These micro- and macro-level determinants may in turn be related to demographic changes as put forward by Easterlin (1978) and more recently by Shimer (2001).

<u>Ageing of the labour force</u>

In Figure 4.1 and Figure 4.2 we plot the time path of the crude labour force rate (the total labour force divided by the population of working age) and the mean age of the labour force for five selected OECD countries (**France, United Kingdom, Germany, Spain, and the US**). We have chosen France, United Kingdom, and the US as representatives of populations that age more slowly as compared to the fast-ageing countries Germany and Spain.

Moreover, these countries are also representative of different social security systems. Regarding old-age insurance, European countries have a long tradition in state-provided pension benefits and the pension system is still for the major part based on public provisions and constructed on the so-called pay-as-you-go principle. France, West Germany, and Spain have very large mandatory public pension systems while private schemes are little developed: corporate schemes are seldom compulsory and individual schemes are trifling. On the contrary, private schemes are important in the UK and especially in the US. In the US, large parts of pension income are from pension funds by companies (employees). In the UK, the public provisions lost part of their importance in favour of individual private arrangements (savings and insurance contracts). The different sources of income for retirement we mentioned are usually referred to as the First (State), the Second (Corporate) and the Third

(Individual) pillar. As is well known (Gruber and Wise 1999), these **alternative pension systems (will) constitute different incentives to continue work at older ages and also provide different pathways to leave the labour force**.

Figure 4.1 clearly shows the shrinking of the **crude labour force rate** for males while the crude labour force rate for women has increased during the last two decades. From 1983 to 2000, the highest crude labour force rate for males among the countries studied was observed in the US followed by the UK, West Germany, France, and Spain. While the crude labour force in the US is still close to 80 per cent for males in the late 90s, the value for France and Spain has already declined to 70 per cent during the last two decades. Contrary to the trend in the labour force of males, the crude labour force rate for women has increased over the last two decades. Similar to men, the highest labour force participation was observed among females in the US, followed by the UK, France, West Germany, and Spain. Neither for males nor for females do our data indicate a convergence of crude labour force rates across countries over time.

However, as these figures suggest, the trend in the crude labour force rate does not yet indicate that ageing of the population may imply a shortage of labour. In fact, comparing the European and American labour force rates for females indicates that there might still be a potential labour force pool among women that has not yet entered the labour market.

To capture the ageing of the labour force we plot the **mean age of the labour force** for the same set of countries and time period in Figure 4.2. During the time period 1983-2000, West Germany had the oldest labour force for males with its mean age increasing from about 39 years in the early 1980s to close to 41 years by the end of the 1990s. The male mean age of the labour force in France, the UK, and Spain has been lower during the whole time period (except for Spain in 1986 and 1987) and approaches the values of the US in the late 1990s. For all countries, the mean age of the female labour force is still below the corresponding figure for males.

During the 1990s, a pronounced increase in the mean age of the labour force of females led to a convergence of the respective male and female ages. For the UK, the US, and partly also for France, the gender gap in the age of the labour force almost disappeared in the late 1990s. In West Germany and Spain, the mean age of the female labour force is still considerably lower than the corresponding figure for males. Compared to the development of the crude labour force rate, the picture for the age of the labour force indicates that population ageing is clearly having its impact on the composition of the labour force.

Part of the decrease in the crude labour force rate and the increase in the mean age of the labour force over time is caused by a **compositional change of the population**. That means, without any change in the labour force participation rate for each age group a rise in the proportion of older workers in the labour force (which have lower participation rates) would, all other things being equal, lower the economy-wide crude labour force rate and increase the mean age of the labour force. This is the standard age composition effect commonly controlled for in demographic analysis and generally used to explain the shrinking and ageing of the labour force. However, besides the pure compositional change, certain changes in the age-specific labour force participation rates apply as well. **Labour force participation rates** have on average **decreased at younger and older ages** (as caused by later entry into and earlier exit from the labour market) while they have **increased at middle ages for females** (see Gruber and Wise 1999).

Decomposing labour market indicators

To determine how much of the change in the crude labour force rate reflects a change in age-specific labour force participation rates as compared to a change in the age composition of the population we apply the decomposition method by Vaupel (1992). (For a decomposition of the mean age of the labour force see Prskawetz et al. 2004).

More specifically, in Vaupel and Canudas Romo (2002) it is proved that the change of the average of a variable over time can be decomposed into two components. The first component (level-1 effect) measures the average change of the function of interest while the second component (level-2 effect) measures the covariance between the variable of interest and the intensity of a weighting function (see Appendix B).

Examples of such indicators are, for instance, the crude labour force rate CLF(t):

$$\mathrm{CLF(t)} = \frac{\int_{\omega_1}^{\omega_2} l(a,t)N(a,t)da}{\int_{\omega_1}^{\omega_2} N(a,t)da}$$

Where *l(a,t)* denotes the fraction of people aged *a* at time *t* who participate in the labour force (the labour force participation rate), the variable *N(a,t)* denotes the number of people aged a at time *t* and ω_1 and ω_2 are the lower and upper age bounds, respectively, of the labour force. The crude labour force can be considered as the expected/mean value of the labour force participation rate *l(a,t)* with *N(a,t)* being the weighting function.

Application of the decomposition method to the crude labour force (see Appendix B) yields a **decomposition** of the (absolute) change in the crude labour force over time into (a) the average change in age-specific labour force participation rates (**direct effect**) and (b) a **structural or compositional effect** that relates to changes in the age composition of the population.

In Table 4.1 and 4.2, we report the contribution of the direct and compositional effects to the change in the crude labour force rate between 1985 and 2000 for females and males separately. As evidenced in Table 4.1, the largest increase in the crude labour force rate for women took place in Spain followed by West Germany, the US, the UK, and France. Except for the UK and the US, more than 90 per cent of the change in the female crude labour force rate can be explained by the average in the change of the age-specific labour force participation rates. For the UK and the US, the indirect (age structure or level-2) effect constitutes about a quarter and one eighth, respectively, of the overall change. For males (Table 4.2) the biggest decline in the crude labour force rate took place in France, followed by West Germany, Spain, the UK, and the US. Similar to females, the direct effect of a change in age-specific labour force participation rates dominates. For West Germany and France, about 60 and 90 per cent, respectively, of the overall change in the crude labour force is captured by changes in the direct effect. For males in the UK, Spain, and the US, the decline in age-specific labour force participation rates exceeds even the total decline in the crude labour force rate and the compositional change becomes positive. In other words, for age groups with high labour force participation we observe a positive growth rate in the corresponding subgroup of the population. This is exactly what a positive compositional effect implies. We estimate negative compositional effects only for men in France and West Germany. For those countries, we therefore observe negative growth rates of age groups with high labour force participation.

Table 4.1:
Decomposition of the change in the crude labour force rate (per thousand) for females over time from 1985 (1987 for Spain) to 2000 for France, West Germany, Spain, UK and US

	France	West Germany	Spain	UK	US
Level 1 effect	2.1	5.2	7.7	3.4	3.9
Level 2 effect	0.2	0.0	0.5	1.1	0.6
Total change	2.3	5.3	8.2	4.4	4.5

Source: Prskawetz et al. (2004)

Table 4.2:
Decomposition of the change in the crude labour force rate (per thousand) for males over time from 1985 (1987 for Spain) to 2000 for France, West Germany, Spain, UK and US

	France	West Germany	Spain	UK	US
Level 1 effect	-3.4	-1.7	-2.9	-2.9	-1.1
Level 2 effect	-0.4	-1.1	0.4	1.0	0.6
Total change	-3.8	-2.8	-2.5	-1.9	-0.4

Source: Prskawetz et al. (2004)

To gain more insight into the contribution of each age group to the total change over time, one can apply a similar decomposition to five-year age groups. Results of such an age decomposition are summarised in Prskawetz et al. (2004). The overall picture is a decrease in the crude labour force rate at younger (less than 23 years) and older ages (over 63) for both females and males. Only for the US (independent of gender) and females in the UK is the change in the crude labour force rate positive at older ages. As noted earlier, this might be caused by the different pension systems, and hence, retirement incentives in the US and the UK compared to the other countries included in our study. For age groups in between, the change in the crude labour force rate does not show a uniform pattern for males, and it is also quite small. For males we may therefore conclude that younger and older age groups contribute most to the change in the direct and compositional effect over time. For females at ages 27.5 through 57.5 a pronounced increase in the crude labour force participation rate is apparent, with Spain and West Germany having grown most strongly. A closer look at female age-specific changes shows that the increase of the labour force participation rate at ages 27.5 through 57.5 contributed most to the increase in the overall crude labour force. While the local maximum of the direct effect for those age groups is close to the late 40s for France, West Germany and the US, it is evident that for the UK and Spain the increase in labour force participation rates in the early 30s and early 40s, respectively, was the largest factor.

In summary, our results show that the **decrease in the crude labour force rate for males** between 1985 and 2000, and also its **increase for females** in the same period, were

dominated by the change in age-specific labour force participation rates as opposed to changes in the age distribution of the total population. For males we have shown that mainly changes in labour force participation rates at younger and older ages explain the change in the crude labour force rate. For females, increases in labour force participation rates at ages between 25 and 55 years account most for the overall change in the crude labour force rate. Across countries, the decrease in the crude labour force rate for males was most pronounced in France, West Germany, and Spain, compared to the UK and the US. For females, the increase in the crude labour force was highest in Spain, followed by West Germany, the US, the UK, and France. Hence, France has experienced one of the most negative labour force developments. Not only did the crude labour force rate among men decline most, but also the increase in the female labour force rate was the lowest.

Decomposing the change in labour force indicators is particularly important if we consider a comparison across countries. Let us assume that in two countries we observe an equal increase in the mean age of the labour force. However, the underlying mechanism may be very different. In country one it could be explained by a decrease in the labour force participation rate at younger ages and a simultaneous increase at higher ages without much of a change in the composition of the labour force. In country two the phenomenon could be attributable to age composition alone without any change in the age-specific labour force participation rate. Obviously, the implications for the two economies would be very different.

We argue that for cross-national comparisons of changes in labour market indicators it is important to understand the components of such changes and to present alternative indicators for comparison. The method of decomposing an overall change into direct and compositional effects, as presented in this section, helps to quantify the causes that explain shrinking versus ageing of the labour force. Both developments are associated with the ageing of the population. Though our study only refers to past changes in labour market indicators and cannot assess the future impact of population ageing on the labour market, our results indicate that there is some scope for attenuating labour force ageing and labour force shrinkage through policy interventions that aim to change labour force participation rates. Of course, for countries where labour force participation rates for women and men are already high the margin for such behavioural changes are smaller than for countries still faced with low female and male participation rates.

The subsequent paragraphs are based on the Commission of the European Communities report (2004) of Labour Markets in the EU: An Economic Analysis of recent performance and prospects.

4.2 Current labour force structure in the EU member states

The Lisbon targets aim at an overall employment rate (population aged 15-64) of **70%**, a female employment rate of above **60%** and an employment rate for older people (population aged 55-64) of **50%** by 2010. A growth rate of 3% of GDP is envisaged for these targets to be reached in 2010.

The macroeconomic slowdown and the lack of well-timed political actions indicate that the aim concerning the **overall employment** rate will be hard to fulfil. Gender-specific employment rates indicate that while male employment, especially that of younger people, had a negative impact on employment growth in Denmark, Germany, Austria, Portugal and Finland, **female employment** developed quite promisingly. Despite a positive trend of **older workers' employment** with the background of pension system reforms, the Lisbon target seems to be missed (Table 4.3).

A more detailed analysis of the employment of key demographic groups has been performed in the Commission of the European Communities (2004) report. The increase in **female employment** can be contributed to institutional factors, changing social and cultural attitudes and rise in female educational attainment. Nevertheless married women and mothers show significantly lower labour force participation across the EU-15 countries. Part-time work and duration of unemployment are also higher among women as compared to men. Cross-country differences in female employment can furthermore be explained by cross-country differences in the tax system, child benefits, childcare subsidies, and prevalence of part-time work.

The low employment rate for **older working-age people** can be explained to a great extent through the system of early retirement benefits for redundant or unemployed elderly people as well as pension reforms creating disincentives to staying in the labour market. In contrast to life cycle models people do not exit the labour market at an age which maximises overall welfare. Reasons for these trends are multiple, e.g., disincentives to work after having reached the statutory retirement age, social norms, ignorance about possible advantages of postponing retirement, health, mandatory retirement rules, disadvantageous rules on continued earnings, violation of actuarial fair pensions, social norms and overall unemployment, etc. are all factors which influence an individual retirement decision. Key determinants influencing the retirement decision, however, are the minimum age at which retirement benefits are available, the system's generosity and the implicit tax imposed on continued work having reached statutory retirement age. On the demand side, older workers are hit relatively hard in times of short-lived technological improvements and due to obsolete skills and rather low education levels. These problems are aggravated since older workers receive relatively low training (since their potential period of amortisation is short). Training would probably not lead to higher wages, but higher job security because of reduced labour costs. Employment difficulties are once more raised, as wages do not reflect productivity but increase with seniority. Employment protection legislation favours the employment of older working people, but could interfere with their re-entry.

Further detailed analysis of the labour force participation of young people and migrants is summarised in the Commission of the European Communities (2004) report.

Table 4.3:
Labour market performance in EU-15 member states

	Employment rate		
	All	Female	Older workers
Country	2003	2003	2003
BE	59.6	51.8	28.1
DK	75.1	70.5	60.2
DE	65.0	59.0	39.5
EL	57.8	43.8	42.1
ES	59.7	46.0	40.8
FR	63.2	57.2	36.8
IE	65.4	55.8	49.0
IT	56.1	42.7	30.3
LU	61.8	50.0	34.2
NL	73.5	65.8	44.8
AT	69.2	62.8	30.4
PT	67.2	60.6	51.1
FI	67.7	65.7	49.6
SE	72.9	71.5	68.6
UK	71.8	65.3	55.5
EU 25	62.9	55.1	40.2
EU 15	64.4	56.0	41.7

Source: Commission of the European Communities (2004), p. 9

Suggested labour market reforms in the EU

It is expected that social and cultural changes, rising educational attainment and the liberalisation of part-time work will increase the employment rate of younger women and consequently overall employment rates will go up as well. To encourage the employment of older workers, politicians already have started to abstain from early retirement and support the employability of older workers. However, to fulfil the Lisbon target the **unemployment rate of women and older workers has to be reduced** by about a half (see European Communities report, 2004, p. 31). Parallel to increasing employments of women and older workers, the employment rate for younger workers is expected to decrease as a consequence of continued enrolment in higher education.

Important labour market reforms designed to reach the Lisbon target include the reform of the tax and benefit systems, policies to prevent early retirement, increase in the availability and feasibility of part-time work for young people and women, anti-discrimination laws for women and migrants, etc. The **role of education and training on employment is different for different educational groups**. An increase in upper secondary education is expected to have a positive employment impact while tertiary education is expected to raise productivity but not necessarily employment. The positive productivity effects of education are being offset by the negative short-run effects of lower employment.

The trade-off of employment and productivity is discussed in the report by the Commission of the European Communities (2004). While a static comparative analysis implies that employment and productivity growth are negatively related (arguing that less productive and less skilled people are integrated in the workforce), the long-run effect of boosting employment is positive, i.e., “the more jobs, the better”. Hence, the twin goals of the Lisbon target to increase employment and productivity are not contradictory unless misguided labour market policies are in place. However, empirical evidence clearly indicates that labour market institutions can explain a significant share in the cross-country differences in labour market performance (Commission of the European Communities 2004, p. 16ff).

Regarding the **EU-15** as a whole, the largest potential to raise overall employment lies within those countries with lower employment rates and/or a larger working age population. Specific reforms and their importance to increase productivity and employment, however, are country-specific. Key challenges are increasing the adaptability of workers and enterprises, integrating more people into working life, greater investments into human capital and implementing reforms effectively through effective government.

Labour markets in the enlarged EU

The pathway to market economies in the new EU countries caused large structural problems in the labour markets of central and east European countries, which led to a decrease of employment and in parallel to an increase of unemployment.

Labour market performance varies within the new EU member states itself. On average employment rates are lower than for the EU-15, but higher as compared to the lowest obtained within the EU-15. Low employment rates prevail especially among younger and older people and recently also among females. Unemployment is higher as compared to the average among the EU-15. Young and low-skilled persons as well as ethnic minorities are most affected by unemployment and long-term unemployment is common. Similarly, regional unemployment rose during the 1990s together with a change in employment structure by sector, occupation and firm ownership, while labour mobility decreased at the same time.

A large income gap and small education and skill differentials should theoretically **favour labour flows towards EU-15 countries**. The prospective labour flows are not clear yet since free labour movement is eliminated for the first seven years after accession. The largest inflows are expected for Germany and Austria.

Low employment rates in the new member states strengthen the challenge towards the Lisbon target. However, the larger growth potential of those countries may facilitate these aims to some extent. While broad policy challenges do not differ too much between old and new EU member states, the emphasis is slightly different. In particular, structural shifts in the labour market in terms of reallocation **towards the service sector** will continue for some time. Some flexibility in institutions is required, which supports labour mobility across sectors, regions and occupations and upgrades of the skill level.

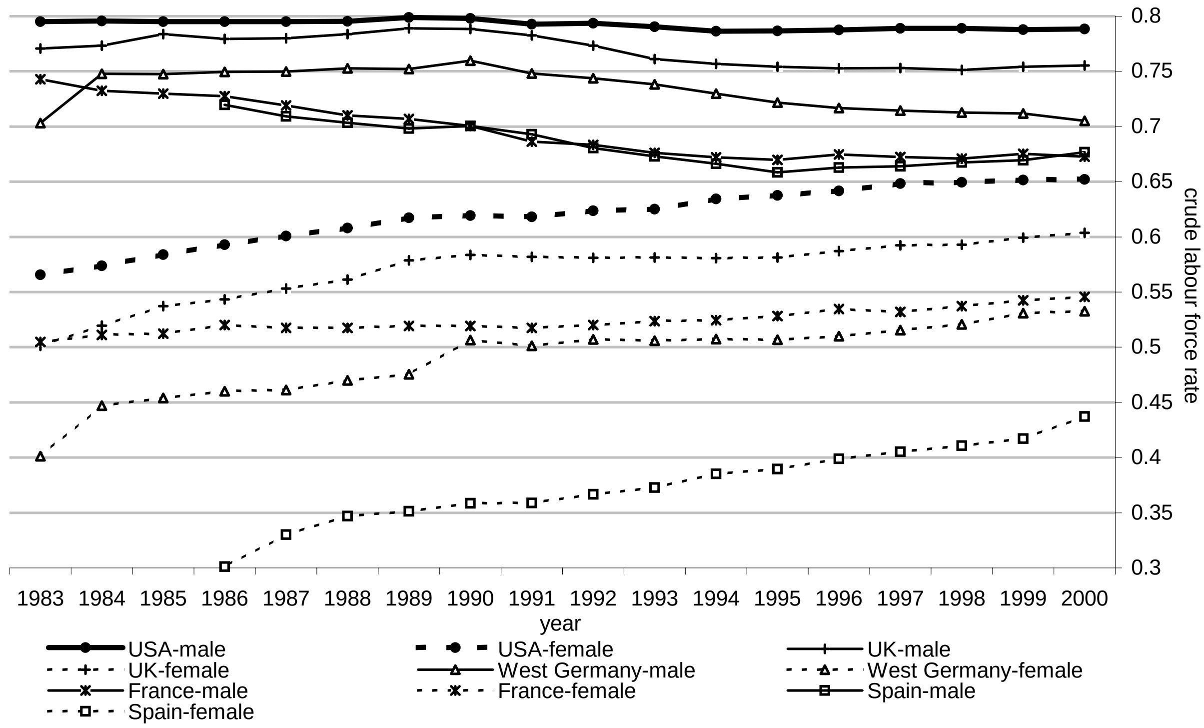
Conclusions

Our study on **five OECD countries** (France, UK, Germany, Spain and US) clearly indicates that decreases/increases in the crude labour force rate (the total labour force divided by the population of working age) for males/females between 1985 and 2000 were **dominated by changes in age-specific labour force participation rates** as opposed to changes in the age distribution of the total population. For males we could show that it is mainly changes in labour force participation rates at younger and older ages which explain the change in the crude labour force rate. For females, increases in the labour force participation rates at ages between 25 and 55 years account for most of the overall change in the crude labour force rate. Though our study only refers to past changes in labour market indicators and cannot assess the future impact of population ageing on the labour market, our results indicate that there is some **scope for dampening the effects of labour force ageing and labour force shrinkage through policy interventions aimed at changing labour force participation rates**. Of course, for countries where labour force participation rates for women and men are already high the margin for such behavioural changes are smaller than for countries still faced with low female and male participation rates.

As a recent study by the Commission of Europe shows, however, the Lisbon target of an overall employment rate of 70%, a female employment rate of 60% and an employment rate for older people of 50% by 2010 will be hard to fulfil for all countries although some countries have already achieved one or more of the goals. Regarding the EU-15 as a whole, the **largest potential to raise overall employment lies within those countries with lower employment rates and/or larger working age population.** Low employment rates in the new member states strengthen the challenge towards the Lisbon target while their larger growth potential may facilitate these aims.

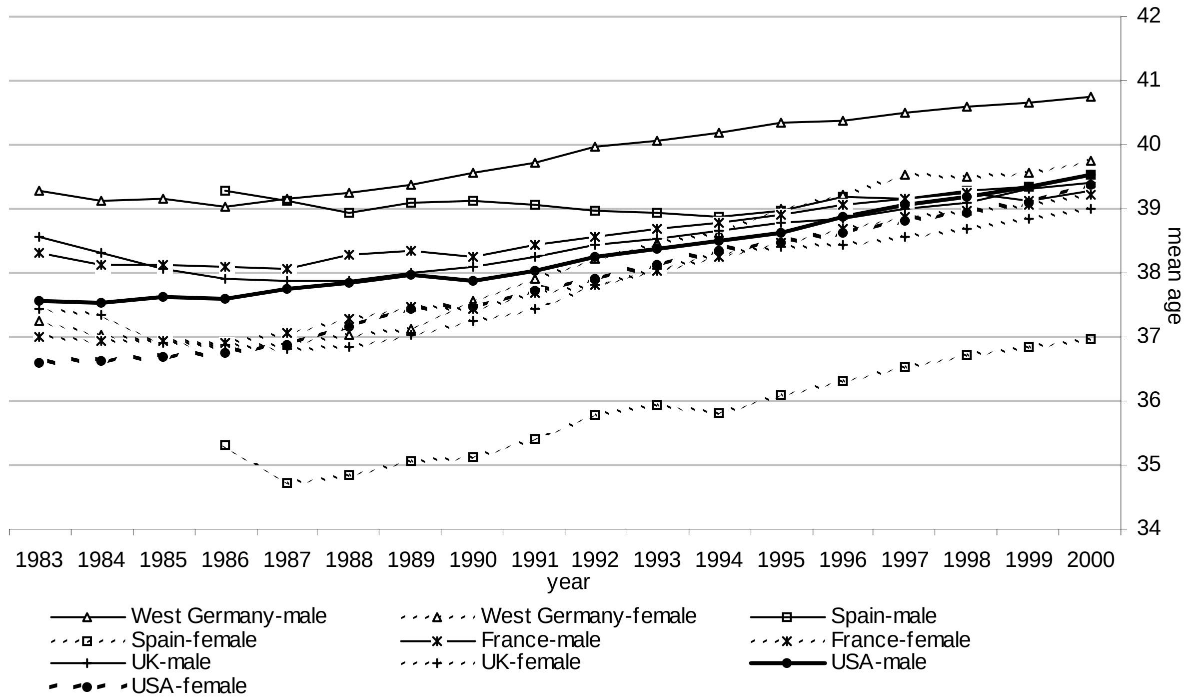
While a static comparative analysis implies that employment and productivity growth are negatively related (arguing that less productive and less skilled people are integrated in the workforce) the **long-run effect of boosting employment is argued to be positive, not least from a fiscal perspective since it broadens the tax base**.

Figure 4.1:
Crude labour force rate, 1983-2000



Source: Prskawetz et al. (2004)

Figure 4.2:
Mean age of labour force by selected OECD countries, 183-2000



Source: Prskawetz et al. (2004)

5 Demographic structure and economic productivity: theory and evidence

The current section of the report will focus on reviewing existing research that has investigated the age-productivity relation. Our main focus is on the micro level (including individual and firm-level-specific productivity). The first section gives a short review on macro level studies.

5.1 Macro level studies

While the relation between age and individual productivity is less clear-cut, there has been recent evidence of a significant relation between changes in the adult population and aggregate productivity.

In an econometric study on the experience of 18 industrialised countries, Beaudry and Collard (2003) showed that **over the period 1960-1974**, **adult population growth** (i.e., of the population aged between 15 and 64) is found to **have exerted only a small and insignificant effect on GDP per worker**, and this **effect turned negative for the period 1974-1996**. Their results imply that a country with a yearly adult population growth of 1 per cent greater than the average would experience poorer growth in output per worker of approximately 1 per cent per year which, compounded over 22 years, corresponds to a difference of 25 per cent in labour productivity. (These results are similar to earlier findings in Cutler et al. (1990) who found in a sample of 29 countries (with a labour productivity of at least 30 per cent of U.S. labour productivity) that a 1 per cent decrease in the annual labour force growth rate raised productivity growth by 0.62 percentage points a year from 1960-85, i.e., adult population growth is negative for productivity growth similar to the findings in Beaudry and Collard 2003.) Recalling neoclassical growth theory (which implies that economies with a lower growth rate of adult population would accumulate more capital) the authors argue that those findings could be evidence of **capital-biased technological change** and they continue to set up a simple growth model that incorporates those considerations.

The study by Beaudry and Collard (2003) relates closely to the empirical evidence which has shown that input accumulation cannot explain the majority of cross-country differences in output per worker, but that the “residual”, and therefore, **total factor productivity** must account for the differences, see e.g., Prescott (1998). In a recent paper Feyrer (2004) has shown that the age structure of the workforce has a significant impact on aggregate productivity (where he measured productivity as the Solow residual). In particular he found that for a sample of 87 countries over the time period **1960 to 1990 workers aged 40 to 49 have a large positive effect on productivity** and he uses his findings to explain the productivity slowdown in the US in the 70s and the boom in the 90s. (More specifically, he found that a 5 per cent increase in the size of the cohort of 40 to 49 years old over a ten-year period can lead to 1.7 per cent higher productivity growth in each year of the decade.) However, Feyrer (2004) does not present a definite mechanism through which demographic change operates although he argues that technology adoption is one of the driving factors that spurs growth, and this might be related to demographics.

A recent study by Kögel (2004) finds a significant and negative effect of the youth dependency ratio (the population below working age divided by the population of working age) on productivity and provides a theoretical model in the style of the life cycle model where he links a **lower youth dependency ratio to higher savings—hence more capital can be spent on technology, hence productivity will increase**. A key paper which presents a theoretical framework for the argument that even a dramatic decline in population growth will not lead to a long-run slowdown in productivity is Dalgaard and Kreiner (2001). The authors allow for endogenous human capital in a basic R&D-driven growth model and develop a theory of scale-invariant endogenous growth where population growth is neither necessary for, nor conducive to, economic growth.

Analyses of the relation between changes to the age structure of the population and aggregate measures of performance, such as technical progress or economic growth, can also provide insight about workers' productivity. Nishimura et al. (2002) investigate the impact of age structure on technical progress and value-added growth in Japanese industries for the years 1980-1998. They estimate the relation between technological progress and the employees' age structure and find that the relation between the **share of educated workers older than 40 years and technological progress is positive in the 1980s, but turned negative in the 1990s**. This may be due to a higher **rate of technological change** in the 1990s, which shifted the productivity peak towards younger ages.

Further studies that estimated the macroeconomic effects of the age structure of the labour force include, e.g., Lindh and Malmberg (1999) and Malmberg (1994). In both studies, demographics are assumed to influence factor accumulation, as opposite to Feyrer (2002) and Kögel (2004) who regard the effect on productivity as the more important channel. While Lindh and Malmberg (1999) find an effect of the age composition of the labour force—in particular **a positive influence of the 50-64 age group**—on growth of GDP per worker in OECD countries for the period **1960-1990**, Malmberg (1994) finds for **Sweden for the 1950 to 1989** period such age structure effects on growth of GDP, on growth of GDP per capita, on growth of TFP (total factor productivity) and on aggregate savings.

Conclusions

Recent econometric studies at the macro level have shown the importance of age structure, and in particular the age structure of the labour force, for economic growth. These studies differ in several respects such as the time period under study, the variables used, the methodology applied, etc. More recent studies follow the current economic growth literature which argues that total factor productivity as opposed to input accumulation can explain cross-country differences in output per worker. In these studies the effect of age structure on total factor productivity is estimated. Results for the OECD indicate that workers aged 40-49 have a large positive effect on productivity over the period 1960-1990. Workers aged 50-64 have also been found to positively affect GDP growth per worker in OECD countries over the same period. However, the age structure effect may not be stable over time. A distinction between the time period before the 1974s and thereafter indicates that the age structure effect on GDP per worker across 18 industrialised countries turned negative in the mid-1970s. These latter findings could be explained by capital-biased technological change. Further research is definitely needed to disentangle the mechanisms through which demographic change operates at the macro level.

5.2 Measuring age-specific productivity at the individual level

It is well known that *workers of different ages may have different levels of productivity* (as well as capacities of learning), although the exact shape is still highly disputed and strongly dependent on the occupation, technological progress and possible cohort effects that work through schooling levels (see Skirbekk 2004 for a review). Alternative methods to estimate those profiles have been suggested in the literature ranging from age-earnings profiles, supervisors' ratings, work-sample tests and employer-employee matched data sets. In the following we present a review of several of those studies and present an alternative new method that relies on ability levels by age combined with shifts in the demand structure for those abilities in the economy (section 5.4). In particular we shall discuss the importance of various mechanisms that determine the age productivity profile such as experience, training, and motivation. Understanding the age-productivity profiles is central to understand retirement incentives at the individual and firm level. Strategies of encouraging older workers to remain longer in the workforce need to be evaluated in tandem with the productivity profile of older workers.

In this section we start by recapitulating the main approaches used to measure job performance differences by age. These include *supervisors' ratings*, *piece-rate samples*, *employer-employee matched data sets* as well as *age-specific employment structure* and *age-earnings profiles*.

<u>Supervisors' ratings</u>

Studies based on **supervisors' ratings** typically do not find any clear systematic relationship between the employee's age and his or her productivity. A meta-analysis by Waldman and Avolio (1986) based on 18 supervisor assessment samples finds a slightly negative impact of age on job performance and argues that only a small part of the productivity variation could be attributed to age. McEvoy and Cascio (1989) review 96 studies on the impact of employees' age on supervisors' assessment and sales records and find no clear effect of age on productivity. Remery et al. (2003) analyse a survey of 1007 Dutch business leaders and personnel managers regarding their workers' age and their productivity. They find that older individuals are seen as less productive in particular in workplaces with more older employees, which is where knowledge about older individuals' work capacities is likely to be highest. Medoff and Abraham (1980, 1981) find that the length of job tenure is either unrelated or negatively associated to performance evaluations of white-collar American workers.

A general disadvantage with the use of supervisors' ratings to rank individuals by age and productivity is that managers may wish to reward older employees for their loyalty and past achievements. This can inflate the evaluations of senior employees and thus bias the results (Salthouse and Maurer 1996). Dalton and Thompson (1971) investigate performance evaluations not only from supervisors, but also from employees (for example engineers) in six large companies undergoing rapid technological change. The ratings from the engineers and their managers suggest that employees in their 30s put in the most effort and perform the most sophisticated technical work, and that productivity drops as the engineers move into their 40s and beyond.

Piece-rates

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 lower productivity levels. Mark (1957) and Kutscher and Walker (1960) provide some evidence that mail sorters and office workers kept productivity quite stable at higher ages, while factory workers' productivity fell after the age of 55. A study of the U.S. Department of Labor (1957) finds that job performance increases until the age of 35 to decline steadily thereafter. By the end of the career, productivity declines by 14% in the men's footwear industry, and 17% in the household furniture industry.

These task-quality/speed tests are potentially more objective as they rely less on subjective managerial assessment, though they may suffer from the fact that the workers are selected in terms of age groups and occupational types (Rubin and Perloff 1993). Further, the time limit common in such studies may bias results. For example, older employees may maintain a higher work speed in the short period they are studied than they would be able to perform 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 researchers in the fields of physics, geology, physiology and biochemistry. The number of publications and the standard of the journals they appear in are found to be negatively associated with the researchers' age. Similar evidence is found in the field of economics, where Oster and Hamermesh (1998) conclude that older economists publish less than younger ones in leading journals, and that the rate of decline is the same among top researchers as among others. Further evidence suggesting a negative association between either age or tenure and scientific output is found in Bayer and Hutton (1977) and Bratsberg et al. (2003).

Miller (1999) describes how the output of artists varies across their life span. He analyses the number of paintings, albums and books produced by 739 painters, 719 musicians and 229 writers and finds that the peak ages for creative output seem to be in one's 30s and 40s, the only exception being female authors who write most in their 50s.

Employer-employee matched data sets

A third way of measuring productivity by age is based on the analysis of **employer-employee matched data-sets**[6], where individual productivity is measured as the workers' marginal

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

impact on the company's value added. These data sets give information both on wages and productivity estimates, which allows a comparison whether productivity estimates differ from individual wages. These studies are likely to be less subjective than those based on supervisors' ratings, and there are fewer sample selection problems than studies based on piece-rates. However, the main challenge with this approach is to isolate the effect of employees' age from other influences on a company's value added, which leads to strong identifying assumptions. It also demands high-quality longitudinal data on both company and individual characteristics.

An overview over how employer-employee studies relate to age is presented in Table 5.1. For most of the employer-employee studies, an inverted U-shaped work performance profile is found (Andersson et al. 2002; Crépon et al. 2002; Ilmakunnas et al. 2004; Haltiwanger et al. 1999; Hægeland and Klette 1999). Here, individuals in their 30s and 40s have the highest productivity levels. Employees above the age of 50 are found to have a lower productivity than younger individuals, in spite of their higher wage levels.

In another study of American companies (Hellerstein et al. 1999), productivity is estimated to increase with age, where those above 55 contribute the most to output levels. However, the authors find that the peak productivity shifts to 35-54 year olds when they use the companies' value added instead of output levels as an indicator of productivity. Moreover, an earlier analysis based on the same data set (Hellerstein et al. 1996) concluded that workers' productivity *decreases* with age also in the case when the companies' output is used as an indicator of productivity. Hellerstein et al. (2004) uses more recent data, and finds a productivity decrease from the mid-50s onward. However, a French study by Aubert and Crépon (2004) finds that productivity increases to ages 40-44 but the development at subsequent ages is uncertain.

A problem with the fact that most studies on age-productivity differences are based on 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, since selectivity increases with age. Employer-employee data sets also have the problem that a company's success can increase the number of new employees and lead to a younger age structure, which could lead to wrong estimates since a young age structure could be the consequence rather than the cause of a company's success. On the other hand, some workers may stay in the labour force simply because they are relatively poor and cannot afford to retire, and be negatively selected.

Older individuals may be given less training purely because of lacking incentives, as both individuals and firms are likely to have a shorter period to benefit from investments in training. Moreover, wages could also have incentive effects, where high wages could lead to somewhat higher productivity than what would otherwise have been the case as well-paid individuals are afraid of losing their jobs. Using a lagged measure of a company's age composition to estimate current productivity can overcome this problem, as worker influx or outflow to the company will then have less impact on the worker's productivity. Andersson et al. (2002) use such lagged measures of workers' age in their analysis of employer-employee data, and their findings support the idea that older workers tend to be less productive than younger ones. However, they also find that tertiary non-technical workers tend to positively affect productivity until higher ages.

Age-earnings profiles

Age-earnings profiles can provide information on productivity profiles in settings where wages reflect current productivity. One example is a study by Lazear and Moore (1984) who examine the difference between earnings profiles of the self-employed and salary workers. They find that the self-employed tend to have little wage variation over the life cycle, while salary workers have increasing wages throughout their career. This suggests that productivity remains stable over the life cycle and the higher wages of older salary workers are due to seniority-based earnings systems rather than to higher productivity. A study by Boot (1995), describes age-earnings profiles for British workers in the first half of the 19th century, when there were few regulations in the labour market. For the physically demanding work analysed there, men reached their peak earnings in their early 30s, and wages decreased substantially from around 40 years of age.

Does wage equal productivity in general? Which dimensions should one consider to determine whether it does (e.g., intra-firm or inter-firm, age-specific or net lifetime)? Company and employee organisation and behaviour often imply that wages are determined by reasons other than individual contribution to the firms' value added (for a brief review, see Winter-Ebmer and Zweimüller 1999).

Age-specific wages often do not seem to equal productivity levels. A wage analysis provided by the OECD shows that in 17 out of the 19 countries observed[7], gross wages peak for the 45-54 age group (OECD 1998). The age-earnings profile is characterised by a relatively steep increase in wage levels until the peak is reached, followed by a mild reduction in earnings during the last years before retirement. The 25-29 age group earns on average 0.72 of what the 45-54 age group earns, while the 55-64 age group earns 0.91 of what the 45-54 age group does.[8]

Age-related differences in wages increase with the level of education (OECD 1998). For individuals with less than upper secondary education, the 25-29 age group earned 0.81 times of what the 45-54 age group earned, while for those with a university education, those aged 25-29 earned only 0.53 times of what the 45-54 age group earned.

Based on evidence presented in the OECD studies the late peak in the age-earnings profile (OECD 1998) often does not overlap with the younger peak in productivity levels. This suggests that there exists a discrepancy between productivity and wages where wages are lower than productivity levels at younger ages and higher at older ages.

Several theories have emerged to explain the rationality of why age-earnings profiles tend to peak later than age-productivity profiles. One important reason is employers' initial uncertainty about new employees' productivity levels (Harris and Holmstrom 1982). Older

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7 The countries in the study were Australia, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Mexico, the Netherlands, New Zealand, Norway, Portugal, Sweden, Switzerland and the U.S. For the Czech Republic and the UK, wages peaked for the 35-44 age group.

8 These percentages represent unweighted averages for the countries in the study.

workers are paid above their marginal productivity since upward-sloping wage profiles strengthen the employees' work effort by raising their shirking costs, lower the firm's need to train new workers, and decrease the risk of sensitive firm information being shared with competing firms if workers leave the company.

Further, when older workers receive higher wages as a reward for past productivity, junior workers' loyalty to the firm can rise since they will also want to reap the rewards of a bonus for long service. Hutchens (1989) notes that this type of incentive systems, *delayed payment contracts*, is most frequently used when the workers' performance is difficult to observe and to measure.

That age-earnings profiles differ from productivity profiles may also be due to individual preferences. Löwenstein and Sicherman (1991) find, based on lab experiments, that individuals have a preference for increasing earnings over the life cycle, rather than decreasing ones (even when the net amount is lower). Similarly, (Solnik and Hemenway 1998) suggest that individuals prefer to receive lower wages as long it allows them to earn more than their reference groups.

Lazear (1979, 1988) argues that a seniority-based earnings system creates incentives for firms to either reduce earnings at the end of individuals' careers or to attempt to lay older workers off, particularly when the population is ageing.

Lazear and Rosen (1989) argue that individuals are rewarded not in terms of absolute productivity, but rather their relative productivity. Rewards and promotions are the results of firm "tournaments", where these decisions are based on whether workers are found to be more or less productive than their colleagues. But attaining relatively high performance could be achieved not only by increasing one's own performance, but also by decreasing others' productivity and hence such compensation schemes could give adverse incentives, particularly when wage differences are high (Milgrom 1988).

Another reason why earnings may differ from work performance is that employers are reluctant to cut wages or to have a wage policy that can be perceived as unfair, as they fear this can affect turnover, quality of future applicants and employee effort (Agell and Lundborg 1995). When wages are lower than what the employees perceive as "fair", based on perceptions of average wages for workers with similar characteristics in other firms, workers may decrease their effort (Akerlof and Yellen 1990).

Whether wage compression is good for productivity or not may depend on the degree of cohesiveness. Hibbs and Locking (1995) find that in Sweden, low within-firm wage dispersion negatively affects productivity for group tasks, while the opposite could be true when individual effort is more important.

Other influences may also distort the relation between performance and wages. Organisation in unions may affect compensation patterns through a more narrow wage dispersion, minimum wages and seniority-based earnings systems (Freeman 1992). Moreover, larger firms tend to pay higher wages (Brown and Medoff 1989).

Another issue one should consider is whether or not it is rational for firms to pay higher wages. Firms seek to maximise profits, and unnecessary compensation decreases profits. Firms attempt to set wages just high enough to have the optimum composition of workers (with respect to their quantity and quality) and the incentives structure so as to obtain a sufficient work effort.

In addition to the four approaches to measure individual productivity, surveys on **entrepreneurial activity** lend support for a specific age-productivity profile. The highest rate of entrepreneurial activity, start-up of new firms or expansions of existing ones, are more likely to be carried out by individuals aged below their mid-40s, according to findings from each of the 34 countries surveyed in the Global Entrepreneurship monitor (GEMConsortium 2004). Most firms are started and operated by men, and peak entrepreneurial activity takes place in ages 25-44. However, one should note that this figure is a *flow* measure, and older individuals are more likely to already have started a firm earlier and be contempt with what they created. Men are twice as likely as women to be involved in entrepreneurial activity, and the ratio of male to female participation varies from 12:1 in France, (the lowest level), to less than 2:1 in Spain and Brazil, the countries with the highest relative level of female entrepreneurship.

Conclusions

Studies that estimate the influence of age on individual productivity are based on different indices, including supervisors' evaluations, piece-rate studies, analyses of employer-employee data sets, age-earnings profiles and entrepreneurial activity. Most piece-rate studies, measuring the quantity and quality of the workers' output, and analyses of employer-employee data sets, where a company's productivity is measured, suggest that **productivity follows an inverted U-shaped profile where significant decreases are found after the age of 50**. A problem with most estimates of how productivity varies by age is that older individuals who remain in the workforce are positively selected and have a higher productivity than those leaving the workforce, which might bias the estimates upward. Although supervisors' evaluations on average show little or no relationship between the assessment score and the age of the employee, subjective opinions may be biased, where for example the management's opinion of older employees may be inflated due to loyalty reasons. Since the relation between individual performance and wages is often distorted, age-earnings profiles cannot replicate the age-productivity profiles. Most commonly the latter profiles peak earlier than the former profiles.

Table 5.1:
Overview of employer-employee data sets

Authors	Region/ country	Sample size	Individual variables	Age categories	Control variables	Productivity measurement	Age-productivity profile	Remarks
Aubert and Crépon (2004)	France	70,680 companies, >3,000,000 employees	Unknown	<25, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54.55-59	Industry type	Firm's value added	Productivity peaks ages 40-44, stable or uncertain thereafter	Corrects for the fact that older workers are located in low-productivity firms, assumes they would otherwise be more productive
Andersson et al. (2002)	Sweden	2,874 companies	Education	16-29, 30-39, 40-49, 50-59, 60-64, 64<	Period, plant and industry effects	Firm's value added	Workers aged 50+ with primary and secondary education have lower productivity, tertiary educated aged 50+ have higher productivity	Manufacturing and mining industries. longitudinal analysis confirm findings
Crépon et al. (2002)	France	77,868 companies, >3,000,000 employees	Gender, occupation, no. of hours worked	<25, 25-34, 35-49, 49<	Company's age and size, industry type, capital	Firm's output	Productivity peaks for 25-34 age group; lowest for those aged 50+	Manufacturing and non-manufacturing
Ilmakunnas et al. (2004)	Finland	>3,882 companies, >279,181 employees	Education, experience, no. of hours worked	average employee age at each company examined	company's age, capital	Firm's value added	Productivity peak around age 40.	Manufacturing
Haltiwanger et al. (1999)	Maryland/ U.S.	Unknown (all companies in Maryland 1984-1997)	Gender, education, immigrant status	<30, 30-54, 54<	Company's age and size, industry type, period effects	Sales per employee	Workers aged 55+ have lowest productivity	All industries

Authors	Region/ country	Sample size	Individual variables	Age categories	Control variables	Productivity measurement	Age-productivity profile	Remarks
Hellerstein and Neumark (1995)	Israel	933 companies	Occupation	<35, 35-54, 54<	Industry type no. of employees, companies' capital and input factors R&D spending	Firm's output	Productivity peaks at 55+	Poor quality of data, and high inflow of young immigrants Lower validity of the study
Hellerstein et al. (1999)	U.S.	3,102 companies, 128,460 employees	Gender, race, occupation, marital status, education	<35, 35-54, 54<	No. of employees, region, type of establishment, industry type	Firm's output or value added	Productivity peak at 55+ if output is used as estimate. Productivity lowest for 55+ if value added is used	Manufacturing
Hellerstein and Neumark (2004)	U.S.	3,101< companies, 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, 1	
Hægeland and Klette (1999)	Norway	7,122 companies, 270,636 employees	Education, experience, no. of hours worked	Dependent on length of education and length of experience	Companies' age, industry type, region, public ownership, foreign ownership	Firm's value added	Productivity peaks in the 30s, declines in the late 30s	Manufacturing

5.3 Determinants of age differences in productivity profiles

Age variation in cognitive abilities and interrelations with training

A large body of evidence supports the notion that **cognitive abilities**[9] decline from some stage in adulthood. Verhaegen and Salthouse (1997) present a meta-analysis of 91 studies that describe how mental abilities develop over the life span. These studies show that important cognitive abilities, such as *reasoning, speed* and *episodic memory*, decline significantly by the age of 50.

That mental abilities tend to decline in adulthood is a universal phenomenon. Age-induced changes of mental ability levels are similar for both men and women, and the same patterns are found across different countries (Maitland et al. 2000; Park et al. 1999). Furthermore, individuals with high ability levels are subject to the same changes in cognitive functioning as those with low ability levels (Deary et al. 2000). Age-related reductions in *memory* and *learning capabilities* have been documented also among many non-human species, ranging from fruit flies to primates (Bunk 2000; Minois and Bourg 1997).

In spite of the seemingly unavoidable age-related reductions in cognitive abilities, targeted training programmes may provide a way of halting the decline. Schaie and Willis (1986a, 1986b) conclude that such programmes can stabilise, or even reverse, age-related declines in inductive reasoning and spatial orientation among many individuals. Similar evidence is presented by Ball et al. (2002), who find that persons who exercise the use of individual abilities such as speed, reasoning and memory enhance the functional level of these abilities.

Certain cognitive abilities tend to be relatively robust against age-induced declines (Schaie 1994). A division can be drawn between **crystallised abilities**, which remain at a high functional level until a late age in life, and **fluid abilities**, mental abilities that are strongly reduced over the life span (Horn and Cattell 1966, 1967). Crystallised abilities are accumulated knowledge, such as semantic meaning and vocabulary size, which tend to increase or stabilise up to a late point in life. The second group, fluid abilities, refers to the performance and speed of solving tasks related to new material, and includes perceptual speed and reasoning abilities.

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

Cross-sectional analyses, which describe 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 for example the case in the "Seattle Longitudinal Study" (Schaie 1996), where both longitudinal and cross-sectional ability differences by age

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

were collected. Findings from the longitudinal data set in that study indicated that *word fluency* does not decline before the age of 53, while according to recent cross-sectional data from the same study, this ability starts to decline already after the age of 25.

Both longitudinal and cross-sectional approaches for measuring age-ability differences are subject to problems. The weaknesses of longitudinal studies could suggest that the age-ability estimates are biased upwards (Willis and Baltes 1980): large attrition, where those who are lost are likely to be negatively selected, means that the sample that remains in later waves is positively selected.[10] Another source of error stems from test practice, meaning that when individuals who participate in the survey in subsequent waves perform better simply because they have taken similar tests before (in earlier waves of the study) and are therefore more trained at being in a test situation and used to the type of questions that are 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, since average ability levels have increased over time for more recent cohorts (Dickens and Flynn 2001; Willis and Schaie 1998). Individuals from younger cohorts are likely to be more motivated when taking ability tests, as such tests are increasingly being used in job candidate selection processes (Jenkins 2001). Furthermore, younger cohorts have more education which is also likely to increase their test performance (Flynn 1987).

Experience and learning

The decreased cognitive abilities of older workers can lead to lower productivity unless their longer experience and higher levels of job knowledge is to outweigh the decline in mental abilities. Warr (1994) suggests a categorisation of professions according to whether age affects performance (see Table 5.2).

Table 5.2:
Job activity and performance

Task	Experience improves productivity	Ability requirements below age reductions	Expected relation with age	Illustrative job content
A	No	Yes	Positive	Knowledge-based with no time pressure
B	No	No	Zero	Relatively undemanding activities
C	Yes	Yes	Zero	Skilled manual work
D	Yes	No	Negative	Continuously paced data processing

Source: Warr (1994)

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

Here, jobs are distinguished according to whether reduced cognitive performance and/or long experience will affect job performance. Salthouse (1984) uses typists as an example of a profession where experience alleviates the impact of cognitive reductions. He finds that older typists use more efficient work strategies and therefore work as effectively as their younger counterparts despite their reduced speed.

The productivity profile may change over time given structural changes in the labour market. **Accelerating technological progress** can increase the importance of being able to learn and to adjust to new ways of working, while a long work experience becomes less important. This is particularly problematic for older employees, due to age-related declines in processing speed and learning capacities (Baltes and Lindenberger 1997; Hoyer and Lincourt 1998).

Fewer training opportunities are offered to **older workers** than to younger ones, which could lower their human capital and productivity level. One reason for the companies' decision on whether to invest in their workers' human capital will depend on the expected number of years left in the working life before retirement. Since senior workers have a shorter duration to pay back firms' investments in human capital and productivity, they are offered fewer opportunities to participate in training programmes. However, if the retirement age were to be increased, the company's expected pay-off from human capital investments would be higher, which could increase the amount of training offered to older individuals and hence improve their human capital level.

The elderly learn at a slower pace than younger individuals especially if what they learn is qualitatively different from what they already have mastered. Rybash et al. (1986) argue that as people grow older, they undergo an **encapsulation of job know-how**, implying that the individuals' skills are attached to certain work domains and increasingly less transferable. In some occupations, the cognitive abilities that remain stable are the ones most closely correlated with job success. Senior employees can remain highly productive within a field that they know well and where long experience is beneficial. An example of an age-robust ability is **tacit knowledge**, procedural knowledge used to solve everyday problems, which can explain why many older managers perform as good as younger ones (Colonia-Willner 1998). However, when performing unfamiliar work, they have to rely on the ability to learn and to adjust, exactly those skills which decline most with age. Senior individuals are less capable than young ones of reorienting themselves to new task requirements and of solving novel problems (Smith 1996) and age-induced productivity reductions may increase with the complexity of the work task (Myerson et al. 1990).

Job experience improves productivity for several years, but there does come a point at which further experience is not likely to have any effect. Ilmakunnas et al. (2004) assess a broad sample of Finnish manufacturing employees, and find that job duration improves job performance for only up to a length of 3.8 years. Ericsson and Lehmann (1996), however, argue that it takes roughly 10 years to achieve expert competence in games and situations where strategic and analytic competence is important, such as in chess. 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 (Phelps and Shanteau 1978; Lehman 1953; Lesgold 1984; Raskin 1936). Since experience may be restricted to certain job types, most individuals who shift their work places tend to do so between similar types of jobs, where past experience is relevant for their work capacity. In summary, experience and increased job knowledge increase productivity up to a point where it is no longer related to job performance.

Cognitive abilities, productivity and wages

Age-related variations in mental abilities are likely to affect productivity levels because they are among the most important determinants of education and work success (Barrett and Depinet 1991; Schmidt and Hunter 1998). Schmidt and Hunter investigate how different individual characteristics, such as education, work experience and general mental abilities, relate to job performance. They find that mental ability tests predict a person's job performance better than any other observable characteristic.

Currie and Thomas (1999) and Tyler et al. (2000) find that mental ability levels measured at young ages determine adult income levels, adjusting for socio-economic characteristics. Currie and Thomas examine scores from a general mental ability test at the age of 7, while Tyler et al. analyse the test results of high school dropouts in math, writing, reading, science and social studies. A range of other studies give further weight to the notion that mental ability levels determine wage levels, including Bishop (1991), Boissiere et al. (1985), Dolton and Vignoles (2000), Grogger and Eide (1993) and Murnane et al. (2000).

Longitudinal studies find an increasingly strong correlation between test scores and wages over time. Murnane et al. (1995) study the relationship between mathematics test performance at the end of high school and hourly wages in the U.S and maintain that the relation is becoming stronger over time. Also Juhn et al. (1993) find empirical support for the increasing payoff to ability levels within narrowly defined school and occupational groups. Furthermore, the increased demand for cognitive skills in the last few decades applies to the labour market as a whole, at least in the US (Autor et al. 2003).

Conclusions

An important cause of age-related productivity declines is likely to be **age-specific reductions in cognitive abilities**. Some abilities, such as perceptual speed, show relatively large decrements already from a young age, while others, like verbal abilities, exhibit only small changes throughout the working life. Experience boosts productivity up to a point beyond which, however, additional tenure has little effect. Older individuals learn at a slower pace and have reductions in their memory and reasoning abilities. In particular, senior workers are likely to have difficulties in adjusting to new ways of working.

5.4 Supply and demand for abilities: a new measure of the age-productivity profile

How job performance varies with age is generally studied using 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 by age. In this part of the report, we estimate why we observe the typical U-shaped relation between age and productivity-potential by analysing causes of age differences in productivity. We base our analysis on **age variation in individuals' abilities** (as outlined in the previous section) and the **changing importance of these abilities** in the labour market. Hence, we study the supply as well as demand for abilities.

Previous investigations on the age-productivity profile have several shortcomings, which we attempt to overcome by using a **dynamic causal approach**.

a) Earlier studies neglect considering *why* productivity varies by age.

b) The shape of the age-productivity profile has been *kept fixed* over time.

c) 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.

d) Analyses of employer-employee data sets rely on strong assumptions (such as identifying causal mechanisms between age of workers and firm performance, or correctly identifying all other influences on firms' value added) regarding the relative impact of the workers' age on their firms' value added, which can bias results.

Our investigation may overcome some of these shortcomings by focusing on the potential determinants of age-differences in productivity and their change over time. Our estimates suggest that job performance follows an inverted U-shape pattern, increasing in the initial labour market years and decreasing towards the end of ones career. In contrast to earlier approaches, the shape and peak of the curve varies over time according to changes in the labour market that imply changes in the demand pattern for abilities.

<u>Time variation in causes of age-differences in productivity</u>

Evidence from employment shifts between industries and changes in the relative wage levels of unskilled and skilled employees suggests that there has been an increase in the demand for cognitive abilities over a long period of time (Acemoglu 2002; Dickerson and Green 2002; Goldin and Katz 1998; Howell and Wolf 1991; Juhn et al. 1993; Phelps Brown and Hopkins 1955; Spitz 2004). Physical strength and bodily coordination have lost much of their importance, while analytic, numerical and interpersonal abilities are increasingly in demand.

The aim of the current study is to provide estimates for a framework of measuring the causes of individuals' productivity potential by age. Rather than studying static output measures of productivity, we focus on time-variant causal factors. This is done by using data on age-specific supply of abilities (cognitive and non-cognitive test scores). These data on abilities across age groups are weighted with a measure of time-variant labour market demand. An estimate of work experience, and how it affects the productivity of workers from different age groups, is also taken into account.

A key feature of the method used is the separation of the factors increasing productivity from those that decrease it. Experience boosts productivity and makes workers more effective. However, getting older is also associated with reductions in the performance level of several work-related abilities. At younger ages, the productivity-improving effect of longer experience is more important than the decrease in ability levels. The net effect is productivity increase. For senior workers, however, additional experience does no longer affect job performance, and productivity is reduced according to the decline in ability levels.

An outline of this framework is given in Figure 5.1. The combined impact of experience (raising performance for the first years) and other productivity input factors, such as physical and cognitive abilities (decreasing performance with advancing age) on age-specific productivity is shown.

We use estimates of ability levels (which represent the output measure of human capital) since these provide a more relevant measure of productivity than measures on human capital input, such as mean length of education or highest educational level attained. As shown in the recent literature (Barrett and Depinet 1991; Barro 1999; Currie and Thomas 1999; Hanushek and Kimko 2000; Schmidt and Hunter 1998; Tyler et al. 2000) measures of human capital output have a stronger effect on economic growth and individual job performance compared to measures of human capital input, such as education.

There are large differences in productivity across individuals within every age group. We illustrate this possibility through the parallel curves in age-experience profiles in Figure 5.1, which result in two parallel curves in the overall age-productivity profiles. These differences stem from schooling, genetic endowment, social influences and other influences which determine an individual's productivity level.

Factors affecting productivity: work-related abilities

The data on the age-specific supply of abilities are taken from the General Aptitude Test Battery (GATB), an American workforce survey carried out by the U.S. Dept. of Labour (the data are presented in Avolio and Waldman 1994). The GATB consists of detailed ability scores from 16 134 white American male and female workers with a wide range of educational and professional backgrounds. The sample was constructed to include a random cross-section of the American workforce. The subjects are aged 16-74, but those above age 65 were excluded from the present study.

We take into account the abilities for which there is knowledge about relative labour market importance[11]. The relative labour 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 labour market. The "matching" of the supply and demand of abilities is given in Table 5.3, where Numerical Ability, Managerial Ability, Clerical Perception, Finger Dexterity and Manual Dexterity are matched estimates of ability demand.

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[11] The General Aptitude Test Battery Subtests comprise nine abilities: We consider five of these abilities: 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 visualise two-dimensional representations of three-dimensional objects), Form Perception (the ability to perceive relevant detail in objects and graphic material) and Motor Coordination (the ability to coordinate eyes and hands when making precise movements).

We omit General Intelligence because this an aggregate that is not well suited for age studies, as it includes both Verbal Aptitude, which is relatively age-robust, and Numerical Ability, which declines substantially over the life cycle. The other abilities we omit tend to overlap with the abilities we include, and we exclude Motor Coordination since we use Finger Dexterity and Manual Dexterity. Moreover, Form Perception and Spatial Aptitude are closely related to Clerical Perception, and we therefore do not consider them in our study.

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

Figure 5.1:
Stylised diagram of factors affecting productivity

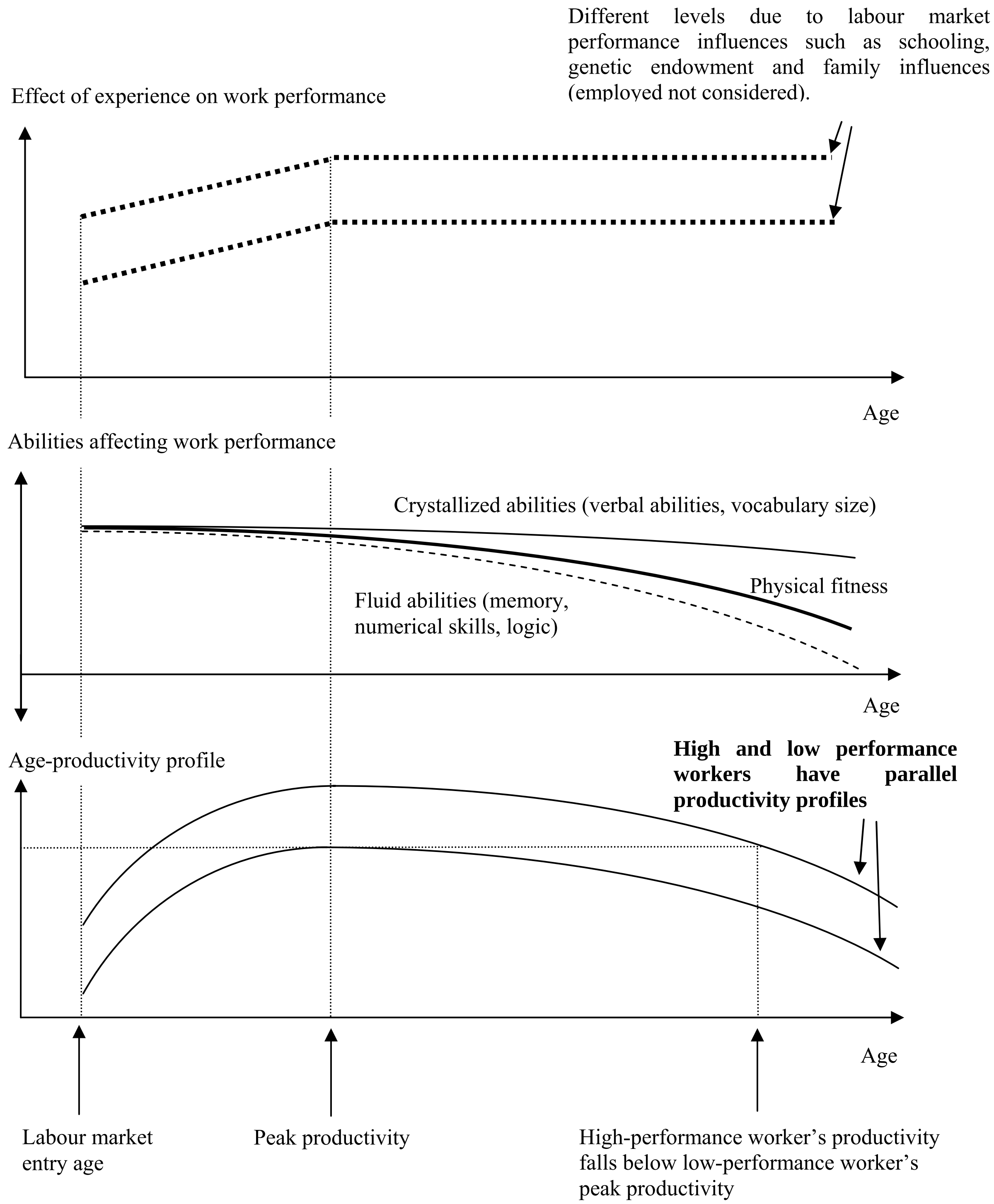


Table 5.3:
Description of aptitude test battery of the matched ability supply and demand

Abilities supplied Source: General Aptitude Test Battery. Avolio and Waldman (1994)	*Abilities demanded* Source: Dictionary of Occupational Titles, Census Data. Autor et al. (2003)
Numerical ability	GED-Math
Managerial ability	Direction, control and planning of activities
Clerical perception	Set limits, tolerances or standards
Finger dexterity	Finger dexterity
Manual dexterity	Eye-hand-foot coordination

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

Managerial ability This measures the extent to which interpersonal and communication skills, managerial skills and non-routine communication are needed in the workplace and to which extent a person is able to understand the meaning of words and language. This ability is relevant for most jobs, particularly where communication, transmitting knowledge and making strategic decisions is a central occupational task. Managerial skills tend to be well compensated in the labour market, and various measures of verbal aptitude have also been shown to be closely associated with higher income levels (IALS 2001). Managerial ability is taken from Colonia-Willner 1998, where it is found that age does not affect managerial ability. The increases at younger ages are due to an increase in verbal aptitude, as suggested from the GATB survey.

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 production processes in routine clerical tasks order to check for errors, transcribing or 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 ones hands and to carry repetitive movements out over time. It could be relevant for jobs where finger skills are important, such as for shoemakers or shirt producers.

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 in the fire-fighting occupation, this ability is important.

The age-specific test score results for these abilities are presented in Figure 5.2 and in Table 5.4.[12] Crystallised abilities (which make up a large proportion of managerial ability)

[12] For instance the value of –0.3 for age less than 19 years and numerical ability indicates that the difference between the numerical ability at ages less than 19 years and the reference age category 25-34 years is 30 percent less than the standard deviation of numerical ability at age 25-34 age.

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 those found in other similar cross-sectional studies (as shown in a survey article by Verhaegen and Salthouse 1997).

Our approach does contain simplifications that can increase the uncertainty level of the estimates: a) Our approach is necessarily restricted to only include a few of the factors that determine job performance, as there are a number of firm and individual specific factors that we do not take into account. b) Estimating the supply of **experience** from different age groups, and how this relates to labour market performance, is subject to particular challenges, as identifying the average length of experience that is beneficial to job performance needs to rely on strong assumptions. c) The factors for which there is information on labour market demand are similar, but not identical, to the abilities that are supplied. d) Creating a productivity potential by matching the supply of abilities with the demand of these abilities is not the same as measuring actual job performance. Hence, our estimates have a substantial degree of uncertainty, but can provide insight into the relative importance of work ability, which previously has not been identified.

Older workers may possess characteristics that are important to the companies' success but difficult to measure. Senior employees may have a wider professional network, give training and guidance, provide tacit knowledge, uphold norms that prevent shirking and opportunistic behaviour, and know better how to deal with problems which arise only at relatively low frequencies. On the other hand, also factors that are negatively affected by age are excluded, such as absenteeism and certain health measures.

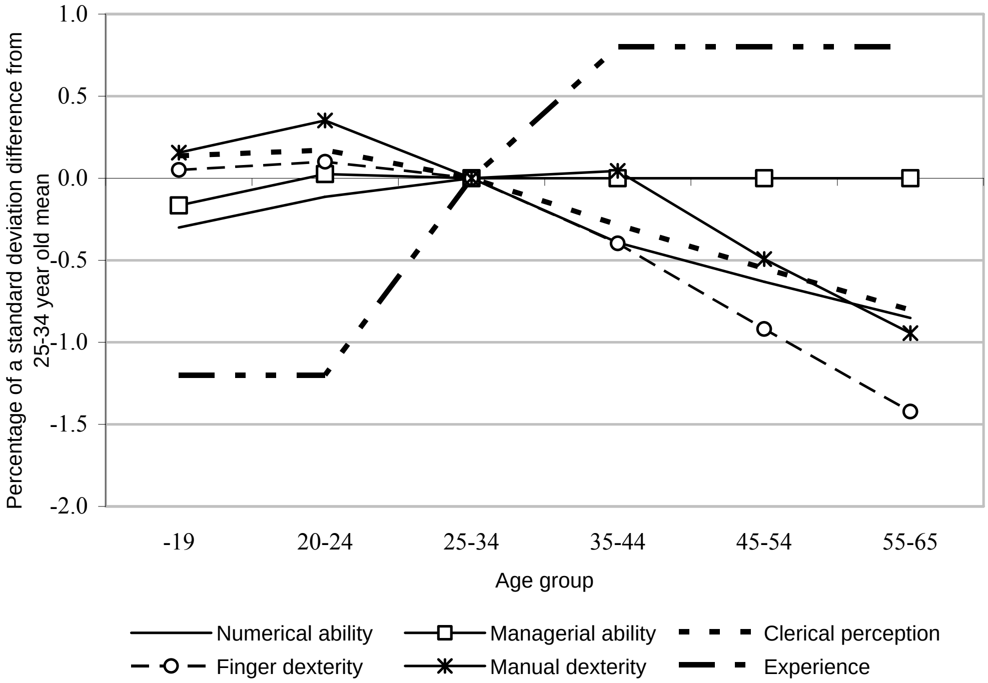
As laid out in the introduction and motivation of our report, firm-level specific characteristics may have a potential role to affect the age-productivity profile. It will be of interest to contrast our findings from the approach presented in the current section with those obtained from matched employer-employee data sets in Austria and Sweden in section 6. In particular, any discrepancy between both age-productivity profiles may partly reflect firm-specific valuation of productivity at different ages that will vary with the economy-wide demand pattern of ability we shall describe in the next paragraph.

Table 5.4:
Average ability measured as deviation and scaled by standard deviation from ability levels of 25-34 year old

Age	*Numerical ability*	*Managerial ability*	*Clerical perception*	*Finger dexterity*	*Manual dexterity*	*Experience*
-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); Colonia-Willner (1998); Ericsson and Lehmann (1996); OECD (1999) and authors' own calculations

Figure 5.2:
Ability levels according to age



Source: Avolio and Waldman (1996); Ericsson and Lehmann (1996); OECD (1999)

Demand for abilities

To estimate the demand side (labour market value) of the different abilities, we use estimates for how the importance of different job tasks has changed over time (see Autor et al. 2003). The data are considered appropriate for this study since they present the level and change of task demands for all employees. The task demand data are matched with the data on age-specific supply of abilities, as shown in Table 5.3.

Autor et al. analyse how **task input** for total U.S. employment has evolved during the time period 1960-1998. They use data from the Dictionary of Occupational Titles (US Dept. of Labour 1972), which describes the task input required in various jobs, and then merge them with data from population censuses that describe how the job structure is changing over time. The labour input of all non-institutionalised employed American workers from more than 450 job categories in ages 18-64 is examined. By combining data on the skill intensity in every job with the composition of the job structure, Autor et al. produce estimates on the extent to which each task input changes over time on an economy-wide scale

Table 5.5:
Demand for abilities. Scale 0 to 10, where 10 is the highest importance

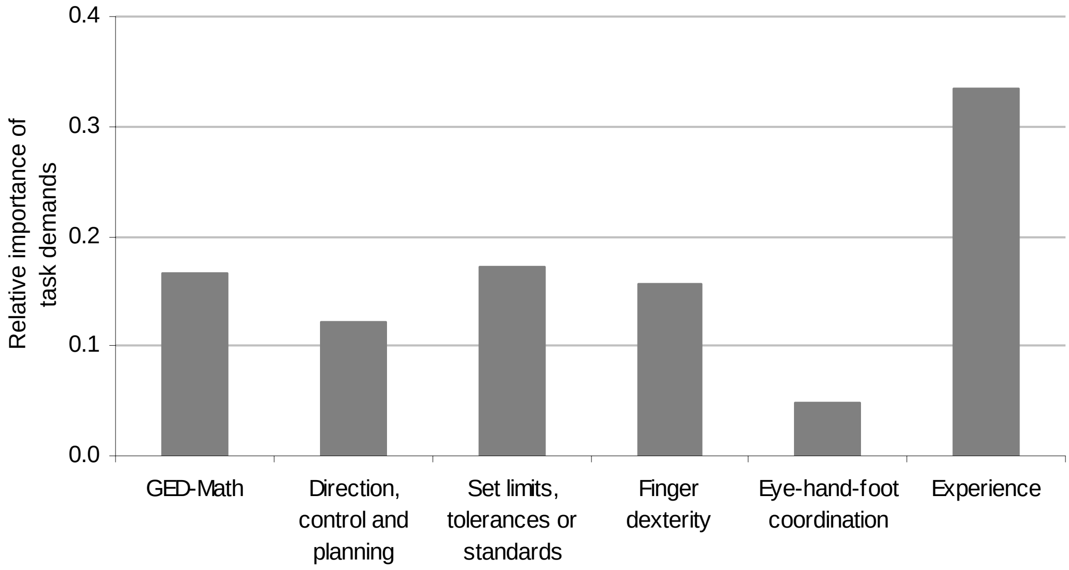
Year / *Ability*	1960	1970	1980	1990	1998
GED Math	3.61	3.72	3.76	3.87	3.97
Direction, control and planning	2.40	2.40	2.46	2.68	2.89
Set limits, tolerances or standards	4.53	4.70	4.61	4.40	4.11
Finger dexterity	3.78	3.90	3.90	3.83	3.75
Eye-hand-foot coordination	1.37	1.29	1.24	1.17	1.16
Experience	8.00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

Source: Autor et al. (2003) and authors' own estimates

In addition to the five abilities discussed above, we include an estimate of **experience** in the model. Experience is calculated in a similar way to the other abilities, where age-specific supply is measured relative to the 25-34 year old workers. No direct evidence exists on how important experience is in the labour market. In order to see the effect of experience, we assume that experience is being 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 (see, e.g., Golini 2004), and assign to it the value 8 on a scale from 0 to 10. In order to estimate the effect of a decrease in the importance of long experience, one of the scenarios estimates the effect of a labour market rating of experience that decrease from 8 to 6 over the period analysed (see Table 5.5).

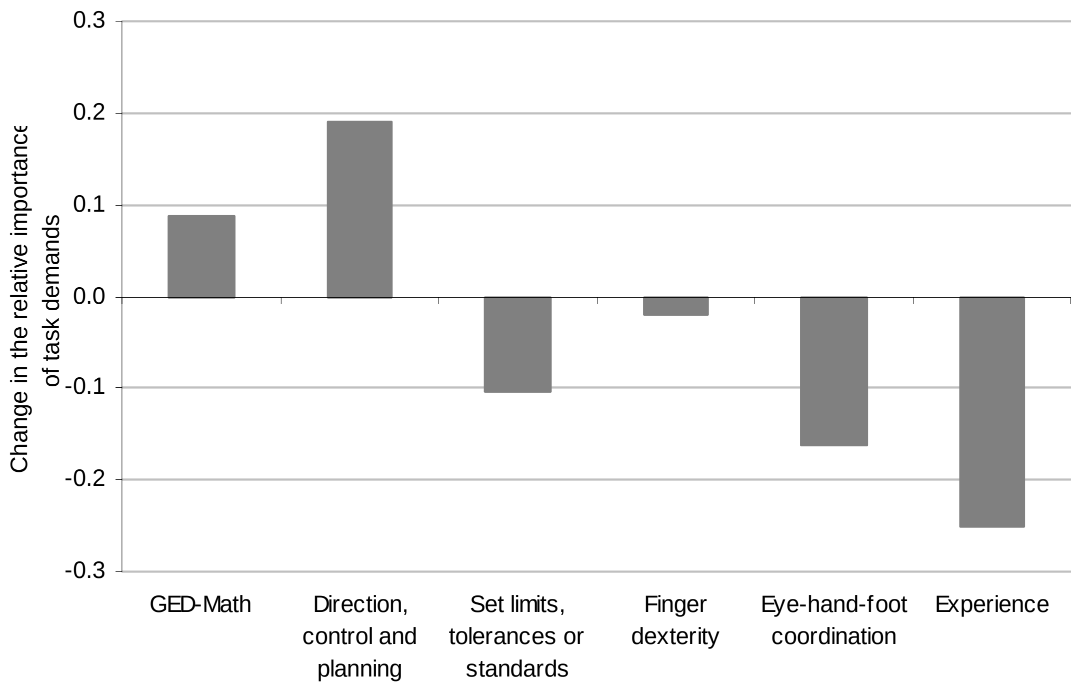
The relative **importance of these abilities** in 1998 is shown in Figure 5.3 and the change in their relative importance between 1960 and 1998 is given in Table 5.5 and Figure 5.4. The reason why we look at the time period 1960 to 1998 is that we have data from this period, which allows us to look at recent and past ability patterns in the demand for abilities. We use the development of five task categories to assess changing labour market demand for the abilities, as described in Table 5.3.

Figure 5.3:
The relative importance of job abilities in the labour market (1998), US



Source: Autor et al. (2003) and authors' own calculation

Figure 5.4:
Percentage change in task demand, 1960-1998. Change in demand of job tasks 1960-1998



Source: Autor et al. (2003); Golini et al. (2003)

Experience

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).

In order to identify the number of working years for which experience increases productivity, we use Ericsson's and Lehmann's (1996) 10-year estimate. This means that members of the age group 20-24 years are categorised as having no job experience, since the average person in this group was below the average age of labour market entrance. In 1996, the median age of labour market entrance was 22.9 years (OECD 1999). The average worker in the 25-34 years group had 6.04 years of experience (with a standard deviation of 5 years), taking into account age-specific labour force participation rates. Individuals aged 35-65 had acquired the maximum productivity enhancing effect of experience of at least 10 years.

Results: Productivity potential by age

We refer to Appendix C for the methodology of our estimation procedure and continue to discuss the results.

The estimates of the **age-productivity index**, taking experience into account, are shown in Figure 5.5 (see Table 5.6 which summarises the estimates illustrated in Figure 5.5 to Figure 5.7). The potential productivity continues to increase until around 40 years of age, when the productivity-reducing effect of lower ability levels outweigh the productivity gains from long experience. Thereafter, a linear decline until retirement age occurs, where the 55-65 year olds' productivity potential is 0.34 standard deviations lower than that of the 25-34 year olds, although they still have a productivity potential above that of those 24 years or younger. The effect of changing labour market demand, with its increasing importance of managerial abilities, is very slight. The relative potential productivity of 55-65 year old workers in 1998 (solid line) is only marginally higher than that of workers in 1960 (dashed line).

Figure 5.6 shows the effect of a decline in the importance of experience (solid line), according to Table 5.3. This leads to a shift in the peak of the potential productivity towards younger ages, where it reaches its maximum for 25 34 year olds and declines thereafter. The potential productivity for those aged 55-65 years is 0.44 standard deviations lower than for 25-34 year olds.

Figure 5.7 shows the situation where experience does not influence potential productivity. The highest productivity is then found for the 20-24 year olds. Thereafter it falls and the oldest age group, 55-65 year olds, has a productivity of 0.61 standard deviations below that of the 25-34 year olds. If experience should raise productivity for a period which is positive but shorter than our estimated 10 years, the productivity profile would peak somewhere in between the two scenarios. The scenario where experience does not matter is, however, not likely to be realistic since it obviously plays a role in job performance in almost any profession.

Table 5.6:
Productivity potential estimates for Figures 5.5 to 5.7. Values relative to 25-34 year olds, expressed in share of 25-34 year olds' standard deviation

Age group	-19	20-24	25-34	35-44	45-54	55-65
Figure 5.5						
1960 productivity potential	-0.42	-0.35	0.00	0.07	-0.14	-0.34
1998 productivity potential	-0.43	-0.35	0.00	0.07	-0.14	-0.34
Figure 5.6						
1960 productivity potential	-0.42	-0.35	0.00	0.07	-0.14	-0.34
1998 productivity potential	-0.36	-0.28	0.00	-0.01	-0.23	-0.44
Figure 5.7						
Experience matters	-0.43	-0.36	0.00	0.06	-0.14	-0.34
No impact of experience	-0.02	0.05	0.00	-0.2	-0.41	-0.61

Source: Authors' own calculation

Figure 5.5:
Age-potential productivity index, based on 1960 and 1998 task demand profile.

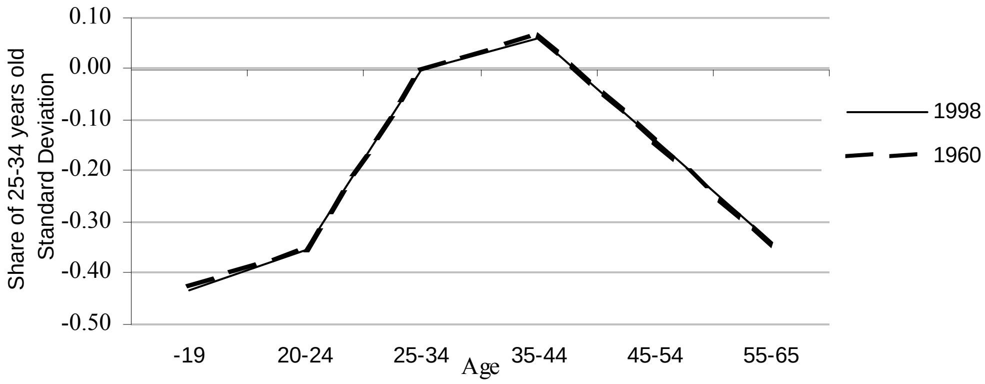


Figure 5.6:
Age-potential productivity index, with decreasing importance of experience.

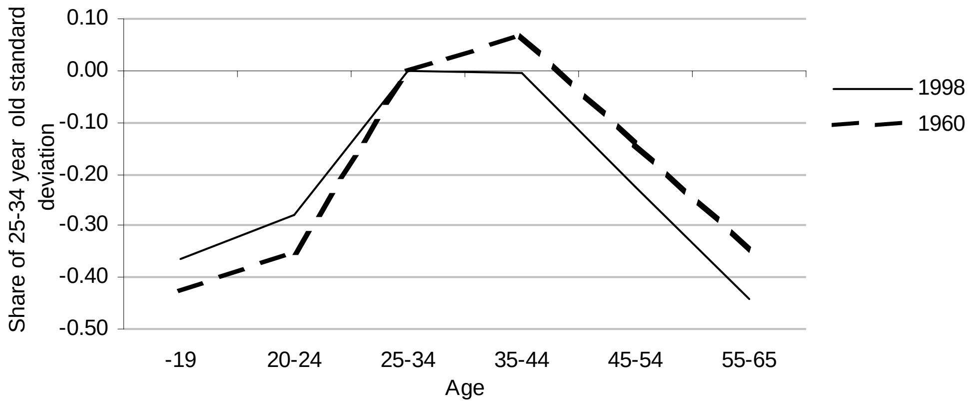
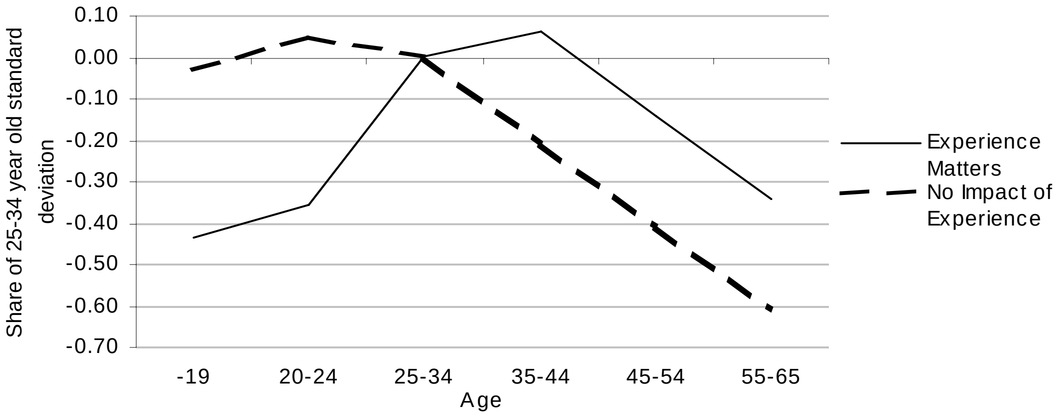


Figure 5.7:
Age-potential productivity index, given no impact of experience.



5.5 Health and population ageing

Due to continuous increases in life expectancy, the number of years one should spend in the labour market in order to maintain old-age social security increases both from the individual and the social point of view. It therefore becomes more important to understand the **potential work capacity of older individuals**.

Understanding how health develops over the life cycle is crucial to understanding an individual's work potential at older ages. **Health effects of advancing age** represent a particularly important issue if frail health would make it difficult to work or if employment represents a health hazard for older individuals. This brings up the important issue of to what extent deteriorating health affects the physical and psychological fitness and limits one's work potential as one grows older.

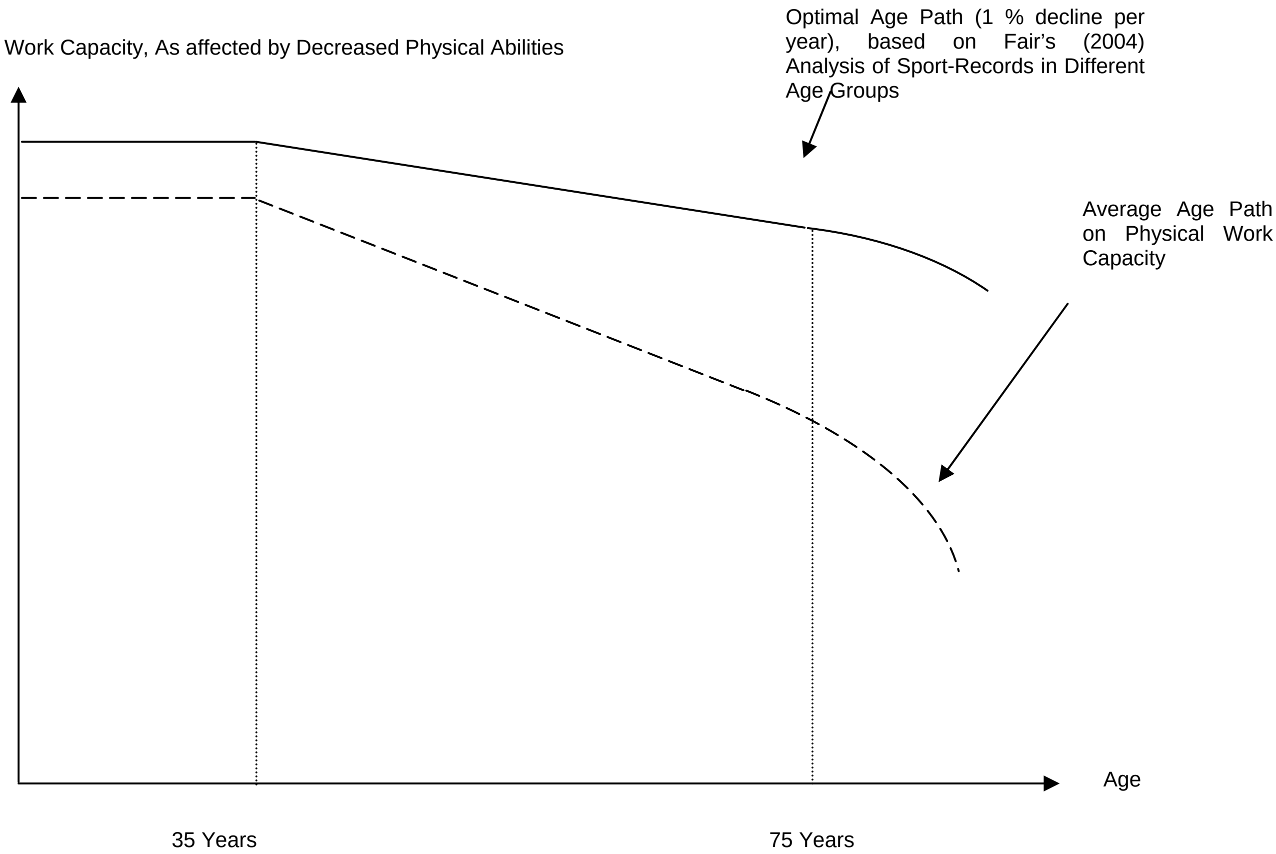
Life expectancy has increased by roughly 1.5 years per decade in industrialised countries at least for the last 40 years, and current female life expectancy lies above 80 years in many developed countries (Oeppen and Vaupel 2002; UN 2005). Also the healthy life expectancy has increased, although it seems uncertain to what extent (Olshansky et al. 1991; New Zealand Ministry of Health 2004).

Over the same stretch of time, retirement ages have dropped markedly. For countries such as France, Germany, Italy and the United Kingdom the decline has been at least 4 years from 1960-1995 (Blöndahl and Scarpetta 1998). This has led to a strong increase in the average duration of retirement. As governments are trying to reverse this trend and again increase labour force attachment among older workers, the potential effects of age on work capacity and productivity need to be evaluated.

Figure 5.8 illustrates a stylised situation of how work capacity deteriorates because of health deterioration over the life course. The upper line represents the optimal case (as indicated by sports records by individuals of different ages). However, productivity variation increases by age, and average productivity decline is considerably higher than that of peak performers. This is indicated by the dashed line below, which has a considerably steeper age gradient, and also shows an earlier age of decline.

Which aspects of age-related health deterioration may be related to work capacity? A moderate decline in muscle strength, eyesight deterioration that can be corrected by using glasses, or becoming slightly overweight are not likely to typically influence work capacity. This section will focus on the type of age-related health deterioration that can affect the ability to carry out work efficiently and increase absenteeism (for a more thorough discussion see Skirbekk 2005).

Figure 5.8:
Stylised Model of Work Capacity Across the Working Life



<u>Sensory systems</u>
Hearing ability declines with age. Anatomic changes in the external auditory canal and ear lower the ability to discriminate between sounds and cause hearing loss. Hearing aids can soften the impact of age on hearing abilities, but some issues are difficult to counter. Particularly the loss of the ability to distinguish high frequency sounds, but also the general loss of pitch discrimination, cause deterioration in the ability to make out speech (World Health Organisation 1993).

Eyesight is affected by age through several mechanisms. In addition to an increased need for eyesight correction, both static visual acuity and in particular the ability to recognise a moving target (dynamic visual acuity) decrease as one gets older. The ability to adapt from a dark to a light environment declines, and the adaptation process takes longer. Older individuals perceive an accelerating alternation of dark and light periods to be a steady light earlier than younger individuals. Moreover, older individuals need objects to be 50-70% lighter and with a stronger contrast to have the same visual ability as younger individuals (World Health Organisation 1993).

Strength, endurance and bone mass

Kemper (1994) argues that from age 25 onwards certain physiological capabilities, such as maximum oxygen intake, maximum muscle strength and skeletal mass, decrease on average by 1% per year. Several **cognitive abilities** deteriorate substantially over the life cycle. Although diseases could have strong negative effects on productivity, also the typical age-variation in productivity matters.

Bone loss occurs with advanced age, and particularly post-menopause women are affected. At the age of 70, men have lost 15% and women 30% of their bone mass. However, exercise and training can decrease bone loss and prevent loss of mobility (Chapman et al. 1972).

Vital **lung capacity** decreases from 80% to 65% from age 20 to 60. The rib articulations calcify and the thoracic cage often stiffens due to osteoarthritic changes. Respiratory muscle strength and stamina drops from the age of 50.

Blood circulation is affected by age. The contractile functions slow and blood vessel walls become less compliant. Moreover, the vessels respond less to sympathetic stimulation. From age 20 to 80, there is a 50% decline in ventricular filling, and a continuous decrease in the maximum heart rate which affects muscle strength and endurance.

One important measure of **health and physical endurance** is the maximum oxygen consumption ($\dot{V}O_2$). This is measured as maximum ml/min[13] (which for a 45 year old woman could be around 2000 on average, while a 45 year old man would have 3000). Cross-sectional evidence depicts a moderate decline with age after the age of 30 (Shwartz and Reibold 1990), while a follow-up study suggests a steeper decline, with up to 25% reduction for individuals above 45 over a 4-year period (Ilmarinen et al. 1991). WHO (1993) suggests that the yearly decline is around 26 ml per year for men and 22 ml per year for women.

Decreases in maximum **oxygen uptake** could affect work behaviour in physically demanding work, as some researchers recommend that the work strain should not exceed more than 50% of a person's maximum oxygen intake, which implies that an unfit woman around 50 could only do light work while standing. This means that many job categories with a high female representation, such as nursing or homecare, could represent a health hazard (Ilmarinen et al. 1992). However, physical exercise can strongly counteract the reductions in the maximum energy uptake.

Muscle capacity reductions can also be pronounced after around 50 years of age. There is a decrease in type-II muscle fibres (anaerobic, fast muscles), and a lowering of activity relative to energy supply. In follow-up studies both the maximal isometric trunk extension and flexion strength of male workers aged 45-50 in physically and mentally demanding jobs decreased by 40-50% during a 10-year period (Nygård et al. 1999), and the decline was similar for blue and white collar workers. This evidence indicates that today's type of work does not prevent musculoskeletal functions from declining; and that also persons working in physically demanding jobs need physical exercise to stay fit. Hence, the average

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[13] The maximum oxygen consumption measure is sometimes adjusted for body weight, e.g., ml/min/kg.

blue-collar male worker is less able to do physically demanding work with advancing age; physical capacity in normal ages decline during the period of 45-65 years (by 20-25%).

The individual differences of how age affects work ability are considerable, as systematic **physical exercise** can keep physical capacity nearly unchanged between 45-65 years. A general problem associated with comparing individuals in longitudinal studies, is that the weakest individuals tend to drop out of the studies, which creates an upward bias in the estimates (Colshen and Wallace 1991; Dehn and Bruce 1972; Hertzog 2003; Lindenberger and Baltes 1997).

Fair (2004) studies sports records for athletes aged 35-100 in various sports activities (running, swimming, chess). This approach may overcome selection issues, as it compares the best at any given age. Fair finds that the declines from age 35 until the late 70s or early 80s are linear and about 1% per year, to accelerate thereafter. Average decline is more pronounced for women than men, and the decline in chess performance is much lower. Although Fair’s study is innovative and may be more revealing than most cross-sectional longitudinal approaches (which are likely to be biased due to selection of project participations at higher ages), it is still influenced by the fact that average age-specific rates differ from top performing ones, and time-trends in health and ability among the elderly could alter the findings over time.

Diseases

Psychological disorders, in particular depressive states, are more often observed at older ages, and prevalence rates vary in the range of 1-16% (Blazer and Williams 1980; Roberts et al. 1997; Weissmann et al. 1985). However, if one adjusts for health deterioration which often is the cause of mental distress, the impact of age on depression has been shown to become insignificant (Roberts et al. 1997).

Ilmarinen (1998) finds both a very high prevalence of musculoskeletal diseases, where, among Finns aged 44-58, prevalence ranged from 31 to 46% for women and 27 to 41% for men in 1981. 11 years later, prevalence increased to 51-56% for women and 48-50% for men. Moreover, as cardiovascular and other diseases also increase with age, the share of the population without chronic diseases drops, in the range of 29-42% among the 44-58 year old to the narrower range of 14-18% among 55-69 year olds.

Overweight

In general people tend to put on weight as they get older. The proportion of body fat roughly doubles between ages 25 and 70 (WHO 1993), increasing the risk of diseases and disability. The increase in the BMI (Body Mass Index) has been documented in several cross-sectional studies. BMI has been found to increase up to 60 years (Rolland-Cachera et al. 1991; Seidell 1995; Seidell et al. 1995; Flegal et al. 1998). Guo et al. (1999) and Heitmann and Garby (1999) have shown that the most prominent increase in body weight usually takes place relatively early in adulthood, and few people manage to permanently lose weight towards the end of their working career.

In general, men tend to be overweight[14] while there is a higher prevalence of obesity[15] among women, particularly when aged above 50 years (Flegal et al. 1998; Stam-Moraga et al. 1999). Men have more skeletal muscles than women—both in absolute terms and relative to body mass. These differences have been found to be greater in the upper body (Janssen et al. 2000).

Once again, if individuals had more healthy lifestyles, with more exercise and a healthier diet, then age increases in obesity rates could be smaller although there is no evidence of a reversal in the current trend towards increasing weight levels for all ages. In European countries, in North America, and more recently almost everywhere in the world, people have gained substantially in weight. From the 1980s to the 1990s, western obesity rates (BMI over 30) grew considerably, and in several cases doubled, such as in parts of Sweden and the United Kingdom. In the 1990s, obesity rates were between 10% for men and 30% for women (WHO Monica 1988b; WHO 2000).

Absenteeism

Absenteeism tends to be higher for older individuals. In addition, the speed of work resumption declines monotonously with age and rehabilitation and disability risks increase as one gets older. It is natural to interpret the differences across age groups as reflecting differences in average health conditions. However, although unavoidable absenteeism can explain much of the increase, also avoidable absenteeism (caused by, e.g., moral hazards due to the relative lack of penalties associated with smoking) increases with age (Nordberg and Røed 2003; Ault et al. 2001; Leigh 1984 and Paringer 1983; WHO 1993).

Despite the fact that most individuals tend to have some sort of chronic disease at older ages, this does not necessarily imply that they are unable to keep up their work capacity. The age-specific risk of serious disability and morbidity has decreased in recent years, and old-age diseases now occur at progressively later ages. More effective medicines and treatment, more knowledge about healthy lifestyles and disease prevention, as well as better socio-economic conditions allow individuals to be healthier at older ages. High blood pressure, arthritis, and other chronic conditions have become less common over time (Crompton 2000; Chen and Millar 2000). For example, only 15% of 65 year old Canadians have a health condition that justifies their exit from the workforce (Michaud et al. 1996).

Workplace adjustments, ergonomics and individual-level changes

WHO (1993) lists a group of factors that should be focused on in order to increase labour force participation among older individuals. This includes a reduced pace of work, fewer working hours (particularly in physical or cognitively demanding work), more variety in the type of work and clearer information about one's work role. A better working posture, careful handling of heavy objects, decreased work speed and adjustments for increased body weight are particularly important to improve the work capacity among older individuals. Also the use

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[14] Overweight is defined as having a Body Mass Index (BMI) of 25 to 30. BMI = kg/(height*height).

[15] Obesity is defined as having a Body Mass Index (BMI) of above 30. BMI = kg/(height*height).

of hearing aids, large monitors and simplified keyboards may increase senior persons' work capacity.

Work performance of the elderly is more negatively affected by noise, they are also less tolerant to stress levels, extreme temperatures, chemicals, vibration, and they require more lighting than younger individuals. Conflicting responsibilities, unsatisfactory supervision, fear of failure, lack of freedom and control, repetitive work tasks, inadequate promotion possibilities and too little appreciation are put forward as lowering the job performance among the elderly.

Obesity, smoking, and alcohol use, all decrease work ability particularly at older ages (Tuomi et al. 1991a; Tuomi et al. 1991b; Tuomi et al. 1991c; World Health Organisation 1988; United States Public Health Service 1985; Selye 1981). E.g., smoking increases respiratory and cardiovascular disease risk and is associated with an increase in sick leaves and accidents. Hence, exercise and a healthy lifestyle can positively affect older individuals' well-being and soften the impact of age on their job performance.

As older workers often need special adjustments to their workplaces, this can have the effect of lowering their value added. Fewer working hours, the acquisition and adjustment of existing equipment, physical and mental training—all factors that could help maintain productivity among older individuals—are cost-intensive. Hence, the direct and indirect effects of deteriorating health could lower a worker's impact on the firm's value added, as the employer's costs would increase.

Conclusions

In summary, the average health **level tends to decrease markedly with age**. Although morbidity-free life expectancy has increased, several age-related decrements may lower the job performance. This includes a decreased functioning of sensory systems, particular hearing and eyesight, as well as a lowered oxygen uptake and higher obesity rates. Exercise, balanced diets and healthy lifestyles, combined with ergonomic equipment in the workplace and proper personnel management, could alleviate some of the age-related declines in health which otherwise would decrease labour market potential.

6 Case studies

The literature suggests a wide range of factors that explain productivity growth, among them technological change, accumulation of human and physical capital, firm organisation, openness, institutions, plant/firm turnover within industries, etc. The importance of these factors varies across as well as within industries and regions, hence **investments to improve productivity are a firm-level decision**. Businesses will employ such productivity enhancing strategies as innovation, capital investment or upskilling of employees if the marginal returns of these investments cover the marginal costs. Though an ageing workforce is often associated with lower productivity, there are no clear-cut empirical findings to support this assumption. In fact, one may even argue that the greater experience and higher average firm-specific human capital of older workers and their lower turnover may be advantageous for firms since these facts indicate that they have been optimally matched to the job. On the other hand, the labour market may become less flexible when the share of the older labour force is higher, because older people are less mobile. As a consequence, the process of structural change slows down, which, in turn, makes matching people and jobs less efficient. Moreover, since productivity at the individual level not only depends on experience but also on skills acquired before entering the labour market, an older workforce implies a more outdated human capital level of formal and general education, which may hinder productivity, in particular in times of rapid technological change. Of course, the demand for different types of skills will not be uniform, neither across industries nor over time. Higher education may also lead to more specialised skills with more limited markets and higher requirements for mobility. Thus, the aggregate effects of ageing in combination with rising education levels among younger workers are highly uncertain and may be quite sensitive to the rate of innovation and structural conditions in particular industries.

To measure productivity, we refer to **employer-employee matched data sets**, where individual productivity is measured as the workers' marginal impact on the firm's added value. The Institute for Futures Studies has access to a Swedish data set where individuals are linked to plant data over the period 1985-1996. For Austria, the Vienna Institute for Demography created a new matched employer-employee data set for 2001.

Employer-employee data sets typically provide information on wages and productivity estimates. This permits us to compare individuals' productivity curves with their incomes. These studies are likely to be less subjective than other ways of measuring productivity by age, such as those based on supervisors' ratings, and there are fewer sample selection problems than in studies based on piece rates (measuring the quantity and quality of individuals' output). In this approach, the main challenge is to isolate the effect of the employees' age from the other influences on the company's value added, which leads to strong identifying assumptions. Such studies also require high-quality longitudinal data on both the company's and individuals' characteristics.

6.1 Plant productivity, workforce age and educational structure in Swedish mining and manufacturing 1985-1996

There are several reasons why productivity at the plant level need not be captured by simply summing up the workers' individual capabilities. First, optimising plants will equalise the marginal productivities of different inputs and, depending on economies of scale and scope, this need not be related to the average productivity of the inputs. Second, dependent on the substitutability of technology and the complementarity of inputs, the productivity of the combined inputs may deviate substantially from the average of individual productivity in isolation.[16] Third, in real markets, lower capital costs, adjustment costs and imperfect competition, etc. are also likely to influence the actual productivity of any given plants by distorting the relation between relative prices and marginal productivity. Similar considerations also apply if we aggregate further to industry, regional or national levels.

<u>Data</u>

We use a panel of employer-employee matched data from Statistics Sweden covering the period 1985-1996. Plant level data are from the Swedish Manufacturing and Mining Survey and contain, inter alia, information about industry, annual averages of white-collar and blue-collar employees, value of output and value added. Employee data are from the ÅRSYS/RAMS database at Statistics Sweden and contain information on the age and education of individuals employed in Swedish manufacturing and mining establishments for a given week in November. By matching these two data sets we have (somewhat noisy) measures of the age and educational composition of the workforce of about **16,000 plants for 12 years** or less. Data are somewhat noisy for three specific reasons: 1) The plant definitions of the two sources differ to some extent such that the matching cannot be achieved or is somewhat uncertain in a minor number of cases. 2) For small plants (less than 5 employees up to 1987 and less than 10 employees thereafter) plant data are based on surveys of samples of the plant population. 3) Data about plants refer to annual averages, while data about employees' age and education refer to conditions in a particular week in November of the respective year. There are considerable variations both in work intensity and worker flows over the year, and there are cases where mergers, split-ups, closures, etc. create large discrepancies between the value-added base of employment and the workforce that we actually do have data about.

<u>Rank plot</u>

The strength of this data is the combination of employee data, output data and several observations for each plant. This allows us to compare the productivity levels of plants with different age and educational structures. Thanks to the panel structure, we can also control for possible plant-specific effects such as location, type of technology, management, etc.

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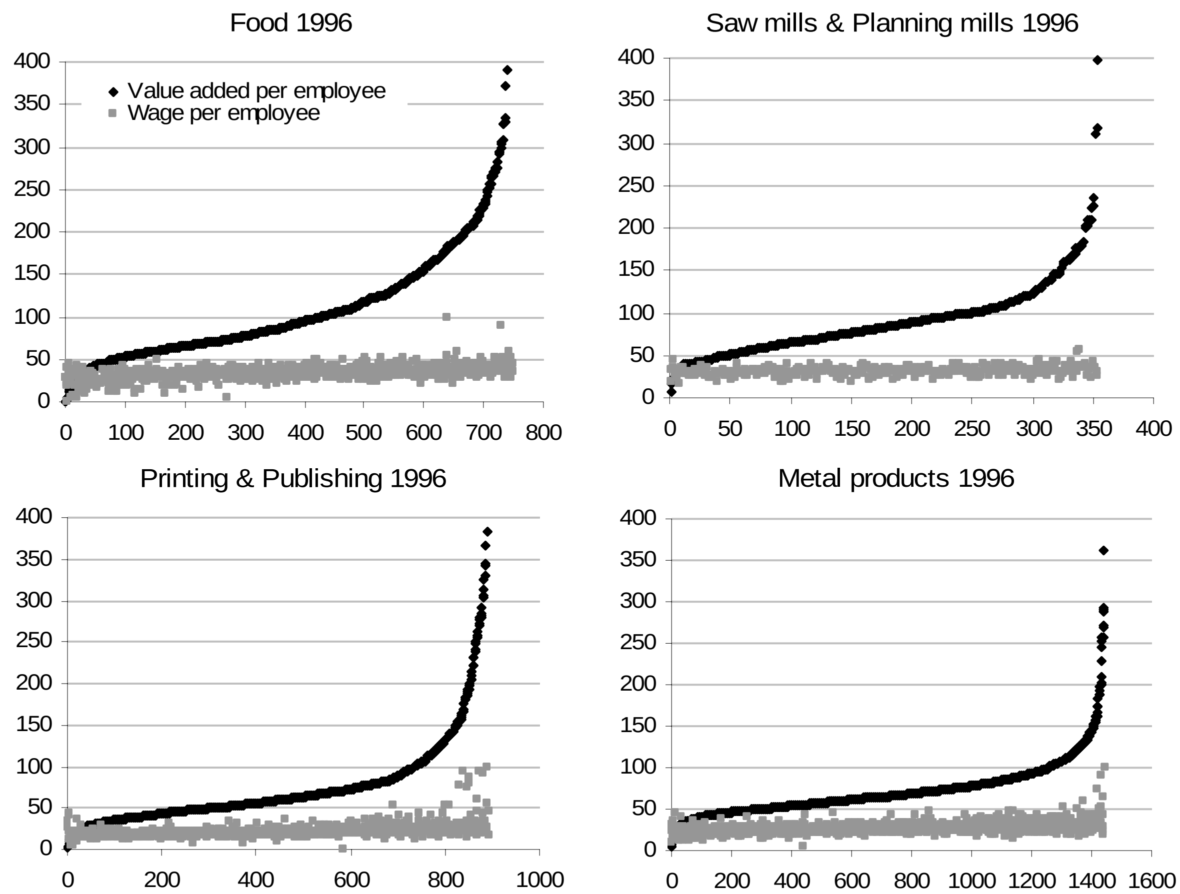
16 It can be shown (see, e.g., Prskawetz and Fent 2004) that the form of the production function strongly influences the change in productivity that results from a given change in the combination of labour inputs.

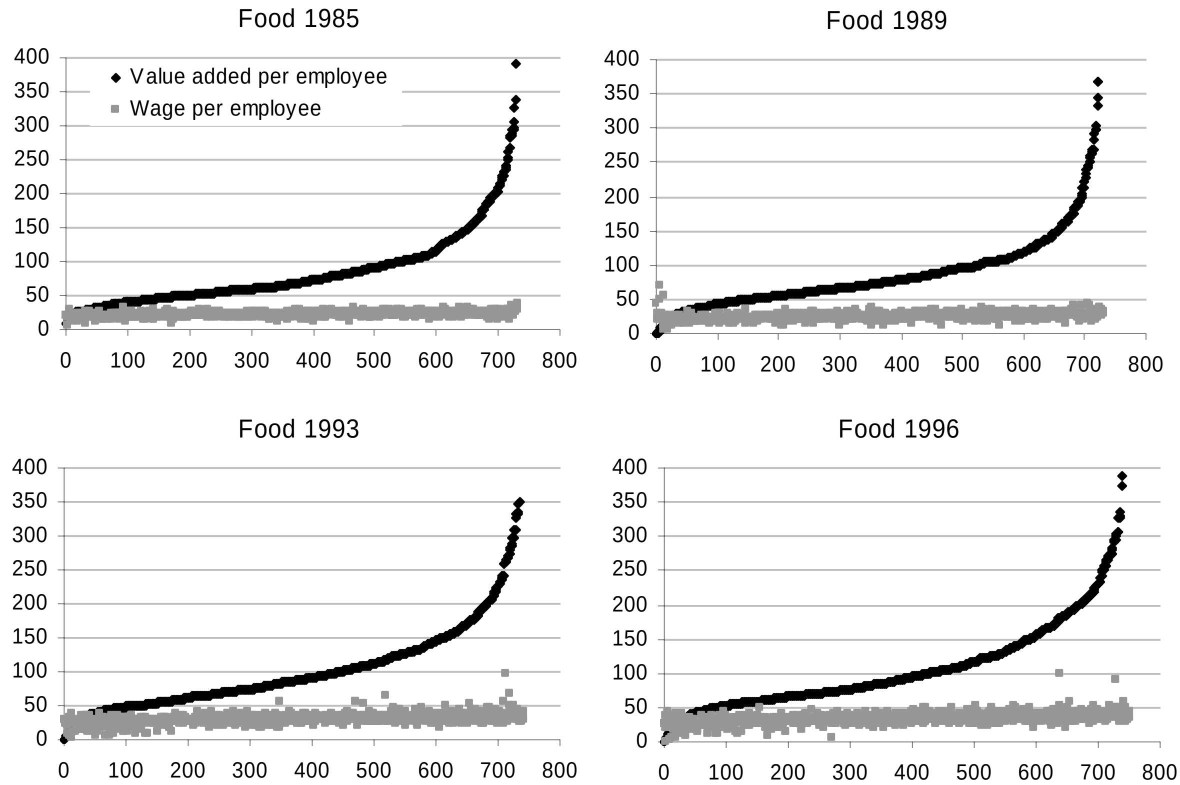
Figure 6.1 shows the ranked plant distribution of value added per employee in 1996 and the corresponding average wage cost in the plant for four different industries. In order to get comparable scales and a reasonable resolution in the graph, a few extreme observations (that are likely to be measurement errors anyway) were dropped. Value added and wage costs are measured in fixed prices expressed in 1968 SEK. Since data were deflated by industry-specific producer price indices according to an outdated industry classification, these indices cannot be directly translated into current values. Multiplying the scale by 0.7—a factor based on the general increase in PPI and current exchange rates—will give us a rough idea of what these values correspond to in terms of current EUR amounts. **Productivity dispersion** is much wider than **wage dispersion,** and for the naked eye it is almost impossible to see any relation between plant productivity and wage level. This pattern is recurrent across all mining and manufacturing industries.

Figure 6.1:
Rank plot of productivity with corresponding wage costs per employee at the plant in selected industries in 1996. The horizontal scale is the rank in the distribution of plants, while the vertical scale are amounts in thousand 1968 SEK (approximately 0.7 times this figure equals current EUR).



In Figure 6.2, the food industry was chosen to show that the same pattern persists over time as well. Forslund and Lindh (2004) demonstrate that this pattern has been persistent in all manufacturing and mining industries in Sweden ever since 1970 and that a truncated Cauchy distribution of log productivity over log employment (Student's t-distribution with one degree of freedom) with time-varying spread and mean parameters is a very good parametric representation for all years and industries. So far, no coherent theoretical explanation has been given for this remarkable consistency. Forslund and Lindh also show that there actually is a slightly positive, albeit very weak, correlation between wage level and productivity.

Figure 6.2:
Rank plot of productivity with corresponding wage costs per employee in the lower line for the food industry in 1985, 1989, 1993, and 1996. The horizontal scale is the rank in the distribution of plants, while the vertical scale are amounts in thousand 1968 SEK (approximately 0.7 times this figure equals current EUR).



These graphs[17] clearly show that wage levels at the plant offer little economically relevant explanation for the variation in productivity. While individual wages may still be significantly related to individual productivity and wages will, on average, be somewhat higher in high productivity plants, it seems that the workforce at the plant level has been combined in such a way that wage costs of labour as an aggregate have been equalised across the plant population.

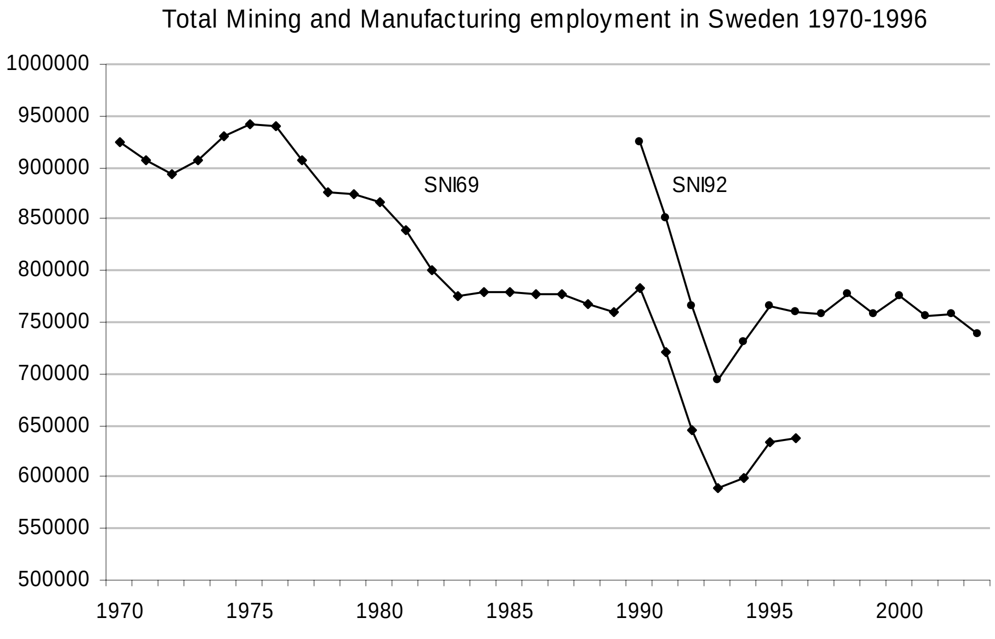
[17] This type of graphs is often referred to as Salter curves (see Salter's (1960) pioneering study of industrial structure).

The graphs above lead us to hypothesise that, in the Swedish context, competition within industries mainly results in an **equalisation of wage levels**. This may not be the case within all constitutional contexts, but Swedish wage bargaining practices strongly emphasise "solidaristic wages", i.e., equal pay for equal work, which sometimes even becomes "equal pay for all" in the debate. In combination with the so-called Rehn-Meidner model,[18] solidaristic wage policies have resulted in very compressed wage distributions. Rank plots from Austria (see Section 6.2 of this report) are fairly similar in that there is little apparent correlation between wage levels and productivity.

Employment structure

Starting in 1991, Sweden entered a deep recession in 1992-93. As shown in Figure 6.3, this drastically accelerated the downward trend in manufacturing employment. The new SNI92 classification includes more industries under the heading of mining and manufacturing. In this new scheme, employment is about 18 per cent higher than in the old SNI69, which is the basis for the database we use here. Figure 6.4 shows that this downturn in employment mainly hit the young (ages 16–29) and mostly those having primary education only in the other age groups. The number of employees having tertiary education rather increased during this crisis.

Figure 6.3:
Total employment in mining and manufacturing 1970–2003 according to IS (SNI69) and RAMS (SNI92)

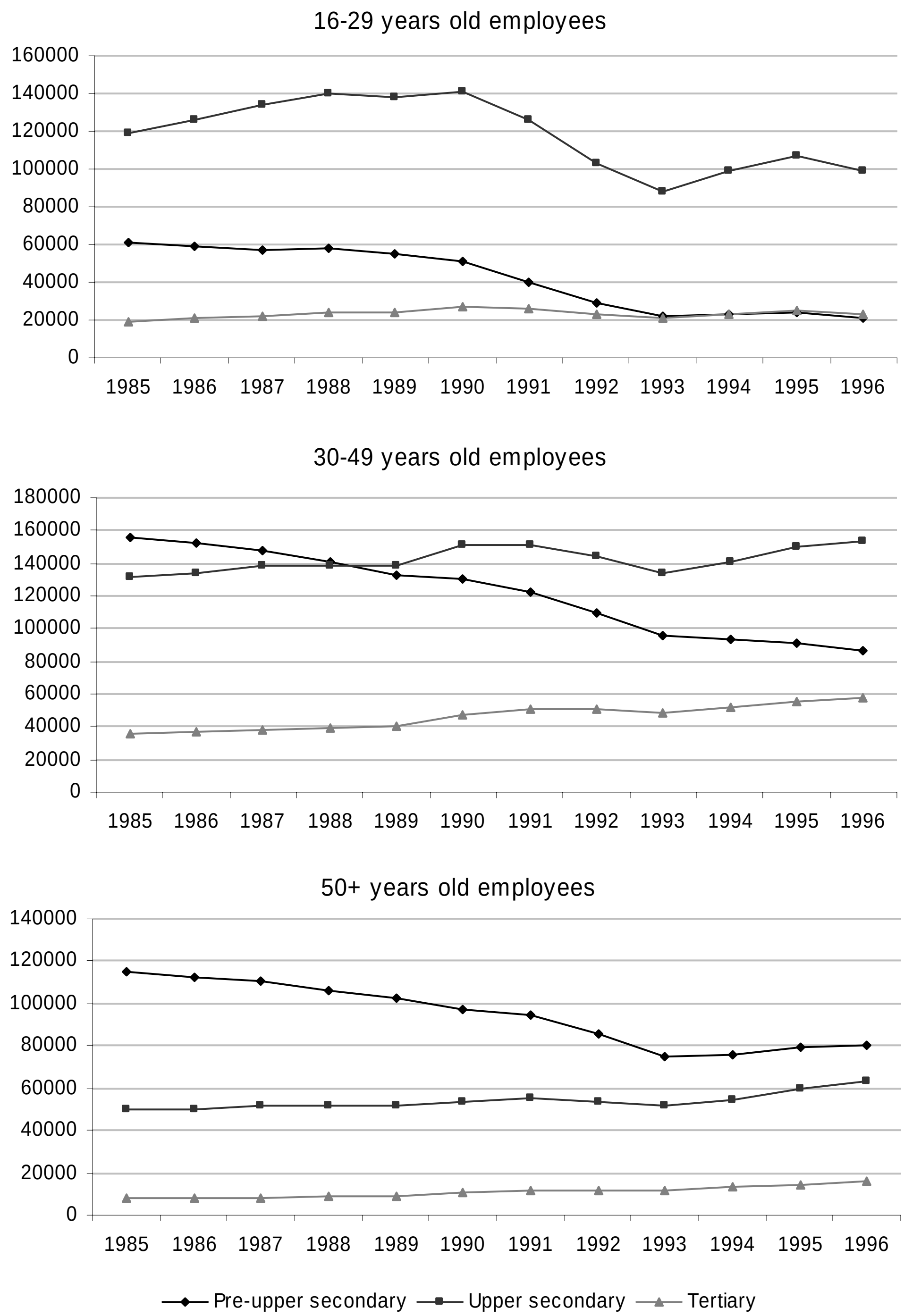


Note: As the classification of industries changed in 1993, the figures for the overlapping period are given to permit comparisons.

18 Rehn and Meidner (Landsorganisationen 1951) propose to use equal pay scales. This should facilitate a faster restructuring of the industry by allowing more productive firms higher returns to capital for reinvestment and a faster scrapping of underperforming firms. While it is doubtful whether this strategy actually worked (Forslund and Lindh 2004), it did provide economic incentives for both employers and employees to enforce a high degree of wage equality.

During the period 1985-1996, both the **age and educational composition** of Sweden’s workforce changed drastically. Figure 6.4 illustrates this development for the mining and manufacturing industries. The number of workers having primary education only decreased continuously over the whole period. In all age groups except those above 50, secondary education became the most numerous group, and it is clear that today (2005) this also holds true for those aged 50-59. The share of individuals having tertiary education also rose, albeit slowly, during this period.

Figure 6.4:
Plots of average numbers of employees in age groups at different educational levels 1985-1996



The manufacturing industry is known to be sensitive to changes in business activities. Although the cyclical pattern is pronounced, **job flows** are usually lower in manufacturing than in other sectors. One reason for this difference probably is that manufacturing consists of rather large units, and there is a negative relation between establishment size and job reallocation rates, i.e., job flows are lower in larger than in smaller establishments.

The labour composition in the manufacturing and mining industries clearly underwent major restructuring during the period covered by our data.

Statistical estimates of the relation between productivity and age structure

The estimates presented below aim at answering the empirical question of how **labour productivity at the plant level**, measured by value added per employee, is related to the age composition of the labour force. Log value added per employee is related to log age shares at the plant. The workforce was divided into three age groups: less than 30 years, between 30 and 50 years, and above 50. This division roughly corresponds to the earliest part, prime age, and later part of working life. Note that the 50+ group here also includes people above 65. To control for education levels, we computed an approximate measure of mean years in education by assuming that primary education takes 9 years, secondary education takes 12 years and tertiary education takes 15 years.[19]

In Table 6.1 we present regression estimates of the relation between plant-level labour productivity (log of value added per employee) and logged shares of age groups as well as the plant mean of years of education among the workforce. This basic specification was chosen to minimise problems with co linearity, i.e., too close covariation in the explanatory variables that gives imprecise estimates because the information in the variation overlaps. We experimented with finer sub-divisions, but the divisions presented here turned out to be the most stable way of characterising the workforce. Finer divisions do not work well in the regression equations, because they yield imprecise and unstable estimates.

The first column contains the estimate on pooled data, mainly for the purpose of comparison, since we know that too many specific differences between plants were left unaccounted for.

The **age profile** then turns out to have a **clear hump shape,** with the age group 30-49 having the most positive coefficient. This is consistent with the results generally reported on individual productivity and in the few previous studies available on plant data. Sub-divisions into more finely divided age groups yield similar pattern estimates of this hump but with much larger standard errors, since in particular the middle age groups are strongly correlated. For this reason, we do not report these estimates here but only note that the peak of the hump tends to move upwards to around 50 as we control for fixed plant effects and education.

The coefficient for mean education is strongly significant and indicates a fairly high productivity return to education. The specification is similar to the wage regressions (Mincer equations) commonly used to assess returns to education for the individual, which are around

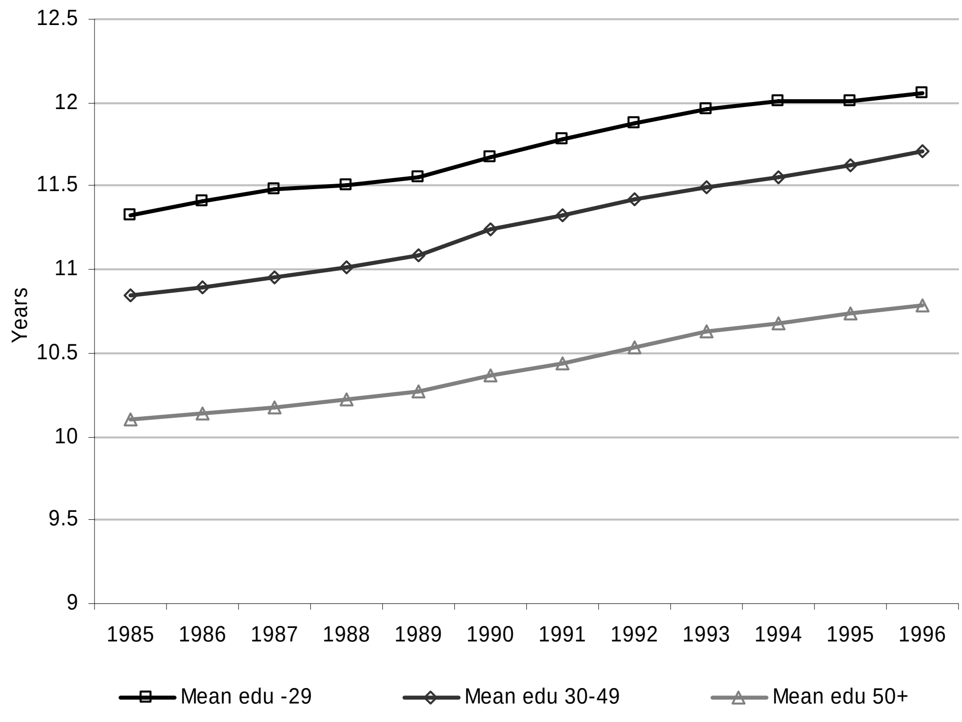
[19] What we call ‘primary’ here corresponds to less than upper secondary level in international classifications, i.e., up to 9 years of education, since this has been the compulsory level in Sweden since the end of the 1950s.

8 per cent in Sweden. It is only in the specifications including time effects that the productivity return at the plant level is below this level of private returns, and we shall argue below that including time effects poses serious problems for the interpretation. To be comparable to the elasticities estimated for the age shares we should (at the mean of the distribution) multiply the education coefficient by around 5, thus indicating a much higher elasticity of productivity with respect to education than with respect to age.

One possibly confounding factor is that adding a mean education variable does not suffice to control for the mixture of education and age effects that we get by correlating education of a certain vintage and the age structure as such. However, since the young cohorts are usually better educated than the older ones, any bias of the estimates would tend to overestimate the productivity of the young and underestimate that of the old. An indication that this may be the case is found when we compare the first column in Table 6.1 without education control with the second column where education was added. Once we control for fixed plant effects, the addition of the education variable has less effects on the other estimates. Below we shall also discuss education-specific age effect estimates.

It is worth noting that the difference in the mean length of education of each age group is remarkably stable over the entire period (see Figure 6.5). Individuals aged 30-49 have slightly less than two years more education than those aged 50+; and people aged 30-49 have about one year less education than those below 30. Thus, in spite of an increase by roughly 1.5 years in the overall mean education, the relation between age groups is practically constant in this respect.

Figure 6.5:
Mean education trend within each age group over the period 1985-1996



Of course, our equation omits numerous factors that may be important for productivity, e.g., capital, type of production, geographical location, intermediate inputs in production, technology, etc. By controlling for plant-specific effects we achieve a measure of control for these omitted variables provided they are more or less constant throughout the period.

The basic design of the plant may substantially influence plant level productivity. Examples of factors that can be costly to change in an already established plant are its location in relation to transport infrastructure, the size of premises and buildings, systems for internal transport, the physical set-up of the production flow, the dimension of tubes, vessels etc. If buildings were designed to accommodate a specific type of machinery, it may also be difficult and costly to make major changes in the type of machinery used in the plant. Taken together, the quasi-fixed factors imply that the production characteristics of plants may more or less reflect the technological level and relative prices of production factors at the time they were designed and built. If, in addition, the age structure of the labour force is influenced by the time a plant has been in operation (as is reasonable to assume), the pooled parameter estimates for different age variables might not capture the productivity effect on labour force ageing but instead serve as an indirect measure of the industrial plant's technological age.

Table 6.1:
Basic regressions on pooled data (1), with fixed plant effects (2), and time effects (3). In (4) and (5), this is repeated for a restricted sample where only plants with an average of more than 49 employees are included. Absolute values of t statistics are listed in parentheses.

Dep var: log VA/empl	1	2	3	4	5	6
Log share -29	0.020	0.006	-0.021	-0.003	-0.023	0.020
	*(5.66)***	*(1.77)*	*(7.54)***	*(0.99)*	*(2.86)***	*(2.45)**
Log share 30-49	0.128	0.080	0.032	0.028	0.138	0.097
	*(20.38)***	*(12.91)***	*(5.98)***	*(5.32)***	*(6.72)***	*(4.76)***
Log share 50+	-0.043	-0.023	0.012	0.001	0.081	0.011
	*(13.78)***	*(7.51)***	*(4.69)***	*(0.50)*	*(7.70)***	*(0.99)*
Mean education		0.146	0.098	0.041	0.201	0.038
		*(61.05)***	*(29.36)***	*(11.35)***	*(24.66)***	*(3.47)***
Constant	4.255	2.628				
	*(393.37)***	*(91.61)***				
Plant size restriction					>49 empl	>49 empl
Fixed plant effect			Yes	Yes	Yes	Yes
Fixed time effect				Yes		Yes
Observations	95,443	95,443	95,443	95,443	28,624	28,624

* significant at 5%; ** significant at 1%

We control for such plant-specific effects by removing the **plant-level mean** from the variables. When we control for fixed plant-specific effects in column (2), the 50+ group reaches significantly more positive effects than the 16–29 group and education becomes a little less productive. When further controlling for common time-specific effects (mostly the business cycle but also general changes in the age structure of the population) in column (3), the magnitude of the coefficients decreases while their basic pattern remains intact.

Indivisibilities as well as labour laws will make it difficult for **smaller firms** to achieve an optimal composition of the workforce. Because possibilities to adjust the composition of the latter are much more constrained and smaller workplaces also tend to have relatively larger measurement errors in general, we would expect to see differences between small and large plants. And indeed, we see that the coefficients in column (4) are much larger and more precisely estimated in the sample where smaller plants were excluded. However, when adding time effects they again tend to vanish. In smaller plants, the estimates have similar patterns but the differences are statistically hardly significant and much smaller.

Using shares to catch the age structure may be problematic. First, the interpretation of the coefficients is not entirely straight forward since we cannot change an age share without also changing other shares. Thus, these variables are neither independent nor are they connected by any specific functional form. Since they tend to correlate, colinearity issues easily arise. For these reasons, many researchers prefer to use such statistics of distribution as the mean or ratios of old and young, etc., or—in some cases—polynomial restrictions on age coefficients. In Table 6.2, we therefore report estimates using **mean age** as the independent variable. Since the age distribution may very well be multimodal with several peaks, this statistic can ignore very substantial changes in the age distribution (e.g., replacing all middle-aged workers by a mixture of only young and old), but at least provides an alternative view of how age distribution affects productivity.

Table 6.2:
Mean age variant of Table 6.1 regressions. Absolute values of t statistics are listed in parentheses.

Dep var: log VA/empl	1	2	3	4	5
Log mean age	-0.075	0.262	0.004	0.633	-0.012
	*(4.80)***	*(14.58)***	*(0.22)*	*(14.53)***	*(0.23)*
Mean education	0.151	0.101	0.041	0.202	0.040
	*(62.51)***	*(30.28)***	*(11.35)***	*(24.88)***	*(3.67)***
Constant	2.807				
	*(41.07)***				
Plant size restriction				>49 empl	>49 empl
Fixed plant effect		Yes	Yes	Yes	Yes
Fixed time effect			Yes		Yes
Observations	95,443	95,443	95,443	28,624	28,624

* significant at 5%; ** significant at 1%

Controlling for plant-specific effects shifts the sign of the mean age variable from significantly negative to significantly positive. Taken at face value, the point estimate for log mean age in column 4 indicates an elasticity of productivity w.r.t. mean age of 0.6; and since mean age averaged over plants is around 40, one additional year is a 2.5 per cent increase and would thus raise productivity by 1.5 per cent. In view of the previous hump-shaped estimates one might, of course, doubt the linearity of this effect.

However, further controlling for time effects reduces the coefficient of log mean age to being insignificantly different from zero. This illustrates a problem posed by time effects in this context. If all plants were to retain their workforce intact from one year to the next, the mean age would increase by one year in all plants and this variable would become perfectly collinear with the time effect. In practice, this does not happen, but nevertheless there is a built-in correlation since the workforce will tend to age when the business cycle turns down and to rejuvenate when it turns up, because new hires are predominantly from the lower half of the age distribution. Thus time effects not only tend to neutralise some of the within-plant variation over time in the age composition at the plant level that would be relevant for judging the effect of changes in the age composition, but are also likely to pick up aggregate changes in age structure that affect the variables in a similar way across plants.

The sample used in these estimations not only contains plants that operated during the entire period 1985-1996 but also those that were opened or closed down during this time. This allows us to check the assumption that productivity levels and labour age structure are correlated with **technological age**. If new plants are more up to date and more likely to employ young workers, we should expect that plants with high value added per worker and high shares of young workers are more likely to be more recent start-ups than plants with low value added per worker and low shares of young workers. Similarly, there should be a high likelihood that plants with a low mean age of workers are more recent start-ups.

Thus, technologically **older plants** with less modern machinery, building designs, etc. will also tend to have an older workforce. There is a risk that we confound the age of the plant with the age of the workforce. In Table 6.2, the switch from negative to positive mean age effects as we control for plant-specific effects indicates that this risk is real. We can explicitly check this by investigating whether **newly started plants** tend to have a younger workforce and higher productivity and conversely, plants that close down have lower productivity and an older workforce. This was confirmed by the bivariate probit equations we ran to estimate whether a young workforce or high productivity have a positive effect on the probability that the firm in question is a more recent start-up. Conversely, plants that are about to close down (in the shadow of death) are predicted by an old workforce and low productivity.

In other words, if we observe a plant with a very old workforce, we would probably be correct in predicting that it is a plant with relatively low labour productivity. However, it would be erroneous to infer from this that rejuvenating the workforce by replacing the 50+ workers by individuals below 30 could increase productivity. Instead, our empirical evidence indicates that such a substitution could, in fact, lower productivity. Rather, scrapping the plant and building a new one could be a more appropriate response.

Direction of causality and bias in the estimates

Since firms and plant management will also adapt the composition of the workforce to productivity outcomes, **bi-directional causality** is a potential problem. It may bias the estimates by correlating the residuals with the explanatory variables and making direct causal explanations dubious. For example, we could think of a negative productivity shock that makes plant managers downsize operations by primarily firing workers in a specific age (or education) group (e.g., old workers). This would lead to a spurious correlation of high productivity with high shares of old workers, and low shares of old workers with low productivity. Of course, given legislation protecting senior workers, the more likely scenario would be that negative productivity shocks and downsizing would lead to an older workforce, and conversely, new recruitment in the case of positive shocks would preferentially favour a younger workforce.

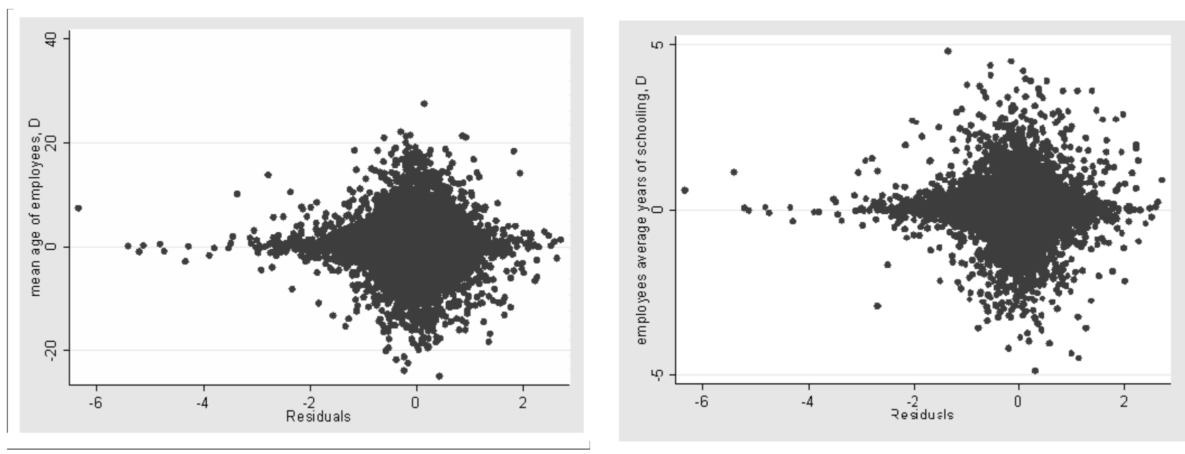
Aubert and Crépon (2004) attempt to deal with simultaneity bias by using more sophisticated econometric techniques on French data of a similar type. They tentatively find that this makes the productivity profile more similar to the wage profile which peaks around 50 or later. We experimented with these econometric techniques for solving the problem.[20] However, the validity of the instrument variables, as expressed in terms of hypotheses about over-identifying restrictions, was rejected by statistical tests. Hence, we do not present these estimates here although the point estimates tended to verify the French results.

More direct approaches were therefore also attempted in order to get at least some clue of the direction and strength with which simultaneity biases would appear in our material.

One way of getting a sense about the importance of simultaneity bias is to use predetermined variables on the right hand side of the regression equation, i.e., to let the productivity of a given year be determined by the composition of the workforce in the previous year. This is especially relevant for our data set, since the productivity variable refers to an average across the year, while the composition is measured at the end of the year, thus increasing the risk that the composition is a consequence rather than a cause of the productivity level.

Therefore the regressions in Table 6.1 were estimated using the employment shares of age and mean education categories from the previous year, since their correlation with contemporaneous residuals should at least be weaker. As we found that this hardly changed the results when using the complete sample, this does not permit us to make conclusions about an endogeneity bias. The causal interpretation of the coefficients may still be compromised since persistence in the composition of the workforce and productivity performance make it difficult to maintain that the composition of the workforce in the previous year is uncorrelated with later performance.

Figure 6.6:
Scatterplots of base regression residuals versus subsequent change in mean age or mean education



Another way of getting a sense of the potential bias is to estimate the productivity shocks and relate them to the ensuing change in composition in the succeeding period. Taking

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20 More specifically, we computed a number of Arellano-Bond type estimators, where lagged levels and differences are used as instruments.

the residuals from a base regression yields a crude estimate of the plant-specific productivity shocks. In Figure 6.6, this is plotted against the changes in mean age and mean years of education. These scatterplots give little reason to suspect any systematic bias in terms of age and educational composition in the ways plants adapt to these shocks.

However, Table 6.4 indicates, though in a statistically weak way, that mean age and education tend to increase when the preceding shock is negative. This is consistent with the aggregate evidence that the recession primarily had an impact on the employment of the young and less educated. Mean age might also increase when shocks are positive, while mean education might decrease. There is some asymmetry in Table 6.3 indicating that small to moderate positive shocks do not cause much of an adjustment of the age-education composition, possibly because growth in productivity is expected to take place if the composition is correct.

Table 6.3:
Shock regression model using lagged residuals from the base model with plant-specific effects. Absolute values of t statistics are listed in parentheses.

Dep var	1	2	3	4	5
Diff mean age					
Lag shock	0.065	0.160	0.357	-0.008	1.267
	(2.42)*	(3.36)**	(1.67)	(0.14)	(2.21)*
Constant	0.302	0.329	0.666	0.310	-1.470
	(36.54)**	(21.00)**	(1.90)	(19.08)**	(1.89)
Shock restriction		<0	<-1	>0	>1
Observations	78,595	38,048	573	40,547	335
Diff mean education					
Lag shock	0.024	0.023	0.042	-0.000	0.027
	(6.34)**	(3.46)**	(1.10)	(0.02)	(0.22)
Constant	0.049	0.046	0.063	0.056	0.008
	(42.29)**	(20.86)**	(1.01)	(24.93)**	(0.05)
Shock restriction		<0	<-1	>0	>1
Observations	78,595	38,048	573	40,547	335

* significant at 5%;** significant at 1%

However, the scatterplots suggest that these correlations may well depend on outliers and should be interpreted very cautiously. While this can hardly be taken as conclusive evidence regarding endogeneity bias it does suggest that the bias is rather weak; and if it is still significant, it should be in the direction that underrates the effects of increasing education and age.

These results prompt a further test by controlling for the growth of employment and productivity at the plant level in the regressions of Table 6.1. The results are reported in Table 6.4. As expected, both of these controls are significantly positive but do not change any essential features in the age-education patterns of Table 6.1.

Some sensitivity tests

It is, of course, uncertain to what extent fixed plant effects are able to control for the omitted capital variables. There is a sub-sample (starting in the 1990s), for which we do have investment data, which allows us to construct perpetual inventory estimates separately for machinery and structures. Without size restrictions, we can then get some 26,000 observations. This permits us to test what difference it makes to include these variables. There is no statistically significant difference in the point estimates for age groups and length of education while t-values tend to rise when we include the **capital controls.** While capital in the form of building structures has a positive significant estimate, machinery has a stronger positive coefficient, which is much more precisely estimated. Nevertheless, the interference with labour share coefficients is negligible. From this we infer that our using labour productivity rather than TFP cannot make a crucial difference to the results.

Table 6.4:
Controlling for plant employment and productivity growth. Absolute values of t statistics are listed in parentheses.

Dep var: log VA/emp	1	2	3	4	5	6
Log share -29	0.015	0.004	-0.023	-0.004	-0.019	0.023
	*(4.08)***	*(1.25)*	*(9.60)***	*(1.65)*	*(2.73)***	*(3.25)***
Log share 30-49	0.135	0.088	0.033	0.028	0.122	0.089
	*(20.53)***	*(13.53)***	*(6.91)***	*(5.94)***	*(6.81)***	*(5.00)***
Log share 50+	-0.045	-0.020	0.014	0.000	0.085	0.012
	*(13.70)***	*(6.28)***	*(6.17)***	*(0.11)*	*(9.16)***	*(1.29)*
D.(log VA/emp)	0.536	0.537	0.518	0.519	0.531	0.530
	*(104.24)***	*(106.84)***	*(207.49)***	*(210.75)***	*(111.46)***	*(112.86)***
D.(log employment)	0.087	0.074	0.017	0.017	0.032	0.015
	*(11.62)***	*(10.06)***	*(4.38)***	*(4.39)***	*(4.54)***	*(2.14)**
Mean education		0.152	0.112	0.047	0.214	0.048
		*(60.86)***	*(36.63)***	*(14.17)***	*(29.18)***	*(5.01)***
Constant	4.258	2.580				
	*(370.65)***	*(86.65)***				
Plant size restriction					50	50
Fixed plant effect			Yes	Yes	Yes	Yes
Fixed time effect				Yes		Yes
Observations	79,193	79,193	79,193	79,193	25,226	25,226

* significant at 5%; ** significant at 1%

It may also be of interest to see whether our estimates are influenced by the specific technologies used. To test the importance of different technologies we entered the **industry-specific measures of the ICT capital share** computed in Gunnarsson et al. (2004). These data were only available for manufacturing, but mining comprises very few plants so the number of plants with more than 50 employees only decreased by a few hundred observations. The share of ICT capital in the industry does have a highly significant positive effect on labour productivity. The changes in coefficients for age and education variables were, however, quite minor and do not indicate that this is particularly important for the results here. In anticipation of the education results discussed in the next section, it could be noted though that Gunnarsson et al. find that it is **the combination of ICT capital with secondary education** rather than tertiary education that drives productivity growth in Swedish manufacturing.

Age-specific education levels

Education is unevenly distributed across age groups, with the younger cohorts being generally more educated (and also more recently, which may be important, e.g., for handling modern ICT technology). Thus we have a correlation between the variables used as independent variables above that may cause another problem in identifying the effects as causal mechanisms where we can attribute a productivity effect solely to age irrespective of education. This issue is related to the familiar problem of identifying age, cohort and period effects separately, which is impossible, in any strict sense, without imposing restrictions of some kind on the data, because there is an exact linear relation between these three kinds of effects, due to the fact that age simply is time minus date of birth.

Table 6.5:
Regressions with education subdivided into three shares. Absolute values of t statistics are listed in parentheses.

Dep var: log VA/empl	1	2	3	4	5
Log share -29	0.015	-0.025	-0.004	-0.029	0.014
	*(4.04)***	*(8.87)***	*(1.52)*	*(3.65)***	*(1.71)*
Log share 30-49	0.110	0.038	0.030	0.139	0.096
	*(17.24)***	*(6.89)***	*(5.56)***	*(6.77)***	*(4.68)***
Log share 50+	-0.018	0.013	0.001	0.078	0.015
	*(5.69)***	*(4.91)***	*(0.26)*	*(7.35)***	*(1.34)*
Log share primary	-0.127	-0.029	-0.004	-0.088	0.004
	*(28.24)***	*(6.35)***	*(0.83)*	*(6.71)***	*(0.28)*
Log share secondary	0.034	0.130	0.066	0.324	0.168
	*(5.61)***	*(22.94)***	*(11.20)***	*(18.90)***	*(8.41)***
Log share tertiary	-0.021	0.004	0.003	0.021	0.012
	*(14.32)***	*(2.88)***	*(2.25)**	*(6.72)***	*(3.80)***
Constant	4.139	0.000	0.000	-0.000	0.000
	*(298.85)***	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Plant size restriction				>49 empl	>49 empl
Fixed plant effect		Yes	Yes	Yes	Yes
Fixed time effect			Yes		Yes
Observations	93,641	93,641	93,641	28,583	28583

* significant at 5%; ** significant at 1%

Because younger cohorts are more and older ones are less educated (and the value of older cohorts' education may have depreciated), controlling for mean years of education may actually confound the estimates, since an increase in education will generally be correlated with a decrease in age. This, plus the fact that our measure of mean education is a rather rough approximation of the actual human capital accumulated, motivated us to take a closer look at how education structure affects productivity.

It is somewhat puzzling to find in Table 6.5 that the **education productivity profile** is also hump-shaped, with secondary education yielding clearly more positive effects than tertiary education. However, it is reassuring that the age pattern is very close to that in Table 6.1, indicating that the particular way in which we control for education matters very little. One potential explanation for this is that shares of people having tertiary education are very small in most plants. Taking the log of this generates large negative values that may act as outliers if the functional form of the relation is misspecified. Another potential problem is the previously mentioned correlation between education and age. Of course, we also have to worry about the simultaneity in determining workforce composition and productivity.

To get a more detailed view of how labour composition and productivity of the plant are connected, we can subdivide the workforce into finer categories that do not overlap. In this way, we differentiate between the education in different age groups and thus compensate for the changes that have taken place both in terms of the overall supply of education in different cohorts and the changes in its content and hence its relevance for current technology.

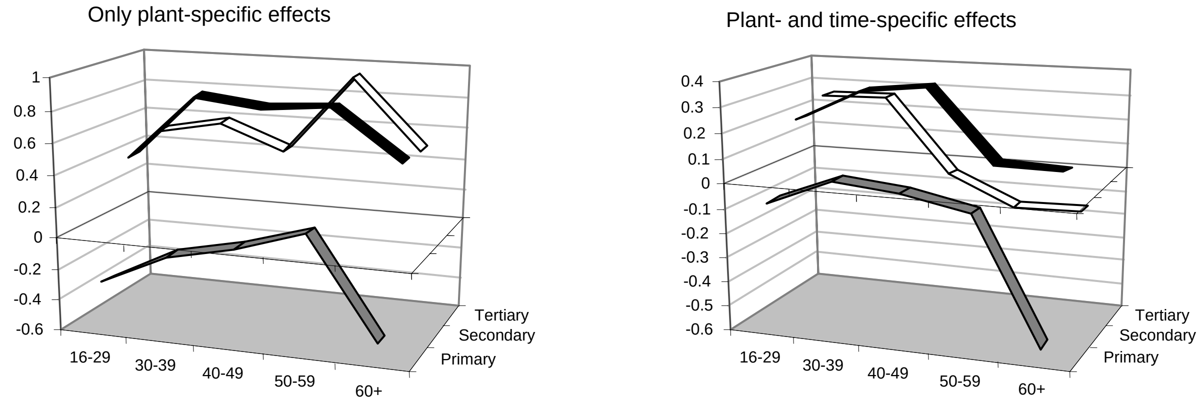
Unfortunately this poses several statistical problems. Using shares now causes even more problems with a logarithmic specification since we have plenty of very small values, especially for the older groups with tertiary education. We also have a much more complex pattern of correlations between the different shares. Below we report results from the most stable specification we found in terms of coefficients' statistical significance.

In this specification, we subdivide into age groups 16-29, 30-39, 40-49, 50-59, 60+ and then further subdivide according to education into those with only primary education, secondary education or tertiary education. With **six age groups and three education categories** this generates 18 different cells an employee can belong to (in fact, we have some with unknown education, due to classification problems especially in the 1980s, which adds another six categories to that number). It is definitely not very meaningful to include small plants in the sample, since they will have a lot of empty categories. In the rest of this section, only plants with at least 50 employees are considered.

The most stable configuration turned out to be a regression of logged productivity on shares that were not logged. Tables also start to get very hard to read, so we only report the coefficients graphically in Figure 6.7. The two estimations control for plant-specific and time-specific effects in one case. The sample was also trimmed by removing the lowest and highest percentile of the productivity distribution in order to avoid extreme values.

Figure 6.7 indicates much more reasonable age patterns in the specification with only plant-specific effects, again pointing to the problems caused by the interaction of time effects with cohort- and age effects. It is hard to believe that tertiary education should have negative effects relative to primary education for all groups above 40. However, although more similar, secondary education still seems to dominate tertiary education for age groups below 50, and the differences of the estimates are statistically significant.

Figure 6.7:
Estimated coefficient values with disjunctive age-education shares. Log value added per employee regressed on shares in the workforce of each age-education category. 40-49 year olds with primary education only were chosen as reference category.



While the problems encountered in achieving stable and significant estimates of education-specific age patterns makes it necessary to delay final conclusions until more detailed and theoretically informed research has been undertaken, two tentative conclusions still seem to be corroborated.

- One is that the inclusion of time effects is indeed confounding the estimates in such a manner that the results can hardly be interpreted in a reasonable way.
- Second, the peaks of education-specific patterns indicate a later peak of productivity effects than has been reported in the literature or observed in the previous estimates with coarser subdivisions and overlapping categories. This could be a result of difficulties to distinguish cohort-dependent education effects from age effects.

The instability may also result from an oversimplified view of how the optimal combination of age and education groups is determined. We have been working with specifications that are, in effect, crude linearised production relations. In practice, they may have only local validity for the particular supply and demand conditions during the 12-year period we observe. The separability between inputs we implicitly assume may be false. However, as some experimentation (including interaction terms) to catch cross-effects was unsuccessful, we are not likely to progress on this until more and better data is available.

<u>Productivity and local labour markets</u>

The **youth unemployment rate** is typically much higher than the unemployment rate for prime aged workers. All other things being equal, it may thus seem reasonable to conjecture that an economy with many young workers should have a higher overall unemployment rate for purely "compositional" reasons.[21] Furthermore, several studies concluded that there is "cohort crowding" (see, e.g., Bloom et al. 1987) at the labour market in the sense that young workers belonging to large cohorts perform relatively poor. If cohort crowding and

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21 See, for example, Perry (1970), Gordon (1982) and Shimer (1998) for empirical studies in this tradition.

compositional effects told the complete story, we should expect large youth cohorts to generate both higher overall unemployment rates and higher youth unemployment rates.

However, recent research starting with Shimer (2001) has questioned whether this hypothesis really holds. Shimer pointed out two major weaknesses in the **cohort crowding literature**. Firstly, the use of time series data provides a weak identification strategy since it is difficult to rule out spurious correlations as a source of the estimates. Secondly, the studies rest on the assumption that the labour market performance of older workers is independent of the youth cohort size. In his empirical analysis, Shimer used state level data from the US, which made it possible to remove all common time varying factors. He analysed how changes in the share of young workers induced by varying birth rates affected unemployment rates. Surprisingly, the results showed that an increase in the share of young workers leads to lower unemployment rates for all age groups. The effect was particularly strong for prime aged workers, thus invalidating the identifying assumption in the previous literature. He further showed that these results dominate the compositional effect so that both the age-specific unemployment rates and the overall unemployment rate actually *decline* when the share of young workers increases. It was also shown that a similar picture arises from a study of labour force participation rates and that a large youth cohort drives up wages of all age groups. However, the compositional effect dominates in the wage dimension, thus overall wages decline.

In Skans (2002, 2005) this line of research was applied to a European setting. The papers use data on **Swedish local labour markets** and follow Shimer (2001) in studying age effects induced by lagged changes in the population structure. The models were also augmented to allow for the full age distribution, rather than just the share of young workers, to affect the labour market. This was motivated by the observation that changes in the share of young workers typically correlate strongly with changes in other parts of the age distribution. Parts of the results were compatible with Shimer's estimates; most notably both studies found that an increase in the share of young workers lowers the youth unemployment rate, thus providing a stark contrast to the cohort crowding hypothesis. However, Skans found no significant effects of large youth cohorts on the unemployment rates of older cohorts, or on the average unemployment rate. A new result was that the unemployment rate increases when there are many 50 to 60 year old workers in the economy. These effects are far from trivial in size; an increase in the share of 50 to 60 year olds by one standard deviation increases the average unemployment rate by more than one percentage point. This is an effect that may explain the "jobless growth" phenomenon that has worried economic analysts throughout the past few years.

It is worth noting that results presented in both Skans (2002) and Shimer (2001) suggest that the demographic effects are mainly structural rather than demand driven. This is indicated by the sectoral effects and shows that the effects are particularly large in the manufacturing sector (Shimer 2001; Skans 2002) and mainly come from a shift in, rather than a movement along, the "Beveridge curve" that depicts the relation between vacancies and unemployment (Skans 2002).

Taken together, the results by Shimer and Skans show that **young people benefit from belonging to large youth cohorts** and that these indirect effects can be strong enough to cancel the negative compositional effects of large youth cohorts. In other aspects, the results are not fully compatible and show a need for further research. Furthermore, the theoretical understanding of the effects is not complete. However, Shimer puts forward a hypothesis (and derives a formal model), which is not only consistent with the evidence, but also provides an intuitive appeal. It is based on the notion that young workers are flexible. They are new entrants to the labour market and as such need to accept jobs that are not perfectly suited for them. In fact, measures on Swedish data clearly indicate that there are considerable mismatches between education level and job requirements, with educational over-qualification reaching levels of 20 to 30 per cent of the workforce. This also means that young employed workers are more willing to change jobs than older ones who had the opportunity to find suitable jobs in the course of their career. Thus, **labour markets with many young workers are more "fluid"** in the sense that a larger fraction of the workers are willing to change jobs.

A labour market that is more fluid may offer attractive opportunities to start up new firms and increases the incentives for existing firms to create vacancies. The reason is that the easier it is to recruit workers from existing firms, the lower are the expected costs of filling a vacancy. The flip side of this story is that the more old workers there are, the harder it is to fill vacancies. Thus, even though the model does not formally account for the whole age distribution, it is (roughly) consistent with the Swedish observation that a large share of workers aged 50 to 60 leads to higher unemployment. This age interval of workers, who are relatively old but still participate in the labour force to a high degree (at least in Sweden), is also less mobile and creates fewer vacancies by quitting.

One interesting feature of the **fluid labour market hypothesis** is that it is consistent with the US evidence on wages in predicting that age-specific wages should increase with a large youth share since the labour market becomes tighter, but that overall wages should decrease due to a compositional effect. Another prediction—one that has not yet been tested in the literature—is that the productivity values follow the same pattern: an age structure that increases the fluidity of the labour market should make each single age group more productive but reduce overall productivity.

Age and productivity at local labour markets

In this section, we use **Swedish local labour market data** to present new evidence on how the age structure affects productivity. Using local labour market data allows us to study general equilibrium effects and at the same time control for economy-wide time effects. Furthermore, we can use information on the lagged population structure to instrument the current population structure in the region in order to justify our causal interpretation of the presented estimates. In our empirical strategy we closely follow Skans (2005) and choose the double fixed effects (time and region) model with the population structure lagged by 16 years as an instrument.[22] The advantage of this strategy is that it allows us to purge the analysis of

[22] We lag both the definition and the timing by 16 years, e.g., the instrument for the fraction of 50 year olds among 16 to 64 year olds in one year is instrumented by the fraction of 34 year olds among 0 to 48 year olds 16 years ago.

all spurious correlations with the business cycle (through the time effects) and avoid problems with endogenous migration (through the instruments), and at the same time remove everything that is specific for each local labour market (through region effects).

Data

The time period under consideration is 1985 to 1996. We define local labour markets in accordance with Statistics Sweden's 1993 definition, which is based on an aggregation of municipalities with frequent cross-border commuting. This leaves us with **109 local labour markets**. Since the resulting size distribution is extremely skewed, we weight our regressions by the 16 years lagged population (ages 16-64).

In order to get data on value added we have to restrict the analysis to the mining and manufacturing sectors for which we have plant level measures. We calculate **regional productivity** as the sum of value added in all industry plants in the region divided by the sum of the employment (average during the year) in the corresponding plants.

Results

In Figure 6.8 we study how the size of each one-year age group affects the logarithm of productivity in each region. In order to estimate all one-year age groups separately we restrict them to follow a fifth-order polynomial functional form (see Fair and Dominguez 1991; Skans 2005).

The results show that the productivity is higher when there are many workers in the age interval 50 to 60. The other striking result is that many 16 to 19 year olds appear to be associated with high productivity. This result is likely to be an anomaly associated with the very low labour force participation in this group (only around 10 per cent). The polynomial restriction may also tend to yield too steep patterns at the ends of the distribution.

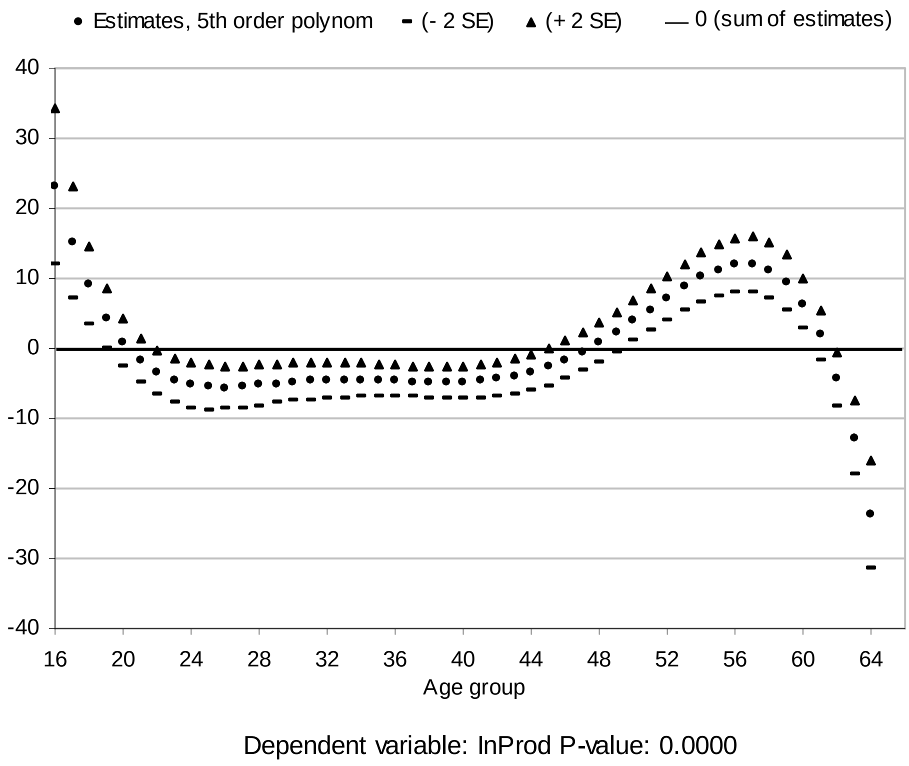
However, an inspection of the residuals shows strong signs of first order autocorrelation, a regression of residuals on the lagged residuals gives a highly significant estimate of 0.40. In order to check the robustness of the results we adapt a very conservative covariance structure, which allows for arbitrary correlations among observations within a region. However, it should be noted that these standard errors are not efficient and are likely to overestimate the uncertainty. Figure 6.9 shows the estimates with adjusted confidence intervals. We can see that the effect of 50 to 60 year olds is still significant, while that of very young workers is insignificant now.

To verify that the results are not due to the imposed functional form we show unrestricted estimates for wider age groups in Table 6.6. We create age categories based on the results in Figures 6.8 and 6.9. Thus, we have the groups 16-19, 20-29, 30-49 (reference), 50-59 and 60-64.

The results in the first column of Table 6.6 replicate the picture from Figure 6.9 (using the same standard errors): there is a large and highly significant positive effect due to large numbers of 50 to 59 year olds. To check for robustness, we also estimate a model including region-specific trends yielding little change in the results, and an OLS model, which, naturally, has somewhat tighter standard errors.[23] In all these cases, the **estimates for 50 to 59 year olds are significantly different** from the reference category, while those for young workers are insignificant.

On the plant level, extreme values can occur since plants that open or close during a year may have distorted relationships between value added and the recorded number of employees. To a large extent, we solve this problem by aggregating to larger geographical units. However, as a sensitivity analysis, we also estimated the models using data based on "stable plants"; this means we focused entirely on data generated by plants that existed from 1970 to 1996.[24] These estimates are presented in the last column of Table 6.6 and in Figure 6.10. They are nearly identical with those for the unbalanced panel, except for the size of estimates, which is roughly half. This is the only case where the youth estimates are (marginally) significant. In further sensitivity checks, we looked at productivity in levels (instead of logs); the results (not reported) were qualitatively very similar to the presented estimates.

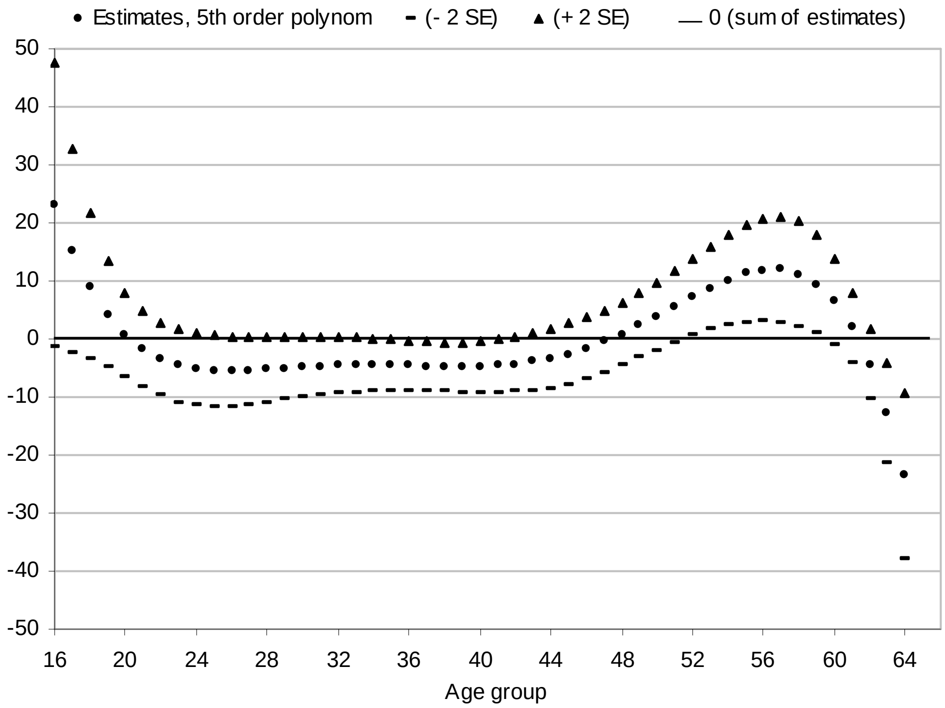
Figure 6.8:
Estimates with heteroskedasticity-robust standard errors



23 Since the estimate for 60 to 64 year olds is significantly lower than in the IV model, the results also suggest that it could be interesting to investigate whether older people move to regions with low productivity before they retire.

24 The 'stable plants' data do not include any observations for the Åsele and Arjeplog regions, which somewhat reduces the sample size. However, given that we use weighted regressions and these regions are tiny, this should not be a major problem.

Figure 6.9:
Estimates with clustered standard errors



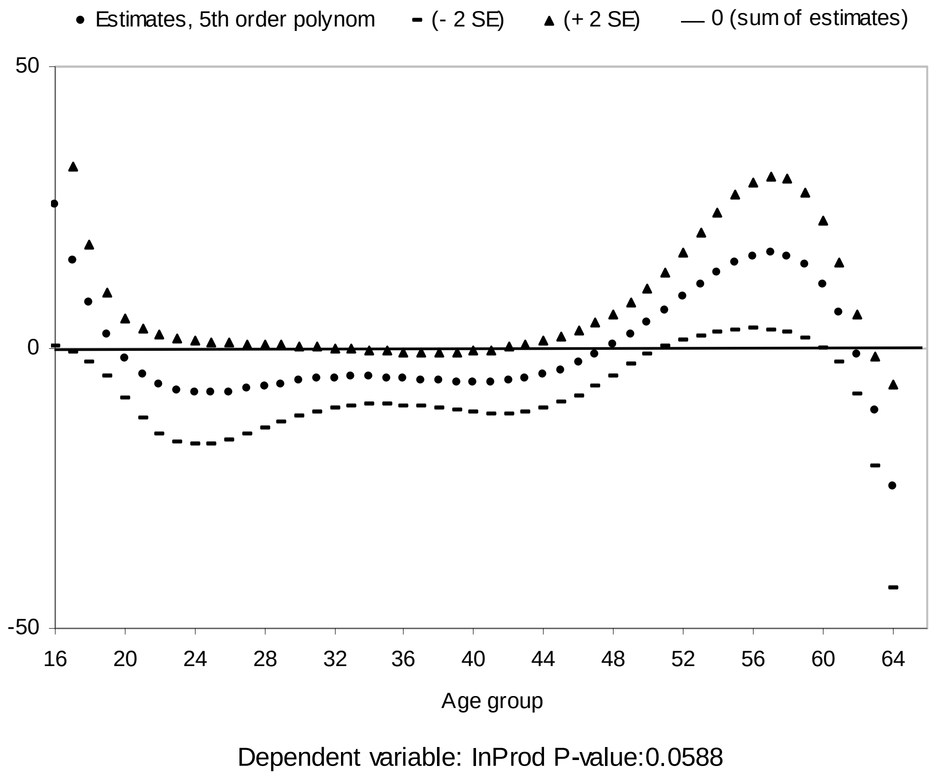
Dependent variable: lnProd P-value: 0.0045

Table 6.6:
Grouped estimates of ageing effects on productivity

Age category	IV	IV with region trends	OLS	IV, stable plants
16-19	13.63	0.827	3.562	14.00*
	(9.707)	(3.951)	(6.134)	(8.123)
20-29	-0.559	1.876	0.372	-2.024
	(2.448)	(2.763)	(1.986)	(2.867)
50-59	12.78***	6.335**	10.77***	17.61**
	(4.564)	(2.855)	(3.787)	(7.206)
60-64	-6.547	1.577	-6.978*	-2.577
	(4.173)	(3.978)	(3.844)	(5.130)
N	1,308	1,308	1,308	1,284
Regions	109	109	109	107
Years	12	12	12	12
Trends/clusters	Cluster	Trends	Cluster	Cluster
R2	0.875	0.926	0.879	0.849

Note: Data covers 109 local labour markets during 1985-1996. “Stable plants” estimates are based on data for plants existing from 1970 to 1996. Instrument is the population structure lagged by 16 years. All regressions include fixed time and year effects. Clusters imply that standard errors are corrected for arbitrary error correlation within regions. All standard errors are robust to heteroskedasticity. Standard errors are listed in parentheses.

Figure 6.10:
Data from a balanced panel, clustered standard errors



Worker and job flows[25]

Even though **net employment changes** might be small, a lot of job creation and job destruction occurs simultaneously. During 1985/86 to 1995/96, an average of 6.5 per cent of all jobs in the manufacturing industry were created every year and 7.7 per cent of all jobs were destroyed. The average annual net change in employment is the difference between the creation and the destruction rate. On average, net employment decreased by slightly more than 1 per cent each year, however, with great variations ranging from 2.85 per cent in 1986/87 to 8.7 per cent in 1992/93. Most of the change in employment during this period was due to the destruction of jobs in establishments that still existed but were contracting. Yet even during the deep economic plunge in Sweden at the beginning of the 1990s, many jobs were created, above all in existing establishments that expanded their workforce.

The **job reallocation rate** (JRR) is the sum of job creation and job destruction rates. As shown in Table 6.7, reallocation was quite high, especially during the recession years. Furthermore, the excess job reallocation rate (i.e., the difference between JRR and net) shows that many more jobs were created and destroyed than would have been necessary to match the net change in employment. Particularly in larger establishments, however, both job creation and destruction seem to have declined since the early 1990s.

The difference between job flows and worker flows consists in the number of workers leaving their jobs and being replaced by other workers. Since no jobs are created or destroyed when workers are being replaced, the job flows will remain unchanged while worker flows

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[25] See Appendix D for a more detailed definition of worker and job flows.

reflect these changes. Note that the difference between hiring (HR) and separation rates (SR) for each year is the same as the difference between job creation and job destruction rates for each year, which is the net employment change. The **worker reallocation rate** (WRR) is the sum of hiring and separation rates.

As can be seen in Table 6.7, hiring and separation rates are much higher than job creation (JCR) and job destruction rates (JDR). Average hiring amounted to 15.9 per cent of total employment, which is more than twice the job creation rate, and separations amounted to 17 per cent, which is also more than twice the job destruction rate. On average, workers who started and quit in the course of a year constituted nearly 35 per cent of all those employed. The number of workers who move in and out from an establishment is much higher than required to account for the creation or destruction of jobs. The **churning rate** shows the volume of worker flows in excess of what is needed to match job flows. The table shows that there are great variations between single years. According to these estimations, churning rates fell from 21.9 per cent in 1986/87 to less than 13 per cent during the worst recession in the early 1990s. Even if excess worker flows increased during the recovery, they were still considerably lower than before the recession.

So far, we have only considered jobs and workers as homogeneous units. However, job and worker flows are seldom evenly distributed across workers with different characteristics. By considering how job and worker flows are distributed among **workers of different ages and with different educational levels** it is possible to look more closely into the restructuring process that took place in the manufacturing industry during the period 1986-1996. Job and worker flows are broken down into four educational groups: primary or pre-upper secondary, upper secondary, university less than 3 years and university 3 years or longer, and into three different age groups: 16-29, 30-49, and 50-64 years.

Table 6.7:
Job and worker flows for manufacturing establishments with 50 or more employees, 1986/87-1995/96

	JCR	JDR	JRR	HR	SR	WRR	Churning	Net
1986/87	9.60	7.64	17.24	20.56	18.60	39.16	21.92	**1.96**
1987/88	8.38	5.53	13.92	20.51	17.66	38.17	24.26	**2.85**
1988/89	6.58	6.69	13.26	19.65	19.76	39.42	26.15	**-0.11**
1989/90	6.84	8.70	15.54	18.59	20.44	39.03	23.49	**-1.86**
1990/91	4.95	10.46	15.41	13.28	18.79	32.06	16.65	**-5.51**
1991/92	4.33	13.00	17.33	10.69	19.36	30.05	12.72	**-8.67**
1992/93	4.67	10.49	15.16	11.14	16.96	28.11	12.94	**-5.82**
1993/94	6.43	5.25	11.69	14.48	13.29	27.77	16.08	**1.18**
1994/95	8.17	4.04	12.21	17.03	12.91	29.94	17.73	**4.13**
1995/96	5.27	4.99	10.26	12.66	12.39	25.05	14.79	**0.28**
Average	**6.52**	**7.68**	**14.20**	**15.86**	**17.02**	**32.88**	**18.67**	**-1.16**

For each group of individuals, the sum of the changes in employment between two consecutive years across establishments is divided by the average of the total employment for the two consecutive years for the same group of individuals. Rates are presented separately for the different age and educational groups.

Table 6.8 presents job and worker flows rates for the educational groups. What strikes the eye in this table is the **sharp decline in employment for those having the lowest education**. While net employment declined for all workers by an average of around 1 per cent during the period, it dropped by more than 4 per cent for those with the lowest education. For those with upper secondary education, it fell by only 0.1 per cent, while it actually rose for those holding a university degree. The decline in employment for those with the lowest education started before the recession, accelerated during the downturn, and continued during the recovery years. When comparing job creation and destruction rates for these four educational groups, it becomes clear that very **few jobs were created for those having the lowest education**.

While average job destruction rates were nearly identical (although higher for those with the lowest education), the job creation rates for those with higher education were more than twice as high as for those merely having pre-upper secondary education.

The highest rates were found among those with the **highest educational level**. While churning rates are very low for the pre-upper secondary education group (on average 13.7 per cent), these rates were higher for those with longer education.

Table 6.8:
Job and worker flows for different educational groups in manufacturing establishments with 50 or more employees, 1986/87-1995/96

	Pre-upper secondary			**Upper secondary**			**University < 3 years**			**University ≥ 3 years**		
	JCR	**JDR**	**Net**	**JCR**	**JDR**	**Net**	**JCR**	**JDR**	**Net**	**JCR**	**JDR**	**Net**
1986/87	6.79	7.78	**-0.99**	11.69	7.50	**4.19**	12.68	7.76	**4.91**	10.23	9.23	**1.00**
1987/88	5.55	5.88	**-0.33**	10.06	5.28	**4.78**	11.66	5.46	**6.21**	9.44	7.05	**2.38**
1988/89	4.37	7.38	**-3.02**	7.03	6.95	**0.08**	8.62	6.31	**2.32**	8.36	7.15	**1.21**
1989/90	5.73	8.44	**-2.71**	8.05	8.53	**-0.48**	10.01	7.27	**2.74**	10.10	7.07	**3.03**
1990/91	3.73	10.97	**-7.25**	4.98	10.84	**-5.86**	6.15	10.52	**-4.36**	8.11	8.89	**-0.78**
1991/92	3.21	13.89	**-10.69**	4.79	12.86	**-8.07**	5.43	11.04	**-5.61**	5.40	11.20	**-5.79**
1992/93	3.57	11.35	**-7.78**	4.88	10.67	**-5.79**	6.42	8.47	**-2.04**	6.42	6.73	**-0.31**
1993/94	2.76	6.57	**-3.81**	8.09	4.87	**3.22**	9.75	3.84	**5.91**	7.75	3.36	**4.39**
1994/95	3.33	4.34	**-1.01**	9.90	3.55	**6.35**	11.73	4.28	**7.45**	11.09	6.09	**5.00**
1995/96	2.82	5.79	**-2.97**	5.61	4.75	**0.86**	7.75	4.33	**3.42**	8.36	4.94	**3.42**
Average	**4.60**	**9.06**	**-4.46**	**8.26**	**8.34**	**-0.08**	**9.92**	**7.62**	**2.30**	**9.38**	**7.89**	**1.49**

	Pre-upper secondary			**Upper secondary**			**University < 3 years**			**University ≥ 3 years**		
	HR	**SR**	**Net**	**HR**	**SR**	**Net**	**HR**	**SR**	**Net**	**HR**	**SR**	**Net**
1986/87	14.83	15.82	**-0.99**	24.07	19.87	**4.19**	27.91	22.99	**4.91**	23.63	22.63	**1.00**
1987/88	14.77	15.11	**-0.33**	23.69	18.91	**4.78**	27.18	20.98	**6.21**	22.29	19.91	**2.38**
1988/89	13.91	16.93	**-3.02**	21.59	21.51	**0.08**	25.03	22.71	**2.32**	21.61	20.40	**1.21**
1989/90	14.61	17.32	**-2.71**	21.39	21.87	**-0.48**	26.07	23.33	**2.74**	23.20	20.16	**3.03**
1990/91	9.93	17.17	**-7.25**	13.86	19.72	**-5.86**	17.71	22.08	**-4.36**	20.19	20.98	**-0.78**
1991/92	7.64	18.32	**-10.69**	11.42	19.50	**-8.07**	14.93	20.54	**-5.61**	15.61	21.40	**-5.79**
1992/93	8.16	15.94	**-7.78**	11.40	17.19	**-5.79**	16.09	18.14	**-2.04**	16.92	17.23	**-0.31**
1993/94	8.98	12.78	**-3.81**	16.06	12.84	**3.22**	21.21	15.30	**5.91**	19.56	15.17	**4.39**
1994/95	10.01	11.01	**-1.01**	18.50	12.15	**6.35**	25.03	17.59	**7.45**	24.82	19.83	**5.00**
1995/96	7.45	10.43	**-2.97**	12.70	11.84	**0.86**	19.96	16.54	**3.42**	21.33	17.91	**3.42**
Average	**11.03**	**15.08**	**-4.05**	**17.47**	**17.54**	**-0.07**	**22.11**	**20.02**	**2.09**	**20.92**	**19.56**	**1.36**

	Pre-upper secondary			Upper secondary			University < 3 years			University > 3 years		
	JRR	WRR	Churn	JRR	WRR	Churn	JRR	WRR	Churn	JRR	WRR	Churn
1986/87	14.57	30.65	**16.08**	19.19	43.94	**24.75**	20.44	50.90	**30.46**	19.46	46.26	**26.80**
1987/88	11.43	29.88	**18.45**	15.35	42.59	**27.25**	17.12	48.16	**31.05**	16.49	42.19	**25.70**
1988/89	11.75	30.84	**19.08**	13.98	43.10	**29.12**	14.93	47.74	**32.81**	15.51	42.02	**26.51**
1989/90	14.16	31.92	**17.76**	16.58	43.25	**26.67**	17.28	49.40	**32.12**	17.18	43.36	**26.18**
1990/91	14.70	27.10	**12.39**	15.82	33.57	**17.76**	16.67	39.79	**23.12**	17.00	41.17	**24.17**
1991/92	17.10	25.96	**8.87**	17.65	30.92	**13.27**	16.47	35.47	**19.00**	16.60	37.01	**20.41**
1992/93	14.91	24.10	**9.18**	15.55	28.59	**13.04**	14.89	34.23	**19.34**	13.15	34.15	**21.00**
1993/94	9.33	21.76	**12.43**	12.96	28.90	**15.93**	13.59	36.51	**22.92**	11.11	34.74	**23.63**
1994/95	7.67	21.02	**13.35**	13.46	30.64	**17.19**	16.01	42.62	**26.61**	17.18	44.65	**27.47**
1995/96	8.61	17.88	**9.27**	10.36	24.54	**14.17**	12.08	36.50	**24.42**	13.30	39.23	**25.93**
Average	**12.42**	**26.11**	**13.69**	**15.09**	**35.01**	**19.91**	**15.95**	**42.13**	**26.19**	**15.70**	**40.48**	**24.78**

Average churning rates for workers with a university degree amounted to 26 per cent. Thus mobility increases with education.

Table 6.9 presents job and worker flows for the **three different age groups**: 16-29, 30-49, and 50-64 years. Several interesting things emerge from this table. First of all, when considering net employment changes, it becomes clear that **employment among the oldest workers** fell rather dramatically during the whole period and not only during the recession years, on average by more than 8 per cent. This is a large decline, especially if compared to the decline among the middle aged (i.e., those aged 29-49) where the average decline in net employment amounted to only around 1 per cent in the same period. Moreover, in the youngest age group, average net employment actually rose by nearly 4 per cent during the period, though with very great variations between single years.

Both the **young and the oldest workers** were severely hit by the economic downturn. During the recession years, destruction rates more than doubled while creation rates more than halved. During the recovery period, however, many new jobs were created and few jobs destroyed for the youngest workers, while nearly no jobs were created for the oldest workers.

The churning rates for different age groups as well as the overall job and worker reallocation rates clearly show that **mobility decreases with age**. Job creation for older workers is substantially lower than job destruction even when the business cycle is at its peak.

Unfortunately it was not possible to directly link productivity data on the plant level to job and worker flows. We can, however, note that the flows reported for manufacturing over different dimensions tend to support the general notion that **older workers are better matched to their jobs and that ageing of the workforce is therefore associated with a general decrease in reallocation flows**. The mechanism behind the somewhat surprising results described above, namely that more 50 to 59 year olds on the local labour market raise productivity might very well be a direct consequence of decreased job and worker reallocation and the entailing costs. While we cannot prove this conjecture with our current data, we can at least say that they are not inconsistent with the hypothesis. US data indicate that non-random worker and job reallocations play a significant role in productivity, but the methodology for estimating it is still experimental. It will take some time before any clear-cut quantitative answers about this important question can be given.

In order to get some sense for the potential importance of labour market institutions we have also made comparisons with similar American data. However, due to such limitations in the data material as differences in definitions, scope and periods of the various data samples, direct comparisons are difficult. Nevertheless, the basic properties of the job reallocation process are quite similar in the US and Swedish manufacturing industries, although worker reallocation seems to be higher in American data.

Table 6.9:
Job and worker flows for different age groups in manufacturing establishments with 50 or more employees, 1986/87-1995/96

	16-29			30-49			≥ 50		
	JCR	**JDR**	**Net**	**JCR**	**JDR**	**Net**	**JCR**	**JDR**	**Net**
1986/87	15.64	6.82	**8.82**	7.84	7.70	**0.14**	4.77	8.88	**-4.11**
1987/88	15.59	3.97	**11.62**	6.20	5.86	**0.34**	2.81	7.24	**-4.44**
1988/89	11.80	5.20	**6.60**	5.30	6.91	**-1.60**	1.86	8.58	**-6.72**
1989/90	10.34	8.85	**1.49**	6.21	8.12	**-1.92**	3.46	9.82	**-6.36**
1990/91	6.67	13.05	**-6.38**	4.76	8.57	**-3.81**	2.73	12.70	**-9.98**
1991/92	6.02	15.27	**-9.25**	4.42	10.02	**-5.60**	2.27	16.71	**-14.43**
1992/93	7.43	12.52	**-5.09**	4.63	7.89	**-3.26**	2.23	13.81	**-11.58**
1993/94	17.65	2.99	**14.66**	4.71	4.60	**0.11**	0.29	9.45	**-9.16**
1994/95	21.16	2.00	**19.16**	6.28	3.91	**2.36**	0.89	7.95	**-7.06**
1995/96	11.30	4.52	**6.78**	4.67	4.24	**0.44**	0.78	7.11	**-6.32**
Average	**12.36**	**7.52**	**4.84**	**5.50**	**6.78**	**-1.28**	**2.21**	**10.22**	**-8.01**

	16-29			30-49			≥ 50		
	HR	**SR**	**Net**	**HR**	**SR**	**Net**	**HR**	**SR**	**Net**
1986/87	34.96	26.14	**8.82**	15.68	15.54	**0.14**	10.44	14.55	**-4.11**
1987/88	37.45	25.83	**11.62**	14.64	14.31	**0.34**	8.83	13.26	**-4.44**
1988/89	35.55	28.95	**6.60**	14.50	16.10	**-1.60**	7.67	14.39	**-6.72**
1989/90	31.68	30.18	**1.49**	14.73	16.65	**-1.92**	8.68	15.04	**-6.36**
1990/91	21.16	27.54	**-6.38**	11.24	15.05	**-3.81**	7.40	17.37	**-9.98**
1991/92	17.18	26.43	**-9.25**	9.37	14.97	**-5.60**	6.22	20.65	**-14.43**
1992/93	18.85	23.94	**-5.09**	9.60	12.86	**-3.26**	6.77	18.34	**-11.58**
1993/94	31.64	16.98	**14.66**	10.76	10.65	**0.11**	6.00	15.15	**-9.16**
1994/95	36.18	17.02	**19.16**	13.15	10.79	**2.36**	6.24	13.30	**-7.06**
1995/96	24.62	17.84	**6.78**	10.57	10.13	**0.44**	5.43	11.75	**-6.32**
Average	**28.93**	**24.09**	**4.84**	**12.42**	**13.71**	**-1.28**	**7.37**	**15.38**	**-8.01**

	16-29			30-49			≥ 50		
	JRR	**WRR**	**Churn**	**JRR**	**WRR**	**Churn**	**JRR**	**WRR**	**Churn**
1986/87	22.46	61.10	**38.64**	15.54	31.22	**15.68**	13.65	24.99	**11.34**
1987/88	19.55	63.29	**43.73**	12.06	28.95	**16.88**	10.05	22.09	**12.04**
1988/89	17.00	64.50	**47.50**	12.21	30.60	**18.39**	10.43	22.05	**11.62**
1989/90	19.19	61.86	**42.67**	14.33	31.38	**17.05**	13.28	23.72	**10.44**
1990/91	19.72	48.70	**28.98**	13.33	26.29	**12.96**	15.43	24.77	**9.34**
1991/92	21.29	43.61	**22.32**	14.44	24.33	**9.89**	18.98	26.87	**7.89**
1992/93	19.95	42.79	**22.84**	12.51	22.46	**9.95**	16.04	25.11	**9.07**
1993/94	20.64	48.63	**27.99**	9.31	21.41	**12.10**	9.73	21.15	**11.42**
1994/95	23.16	53.20	**30.03**	10.19	23.94	**13.76**	8.84	19.53	**10.69**
1995/96	15.81	42.45	**26.64**	8.91	20.70	**11.80**	7.89	17.19	**9.30**
Average	**19.88**	**53.01**	**33.13**	**12.28**	**26.13**	**13.85**	**12.43**	**22.75**	**10.32**

Hirings and separations are much greater than needed to account for the creation and destruction of jobs. Likewise, the number of jobs created and destroyed by establishments is much greater than needed to accommodate any aggregate change in employment. Indeed, job reallocation rates are surprisingly similar in magnitude in countries with more flexible labour markets (e.g., the USA) and countries with more rigid labour markets (e.g., Sweden).

If this finding is true—it is notoriously difficult to compare flows between countries due to differences in data—does this mean that labour market institutions do not matter? Not necessarily. An alternative hypothesis is that labour market institutions maybe do not affect magnitudes of flows as much as they affect the pattern and composition of flows and how these relate to the macro economy. One of the key pillars in the Rehn-Meidner model—which definitely had a great impact on the development of the Swedish labour market—is to speed up economic growth and to promote equality by adjusting quantities rather than prices in response to economic shocks. If this idea distinguishes the Swedish from the US labour market also in everyday practice, one should not necessarily expect to find any systematic differences in the sheer magnitudes of job flows. However, for certain magnitudes of labour mobility, the Rehn-Meidner model, in practice, should imply that the flows in the Swedish labour market are more closely linked to the reallocation of labour from less to more productive units and less driven by imbalances in wages. With more opportunities for wage dispersion in all the different dimensions, one would expect to find that worker reallocations in the US labour market are more closely associated with wage differences. As noted in the subsection on local labour markets, this seems to be the case when we compare Shimer's results (2001) to those of Skans (2005).

There is considerable variety between countries when it comes to institutions that regulate and influence employment protection on the labour market. Swedish legislation is relatively restrictive, although less than in some other European countries. The Swedish Security of Employment Act (Lagen om anställningsskydd or LAS), introduced in 1974, stipulates that there must be a "just cause" for a dismissal, e.g., slacking demand or shortage of work. Most of the rules laid down in the Act are mandatory and allow for no deviations. The Act also regulates the order in which the employer should dismiss workers. The main rule is "last in, first out". Older workers get the strongest protection. For example, if two workers have been with the same employer for an equally long period of time, the youngest is to be dismissed first. Further, workers older than 45 are allowed to add one month for every month they have been employed since reaching that age, to a maximum of 60 months. The seniority rule was, however, not made strictly binding. Deviations are allowed, provided that the employer and the local unions agree on them. One condition for deviation is that the employer has signed a collective agreement, but in Sweden almost all employers are covered by such agreements. According to recent studies, deviations from the seniority rules seem to have been rather common, especially during the economic downturn at the beginning of the 1990s (see Jans 2002).

Up to October 1991, redundant workers above 60 could get a disability pension after their period of unemployment benefit expired. This rule was changed in 1991, and it was no longer possible to get a disability pension because of the situation on the labour market. Nevertheless, the number of early exits from the labour market continued to increase for several years. Statistics suggest that while disability pensions granted for labour market reasons declined, the number of disability pensions granted on other grounds (e.g., a combination of medical and labour market reasons) was on the increase.

Moreover, in most countries employers bear the costs of severance pay either fully or in part. In Sweden, severance pay is regulated in collective agreements between the Employers' Confederation and the trade unions. Employers who dismiss workers due to shortage of work normally do not bear the costs of severance pay. Severance pay amounts are relatively small, and are not allowed to exceed the workers' actual earnings at the time of their dismissal. The fact that workers must have been continuously employed for five years before they are entitled to severance pay may have affected the mobility of older workers on the labour market. Nevertheless, the system keeps down employers' costs for severance pay in case of job displacement.

Although the Employment Security Act covers all workers in regular employment, it offers more protection for older workers. Together with the severance pay given to workers aged 40 or above, these regulations may, in fact, have reduced the mobility of older workers. According to the seniority rules, older workers who quit for a new job will not only be more likely to be displaced, but they will also lose the right to severance pay. Workers leaving an establishment before being formally notified of pending job displacement will not receive severance pay. However, if they stay in the establishment until they are given formal notice, they are entitled to severance pay.

If high adjustment costs were the only force at work, we would expect job flows to be rather modest and less countercyclical in Sweden as compared to countries with presumably lower costs of adjustment. Job and worker flows are, however, far from modest, at least on an aggregate level. In fact, job reallocation rates in the USA are quite comparable to the rates we find in Sweden, although worker reallocation rates seem to be higher in the USA. Thus churning rates are higher in the USA. To the extent that higher churning rates lead to better job matches they promote productivity. However, as the local labour market results might indicate, high rates of worker reallocation may carry excessive adjustment costs that possibly outweigh the benefits of higher worker mobility.

When job and worker flows are disaggregated into age and educational groups, substantial variability is found, with very high rates for the youngest age groups (aged 16-29), somewhat more modest rates for the middle age group (aged 30-49), and very low rates for the oldest workers (aged 50-65). Similarly, job and worker flow rates were found to be low for workers with low education, and higher for workers with higher education. To some extent, this also reflects the fact that the older parts of the workforce have lower education, but it also seems to hold true when looking at birth cohorts in isolation.

These results obtained by an analysis of job and worker flows strongly suggest that the matching process between jobs and workers is extremely important and subject to variation induced by labour market institutions. It also suggests that the process can be subject to policy interventions, provided we have a good understanding of the mechanisms involved. For example, employment protection could be designed in such a way as to offer a choice of ways, in which a baby boom cohort might impact on productivity and employment in cases where our results suggest that there is a trade-off with potentially very different consequences for individuals belonging to different birth cohorts. At present, it is clearly premature to speculate on how such a design might best achieve different objectives but it clearly has important implications both at the macro level and for social and economic justice between cohorts.

Conclusions

That work-force ageing may have a positive effect on productivity goes against many popular conceptions. Our evidence here is somewhat mixed, indicating that there are several processes at work that **make the effects of composition different at different levels of the economy**. Macro-level evidence, however, indicates that a shift from a working-age population dominated by young adults to one dominated by older workers is indeed positive for economic growth. Such studies include McMillan and Baesel (1990), Malmberg (1993), and Lindh and Malmberg (1999).

A positive relation between work-force ageing and productivity growth also has an implication for the relation between mortality and economic growth. If it were true that weaker individual-level performance during the later parts of working life exerts a downward pressure on firm-level productivity, then high mortality among workers above 50 would not necessarily be negative for economic growth. It would have a negative effect on the profitability of educational investment and possibly on savings, but part of this could be compensated by weeding out less efficient workers. However, in empirical studies, increasing longevity has consistently positive effects on per capita income; this may be taken to indicate that labour-force ageing is not a process that works against higher productivity. One possible explanation may be the “second demographic dividend” (Mason and Lee 2004) generated by positive effects on capital accumulation from the middle-aged net savers. According to Malmberg and Lindh (2004) and Lindh and Malmberg (2004), global panel data estimates demonstrate that higher life expectancy is associated with increasingly positive effects from the older part of the workforce.

To sum up the **micro evidence from Swedish mining and manufacturing,** we find a **hump shape in the age effects on productivity with some indications that the peak of the hump may lie somewhere around 50**. We are, however, not able to concludingly solve such estimation problems as the specification of functional form, simultaneity between explanatory variables and productivity, or the thorny issue of identifying cohort effects as distinguished from age effects. The results are, therefore primarily exploratory and subject to revision as research on these issues develops. It is especially puzzling that we have great difficulties in distinguishing any stable and substantial effects from the increasing shares of employees with tertiary education. Our attempt to estimate education-specific age effects indicate that **secondary education is more important than tertiary education for productivity in mining and manufacturing**.

Nevertheless, education obviously has substantial effects on productivity. For the purpose of this report, we may say that even if an ageing workforce tended to become less productive, this could very likely be compensated by increased education of the future workforce.

The result that productivity is enhanced by large groups of 50 to 69 year olds on the local labour market level, as well as the weak relation between productivity spread and wage cost spread, are strong indications that labour market mechanisms and flows play an essential role in determining productivity at more aggregated levels of the economy. Our understanding of the dynamics here is still very poor, but **differences between matching jobs to individual abilities of the young and the old** seem crucial for these results. Thus another tentative conclusion with respect to the purpose of the report is that **well functioning labour markets may be as crucial as education for maintaining productivity also with an ageing workforce**. More research is, however, needed at the meso levels (both regionally, across industries and quite possibly also in the interactions of firms of different sizes) of economy in order to define what is meant by well-functioning labour markets in this respect.

6.2 Firm productivity, workforce age and educational structure in Austrian mining and manufacturing in 2001

Data

(For a more detailed description of the data and variables see also Appendix E.)

We use a cross-section of employer-employee matched data from Statistics Austria for the year 2001. The data set emerged from matching individual data of structural business statistics (Statistik Austria 2003) with the population census of Austria. It covers NACE sections C (mining and quarrying) to K (real estate, renting and business activities) and contains selected economic indicators of **34,375 enterprises** as well as selected socio-demographic indicators of **1,563,873 employees**. The economic indicators include, e.g., information about branch affiliation, number of white-collar and blue-collar employees at the end of 2001, and the value added in 2001 from structural business statistics. Socio-demographic indicators taken from the population census provide information on age, education and occupation of individuals employed in establishments on 15 May 2001. Currently, the construction of a panel is not possible, because information on the plant level classification number for each person interviewed in the census was only available in the 2001 census. Structural business statistics and census data can only be merged by this indicator. (Note: Since value added is only available at the firm level, we did the Austrian analysis on the firm level, while the case study with the Swedish data refers to the plant level.)

To facilitate comparability with the Swedish case study, we only use a sub-sample of firm-level data from the **mining and manufacturing** sectors (NACE sections C and D). We have measures of the age, education and occupation compositions of the workforce of about **9,000 firms** for these two sectors. Data are somewhat noisy for at least two specific reasons: 1) In the population census, the affiliation of individuals employed may be somewhat noisy (due to ascertainment error, etc.), so that matching is imperfect or somewhat uncertain in a minor number of cases. Put differently, according to the population census data, we have too many or too few employees for some firms. 2) Economic data about enterprises refer to the status at the end of 2001, whereas data about age and education of employees, as well as those on occupational affiliation refer to the employment status in mid-May 2001. Consequently not every employee in the population census could be assigned to a firm nor could every enterprise be assigned to employees. For our analysis, we assume that the matching process did not cause any systematic bias and the sample is representative for the Austrian mining and manufacturing sectors.

The advantage of the data provided is the combination of economic data (e.g., value added) of enterprises, on the one hand, and socio-demographic data (e.g., age and education) of employees for each firm, on the other hand. Socio-demographic data are not covered by structural business statistics otherwise. Similarly, the population census only contains the characteristics of employees, but no economic information on the firms the employees work for. The employer-employee matched data allow us to compare the productivity levels of enterprises with different age and educational structures of their employees, but also to control for possible firm-specific effects such as size and age of the firm or type of organisation (multi-plant vs. single-plant firms), etc.

Rank plot

Figures 6.11(a)-(d) show the ranked distribution of value added per employee in 2001 and the corresponding average wage costs in the firm for four different industries.

Figure 6.11(a):
Rank plot of productivity with corresponding wage costs per employee at the enterprise level in food-product and beverage manufacturing (NACE section 15). The horizontal scale is the rank in the distribution of enterprises, while the vertical scale is in 1.000 Euro.

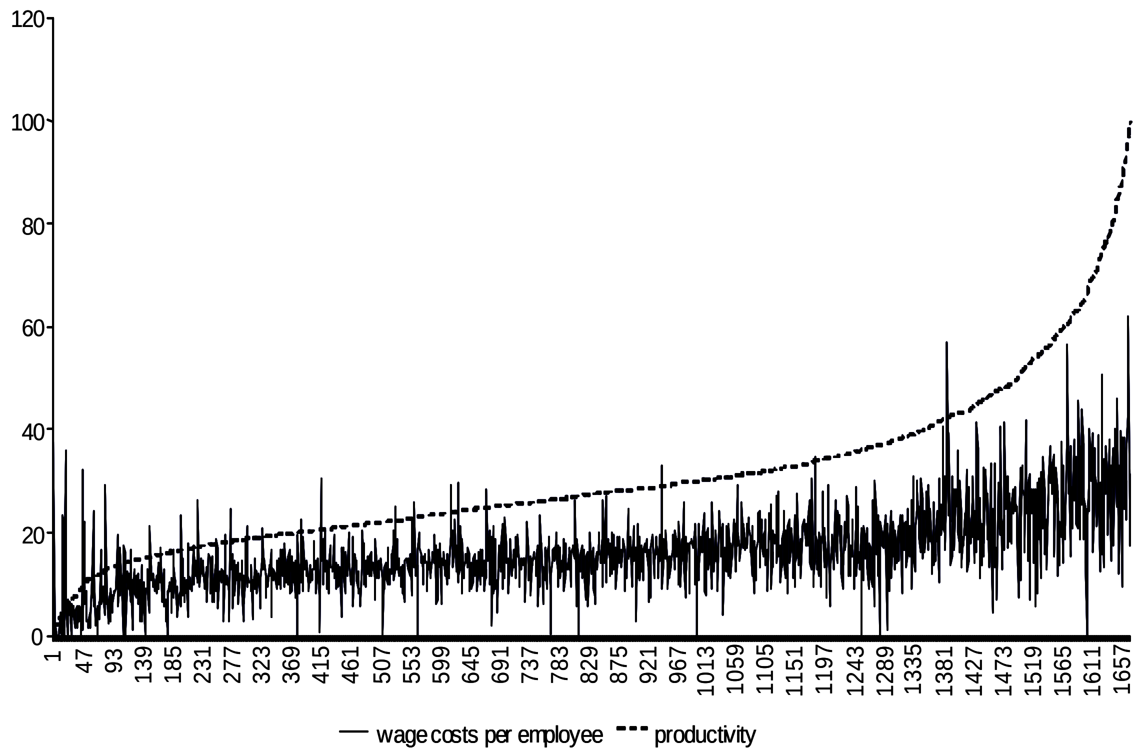


Figure 6.11(b):
Rank plot of productivity with corresponding wage costs per employee at the enterprise level in wood, wood-product and cord (except furniture) manufacturing (NACE section 20). The horizontal scale is the rank in the distribution of enterprises, while the vertical scale is in 1,000 Euro.

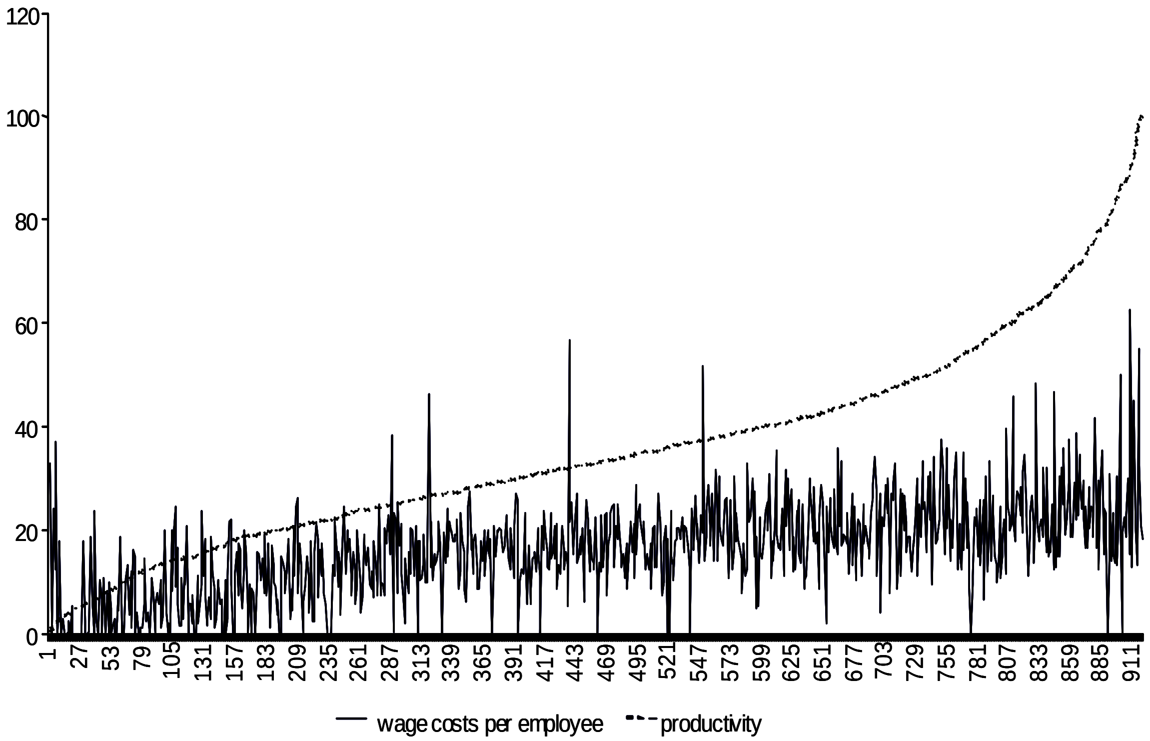


Figure 6.11(c):
Rank plot of productivity with corresponding wage costs per employee at the enterprise level in publishing, printing, and reproduction of recorded media (NACE section 22). The horizontal scale is the rank in the distribution of enterprises, while the vertical scale is in 1,000 Euro.

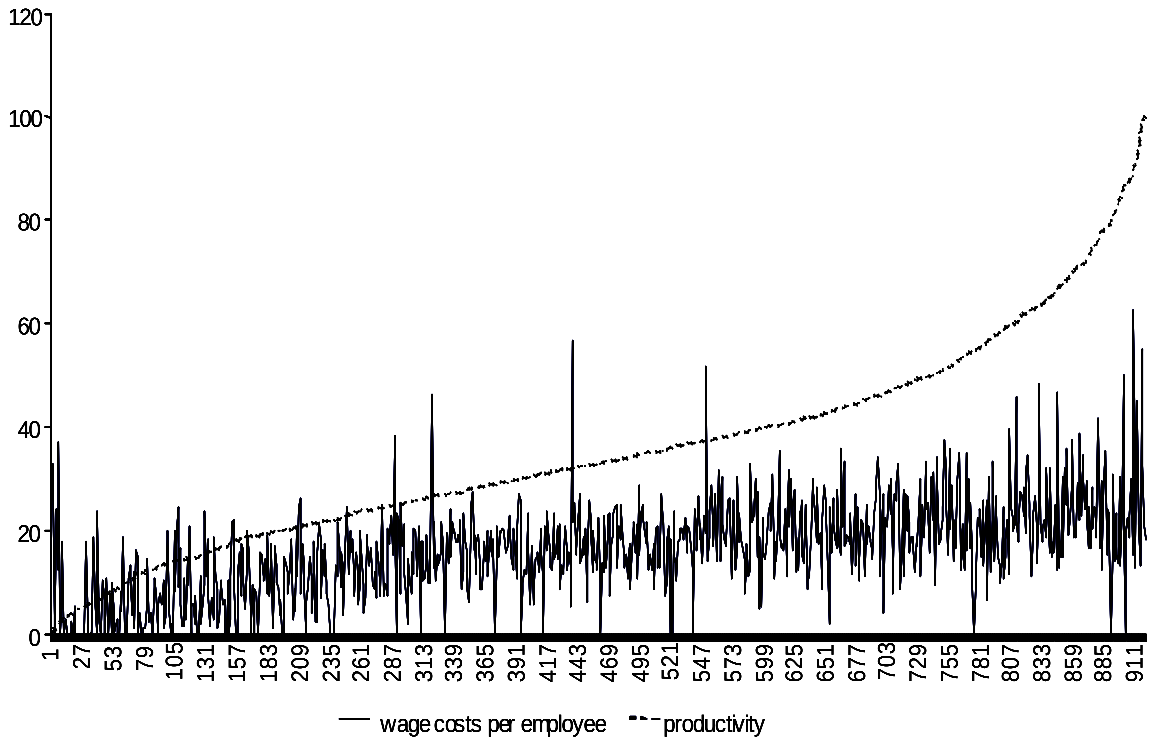
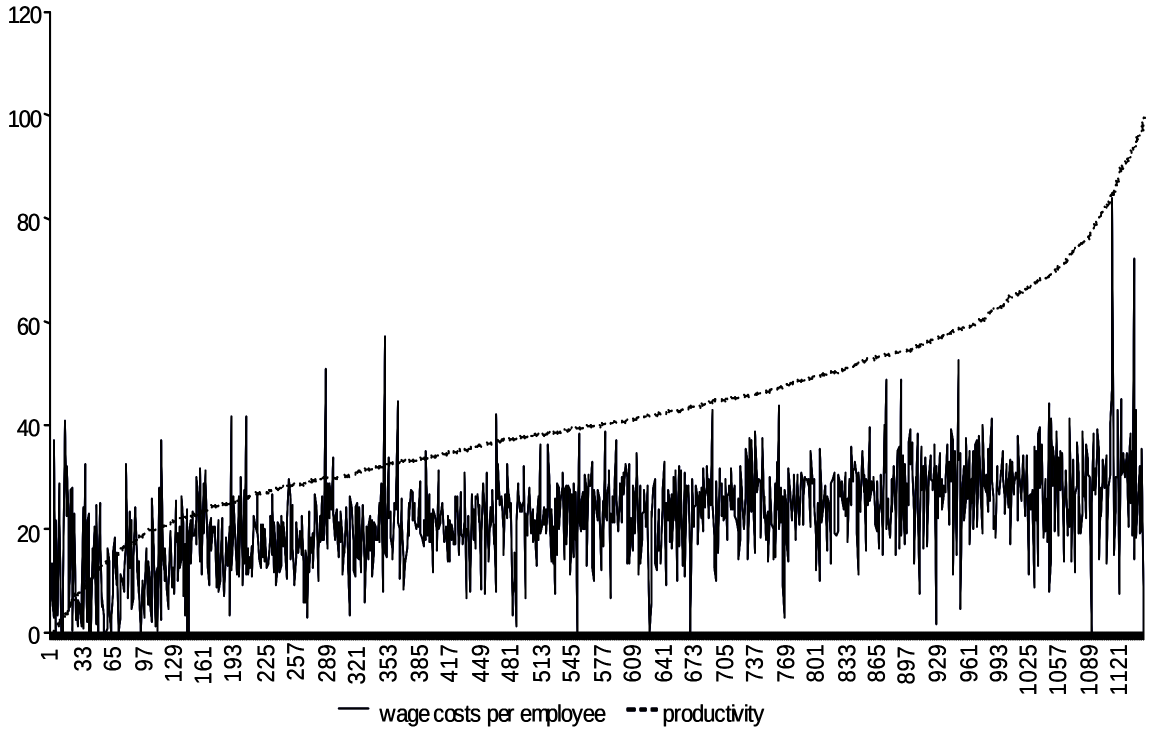


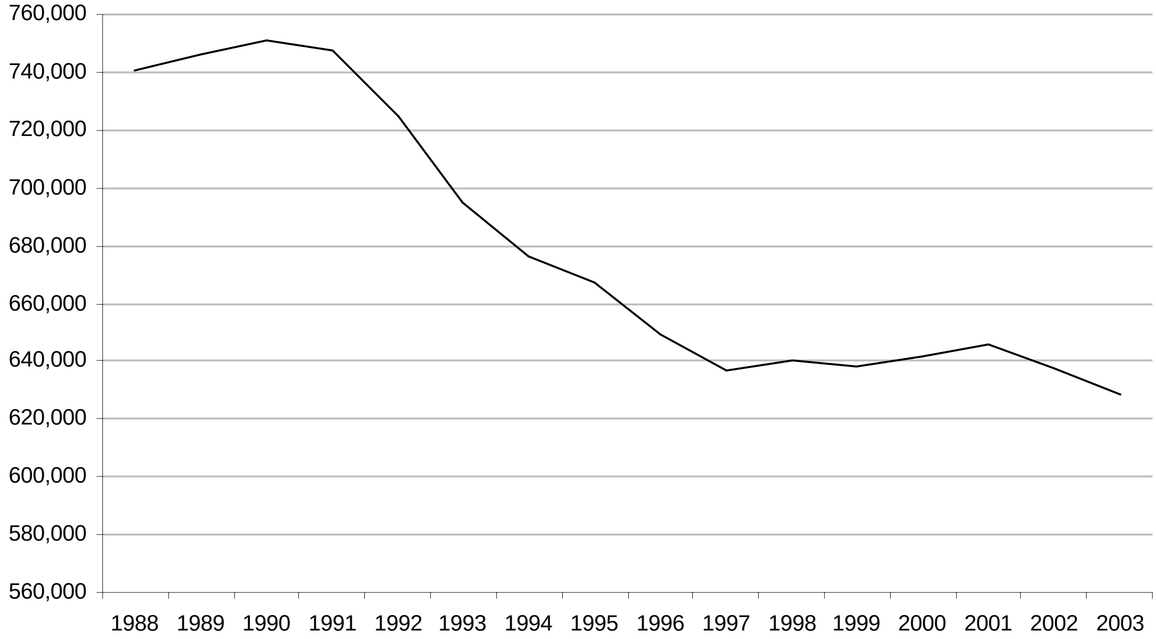
Figure 6.11(d):
Rank plot of productivity with corresponding wage costs per employee at the enterprise level in fabricated metal products manufacturing (NACE section 28). The horizontal scale is the rank in the distribution of enterprises, while the vertical scale is in 1,000 Euro.



In order to get comparable scales and a reasonable resolution in the graphs, a few extreme observations (that are likely to be measurement errors anyway) were dropped. Value added and wage costs were measured in fixed prices and stated in 1,000 EUR. Productivity dispersion is much wider than wage dispersion and it is almost **impossible to see any relation between firm productivity and wage level**. This pattern is recurrent for all mining and manufacturing industries.

These graphs show that wage levels at the enterprise level offer little economically important explanation for the variation in productivity across enterprises. Similar to the Swedish case, individual wages may still be significantly related to individual productivity—and wages will, on average, be somewhat higher in high productivity enterprises. Yet it seems that the workforce at the enterprise level has been combined in such a way that wage costs of labour (as an aggregate) have been equalised across the plant population.

Figure 6.12:
Total employment in mining and manufacturing in Austria in 1988-2002



Note: Mining and manufacturing comprise NACE Sections C and D.
Source: Statistics Austria, National Accounts

Employment structure

The development of total employment in mining and manufacturing was characterised by a **sharp decline in the period 1990-1997** (see Figure 6.12). In these years, almost 15% of the jobs got lost in sectors C and D, mainly for two reasons. First, there is a general trend towards an increase of the service sector and a decrease of production sectors as well as the outsourcing of some business activities (e.g., bookkeeping, menial and IT services, etc.) to specialised firms in the service sector (e.g., tax consultants, lawyers or IT service companies). This phenomenon is well known (tertiarisation of economies) and can be observed in all developed economies. Second, staff was reduced significantly in the wake of privatising several state-owned companies (especially steal and machine manufacturers) in the first half of the 1990s. Employment figures increased slightly from 1997 to 2001, and a moderate decrease has prevailed since 2001. This might be the consequence of stagnation in the economic performance of the manufacturing industry. The manufacturing sector is very export-oriented and dependent on the economic development in Germany and other EU member states, which are Austria's most important trade partners.

Despite the significant decrease of employment in the 1990s, the **manufacturing sector** with its 661,351 employees is still the largest of all NACE sections in the Austrian economy. The value added accounts for 39.3 bn EUR. In terms of employment, this sector's share is 15.95%, and its share for the value added amounts to 20.21%. In the mining sector, 7,322 persons add value amounting to 830.8 mill. EUR. Regarding employment, the share of both sectors (i.e., manufacturing and mining) taken together, is 16.13%, and 20.64 % for value added (see Table 6.10).

Table 6.10:
Employment and value added in all sectors of the Austrian economy in 2001

Code	Sector	Employment		Value added	
		In figures	**Share in %**	**In 1,000 EUR**	**Share in %**
A/B	Agriculture and forestry/fishing	544,651	13.14	4,148,894	2.14
C	**Mining and quarrying**	**7,322**	**0.18**	**830,871**	**0.43**
D	**Manufacturing**	**661,351**	**15.95**	**39,256,633**	**20.21**
E	Electricity, gas and water supply	33,216	0.80	4,256,171	2.19
F	Construction	273,673	6.60	14,528,342	7.48
G	Wholesale and retail trade	613,215	14.79	25,623,723	13.19
H	Hotels and restaurants	224,066	5.40	8,283,104	4.26
I	Transport, storage and communication	258,826	6.24	13,926,884	7.17
J	Financial intermediation	117,355	2.83	10,376,919	5.34
K	Real estate, renting and business activities	418,493	10.09	32,720,192	16.84
L	Public administration, national defence, social security	250,443	6.04	11,821,248	6.08
M	Educational system	206,628	4.98	10,392,142	5.35
N	Health and social work	345,283	8.33	10,464,595	5.39
O	Other community, social and personal service activities	182,112	4.39	7,176,125	3.69
P	Activities of households	9,892	0.24	471,759	0.24
	Total	4,146,526	100.00	194,277,602	100.00

Source: Statistics Austria, National Accounts

<u>Statistical estimates for the relation between productivity and age structure</u>

The following results are based on the mining and manufacturing sectors (NACE sections C and D). All regressions are performed on the enterprise level. The dependent variable is the logarithm of value added per worker. The denominator is the average number of workers in 2001 as contained in the structural business statistics. Whenever possible, the independent variables are taken from the structural business statistics. However, several socio-demographic variables such as age and education level (both measured as shares) have to be taken from the set of workers that was matched with the 2001 census. Since we could not match all workers, this implies that some of the independent variables are based on a sample that is smaller than the number of workers in the structural business statistics. We assume that the matching procedure did not produce any selectivity and will check this for variables that are available in both the structural business statistics and in the census (e.g., employee's gender). The results of the estimates are shown in Table 6.11.

Table 6.11:
Basic regressions for mining and manufacturing on enterprise level (all size classes)

Variable	(1)	(2)	(3)
Log share –29	0.06	0.04	0.06
	(9.29)**	(6.17)**	(7.89)**
Log share 30-49	0.15	0.12	0.08
	(14.04)**	(11.28)**	(7.63)**
Log share 50+	0.07	0.05	0.02
	(10.60)**	(8.03)**	(3.46)**
Log share academics	0.09	0.07	0.04
	(11.20)**	(8.64)**	(4.59)**
Log share upper secondary	0.11	0.09	0.04
	(18.09)**	(13.81)**	(7.31)**
Log share skilled workers	0.13	0.10	0.09
	(11.72)**	(8.73)**	(8.05)**
Log share lower secondary education	0.05	0.03	0.03
	(7.41)**	(3.85)**	(4.12)**
Log share male	0.18	0.16	0.12
	(14.78)**	(12.81)**	(9.42)**
Log share female	-0.03	-0.04	-0.06
	(-3.80)**	(-4.90)**	(-8.16)**
Size of firm		0.07	0.02
		(10.07)**	(3.09)**
Age of firm		0.007	0.02
		(1.07)	(3.39)**
Multi-plant		-0.05	-0.04
		(-2.98)**	(-2.18)*
Log share self-employed			-0.05
			(-14.09)**
Log share white collar			0.07
			(13.70)**
Log share blue collar			0.006
			(1.25)
Log share apprenticeship			-0.04
			(-14.07)**
Log share home worker			-0.04
			(-3.34)**
Log share part-time			-0.01
			(-4.92)**
Constant	1.16	1.47	1.80
	(15.09)**	(17.48)**	(20.59)**
R square	0.19	0.20	0.29
F-test	241.85**	187.92**	196.51**
Observations	9,012	8,882	8,882

* significant at 5%; ** significant at 1%

Note: Absolute values on t-statistics are listed in parentheses.

In the first model, value added per worker is regressed on three age share variables, four educational share variables and the share of genders. The first age variable is the share of the labour force aged below 30, the second age variable accounts for the share of workers between 30 and 49, and the third age variable represents the share of persons aged 50 and above. For the educational shares, we divide into lower secondary education, skilled workers, upper secondary education and academics (see Appendix E). All shares are logarithmised.

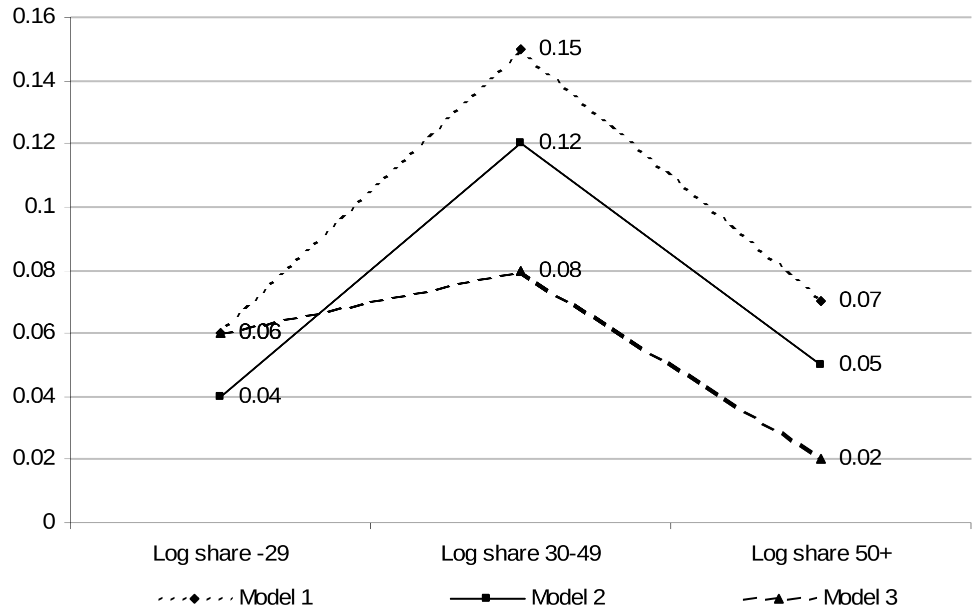
These estimates indicate a **hump-shaped pattern** for the age variable, i.e., firms in which the share of younger or older workers is higher, have a lower productivity than those with a higher share of the middle-aged group. There is not much variation regarding education except that firms with a higher share of workers in the lower-secondary education group have lower productivity. The coefficient of the gender shares has to be interpreted with caution. We find that firms with a higher share of female workers have a lower productivity. This does not necessarily mean that females work less productively. One reason for our findings could be that a high share of female workers works in branches with low labour productivity. Another reason could be that, on average, females do not have high levels of education and might be more likely to work part-time. (In our analysis, we unfortunately cannot control for hours worked since this information is not included in the census data.)

In the second model, we extend the regression by adding firm-specific variables such as the size of the firm (in terms of the number of employees and measured by a continuous variable), the firm's vintage/age (measured by a continuous variable) and whether or not it is a multi-plant firm (coded as dummy variable). When adding firm-specific characteristics, the coefficients of the other variables—and in particular those on age shares—remain stable. The hump-shaped pattern of the age profile is robust and not caused by firm-specific effects, at least not by those we have taken into account. It is interesting to see that the size of the firm increases productivity, although the effect is rather small. This could be an indicator of slight economies of scale. The age of the firm does not have any significant effect. Multi-plant firms have lower productivity. Various arguments could be suggested to explain these findings. Firm-specific economies of scale could be present, which are more likely in single-plant firms. Informal social communication between employees could be better in single-plant firms. Multi-plant firms need administration departments for each plant, which could increase fixed costs. On the other hand, the fact that multi-plant firms are more prevalent in specific branches could indicate that lower productivity is not a feature of multi-plant firms as such, but rather that industries characterised by a higher share of such firms are less productive.

In the third model, we add a further set of variables, which measures the share of workers in different occupations and the share of part-time workers. Once we include the occupational structure and the part-time share of workers in firms as additional variables, the hump-shaped pattern of age on productivity becomes less pronounced. Moreover, the age of the firm becomes significant now (as compared to column 2). From the coefficients for the occupational structure we may conclude that productivity is lower in firms with a higher share of self-employed workers, apprentices and home workers. In addition, the share of part-time workers is negatively related to productivity. Again, these results need to be interpreted with caution since we cannot control for the endogeneity of the independent variables, and in particular the age structure of enterprises. Less productive firms may be forced to increase their share of part-time workers or may attract employees who opt for a lower number of working hours. The fact that the hump-shaped pattern of age is reduced across models 1 to 3 in Table 6.11 indicates that part of the age structure effect is indeed due to the endogeneity of the employees' age structure.

In Figure 6.13, we summarise the age coefficients of the three tables. Including firm-specific and occupational structures within firms dampens the hump-shaped pattern.

Figure 6.13:
Hump-shape pattern of age and productivity in Austria



In order to answer the empirical question of how labour productivity at the firm level is related to the average length of education of the labour force, the regressions were estimated using the **mean length** of education instead of the share of employees having a certain level of education. All other variables were identical with those of the previous analysis. In a first model, we carried out a regression analysis of labour productivity on age shares, mean length of education and gender shares. In the second model, we added some firm characteristics, and in the third model we included some shares about the types of occupation as well as the share of part-time workers.

The **results** with regard to the age share variables **are very similar**. Again, we find a hump-shape pattern of age in all three models. As in the previous regressions, including firm-specific and occupational structures within firms dampens the hump-shaped pattern. The coefficients of all other variables and the significant levels of the other models are similar to the regressions in Table 6.11.

In a next step, the whole sample was divided into one subsample of **small firms** with a maximum workforce of 49 workers and another subsample of **large firms** with a workforce of 50 and more workers. Thus, the influence of firm size was investigated in more detail. The numbers of observations are very unequal. The sample of small firms contains more than three times as many observations as the sample of large firms. The large number of small firms reflects the **dominance of small and medium sized enterprises (SME) in the Austrian mining and manufacturing sectors**. According to Statistics Austria (2003), 93.4% of all firms in mining and 92.9% of all firms in manufacturing employ less than 50 persons. In our sample, the share of large firms is higher than the figures states by Statistics Austria

(2003), because large firms are overrepresented in the structured business statistics sample of Statistics Austria.

The three models introduced above are estimated using these two subsamples. The results are presented in Table 6.12. The results for small firms differ from those for large firms. **For small firms, we find a hump-shape pattern of age similar to the one for the whole sample** (see Table 6.12(a)). In models 1 and 2, the pattern is more pronounced than in model 3. We observe the same phenomenon for the whole sample. Introducing firm characteristics and occupational variables weakens the hump-shape pattern of age. The outcomes for the education variables are very similar to those of the whole sample. The coefficient of skilled labour turned out to be the highest. This means that firms with high shares of skilled workers are significantly more productive. The influence of firm characteristics and share variables for types of occupation are similar to Table 6.11. The coefficient of the dummy for multi-plant firms is insignificant, because small enterprises are hardly ever organised as multi-plant firms.

In the analysis of large firms, observations having log value added below 2 and above 6 were classified as outliers and removed from the sample. The sample size was reduced by a few firms only. The results of the regressions are shown in Table 6.12(b). In the estimation of all models, the share variables for medium ages turned out to be insignificant. The variable for young ages is significant only in model 2. Moreover, the significant level of the third age share is unstable. In model 1, we observe a significance of 1%. By adding firm characteristics, the significance deteriorates to 5% (in model 2). In model 3, the coefficient becomes insignificant by introducing occupation variables. This means that **no clear pattern of the effect of the age structure on productivity can be observed in large firms**. These results suggest that, in Austria, the theory that larger firms are more flexible in adjusting the age structure of their workers is not valid to the same extent as in Sweden. The results could rather indicate that large firms have the power to set prices on the market. Compared to small firms (which predominantly are price takers on the market), these firms are not so pressed to minimise their costs by optimising the age structure of their staff. Another reason for the main result might be that large firms in Austria have workers' councils, which protect the employees' rights. This, in turn, might imply a more restricted flow of workers.

Education has a weaker influence on the productivity of large firms as compared to small firms. Our estimates indicate that the share of academics has a positive and the share of labour force with lower secondary education has a negative impact. Apart from the share of upper secondary education in model 1, the other educational categories have no influence. These results are almost stable across the models. The formal qualification seems to be of lower importance in large firms as opposed to small firms. This might be due to the higher expenses for internal training in large enterprises.

Two out of three firm characteristics are significant. The size of the firm has a pronouncedly positive influence on productivity, which again is a strong sign for economies of scale. As in the analysis of the whole sample, the dummy of the multi-plant firm has a significant, negative sign. Organising a firm as multi-plant enterprise negatively affects labour productivity.

With regard to the occupational structure we find a pattern similar to the one reported in Table 6.11. The only difference is that the coefficients for home workers and part-time workers are insignificant. This might be due to the small share of these types of occupation in large firms.

Table 6.12(a):
Basic regressions for mining and manufacturing on enterprise level (small firms with less than 50 employees)

Variable	(1)	(2)	(3)
Log share -29	0.06	0.05	0.07
	(8.71)**	(6.82)**	(9.23)**
Log share 30-49	0.13	0.13	0.09
	(12.28)**	(10.85)**	(8.20)**
Log share 50+	0.06	0.05	0.03
	(8.74)**	(7.59)**	(3.92)**
Log share academics	0.07	0.07	0.03
	(7.74)**	(7.01)**	(3.20)**
Log share upper secondary	0.10	0.09	0.05
	(15.35)**	(13.58)**	(7.98)**
Log share skilled workers	0.12	0.11	0.10
	(10.10)**	(0.11)**	(8.15)**
Log share lower secondary	0.05	0.04	0.04
education	(6.68)**	(4.76)**	(5.62)**
Log share male	0.17	0.16	0.12
	(13.18)**	(11.87)**	(9.19)**
Log share female	-0.03	-0.03	-0.05
	(-3.21)**	(-3.91)**	(-6.05)**
Size of firm		0.04	0.07
		(3.24)**	(4.85)**
Age of firm		0.01	0.03
		(1.03)	(3.57)**
Multi-plant		-0.05	-0.03
		(-2.27)*	(-1.23)
Log share self-employed			-0.05
			(-15.18)**
Log share white collar			0.08
			(13.43)**
Log share blue collar			0.02
			(3.71)**
Log share apprenticeship			-0.03
			(-11.56)**
Log share home worker			-0.04
			(-2.72)**
Log share part-time			-0.01
			(-5.37)**
Constant	1.28	1.41	1.73
	(15.58)**	(15.22)**	(18.46)**
R square	0.17	0.16	0.27
F-test	157.11**	116.25**	143.97**
Observations	7,066	6,948	6,948

* significant at 5%; ** significant at 1%

Note: Absolute values on t-statistics are listed in parentheses.

Table 6.12(b):
Basic regressions for mining and manufacturing on enterprise level (large firms with 50 and more employees)

Variable	(1)	(2)	(3)
Log share -29	-0.04	-0.08	-0.01
	(-1.13)	(-2.17)*	(-0.35)
Log share 30-49	0.13	0.05	-0.00
	(1.61)	(0.61)	(-0.03)
Log share 50+	0.06	0.04	0.03
	(2.88)**	(2.04)*	(1.42)
Log share academics	0.08	0.07	0.05
	(5.82)**	(4.74)**	(3.57)**
Log share upper secondary	0.04	0.03	0.00
	(2.49)**	(1.82)	(0.18)
Log share skilled workers	-0.01	-0.02	0.07
	(-0.11)	(-0.41)	(1.19)
Log share lower secondary education	-0.09	-0.10	-0.06
	(-3.34)**	(-3.72)**	(-2.19)*
Log share male	0.23	0.21	0.17
	(6.27)**	(5.98)**	(4.68)**
Log share female	-0.02	-0.02	-0.05
	(-1.12)	(-0.79)	(-2.35)**
Size of firm		0.11	0.11
		(8.50)**	(9.07)**
Age of firm		0.01	0.01
		(0.56)	(1.00)
Multi-plant		-0.06	-0.07
		(-2.88)**	(-3.41)**
Log share self-employed			-0.04
			(-3.79)**
Log share white collar			0.08
			(3.64)**
Log share blue collar			-0.02
			(-1.14)
Log share apprenticeship			-0.04
			(-7.01)**
Log share home worker			-0.01
			(-0.31)
Log share part-time			-0.00
			(-0.00)
Constant	2.62	2.76	2.29
	(5.45)**	(5.61)**	(4.70)**
R square	0.17	0.20	0.23
F-test	42.48**	38.92**	32.34**
Observations	1,927	1,915	1,915

* significant at 5%; ** significant at 1%

Note: Absolute values on t-statistics are listed in parentheses.

Age-specific education level

So far, our estimates indicate **a hump-shaped pattern of the educational share variable for the overall sample and the sample of small firms, and a declining pattern with less significant coefficient estimates for larger firms**. As in the study with Swedish data, it is puzzling that the share of skilled workers seems to have a more positive effect than the share of academics for the overall sample and the small firm sample. As already noted, these effects may be caused by the low share of academics or/and the correlation between age and educational share variables. The latter argument refers to the fact that educational attainment as well as educational quality may be higher in younger cohorts.

To control for these possible interaction effects, we proceeded in more or less the same way as our Swedish colleagues and introduced a new variable with four age groups and three educational variables within each age group. This yielded 12 non-overlapping categories. Differently to the Swedish case study, we did not distinguish between the 50-59 and 60+ age groups, since the labour force participation of people above age 60 is very low in Austria. The educational groups are defined as primary education (equivalent to lower secondary schooling), secondary education (equivalent to skilled workers and upper secondary education), and tertiary education (equivalent to academics). We only analysed the set of firms with at least 50 employees to avoid that specific age-education cells are not represented in the data. Similarly to limiting ourselves to the sample of large firms, we classified log value added below 2 and above 6 as outliers and removed these values from the sample.

The coefficients on the age-educational variable are depicted in Figure 6.14(a) (corresponding to an econometric set up as in model 1 in the previous tables) and Figure 6.14(b) (corresponding to an econometric set up as in model 3 in the previous tables). Without controlling for firm-specific effects and occupational structure of the workforce (Figure 6.14(a)) the share of workers with tertiary education has the strongest positive effect on productivity. These effects are largest for firms with high shares of middle-aged workers (30-39 years). The productivity effects for secondary and primary education are rather flat except for the lower productivity effect for firms having young workers with primary education. Introducing firm-specific effects and the occupational structure of the workforce lowers the age-educational profile. Tertiary education still has the strongest positive effect on productivity (irrespective of age).

Figure 6.14(a):
Estimated coefficient values with disjunctive age-education shares, age-education shares and gender shares only

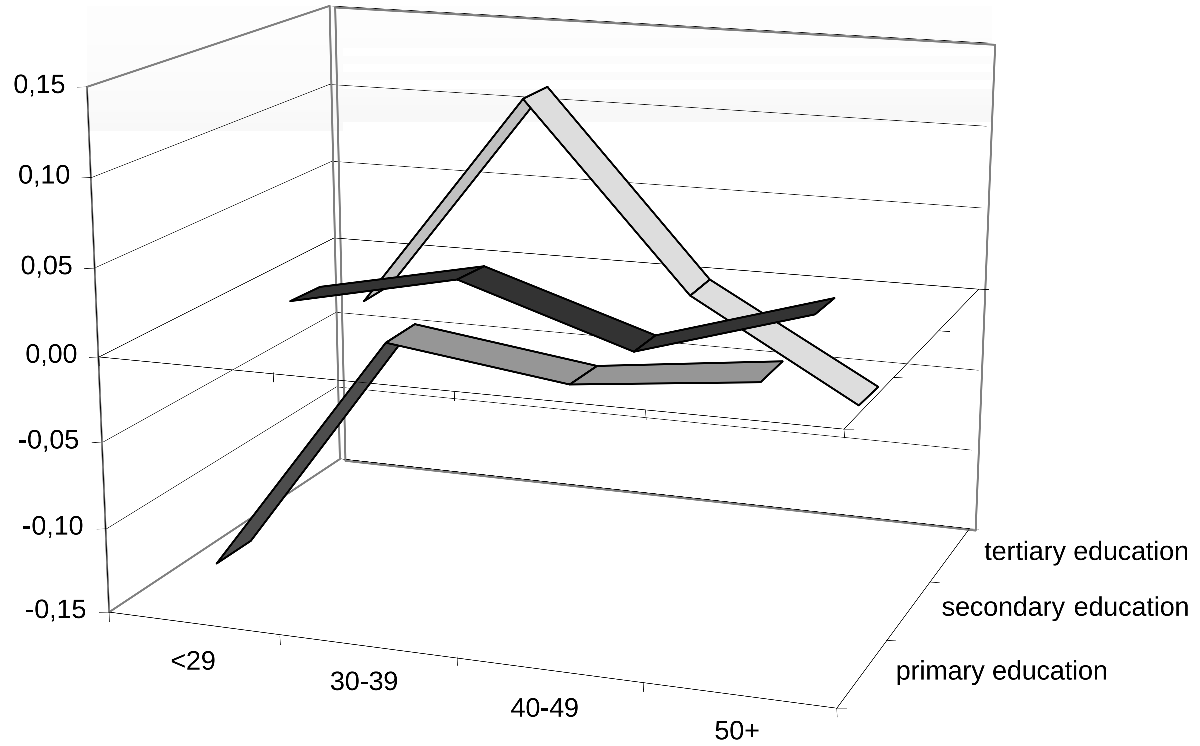
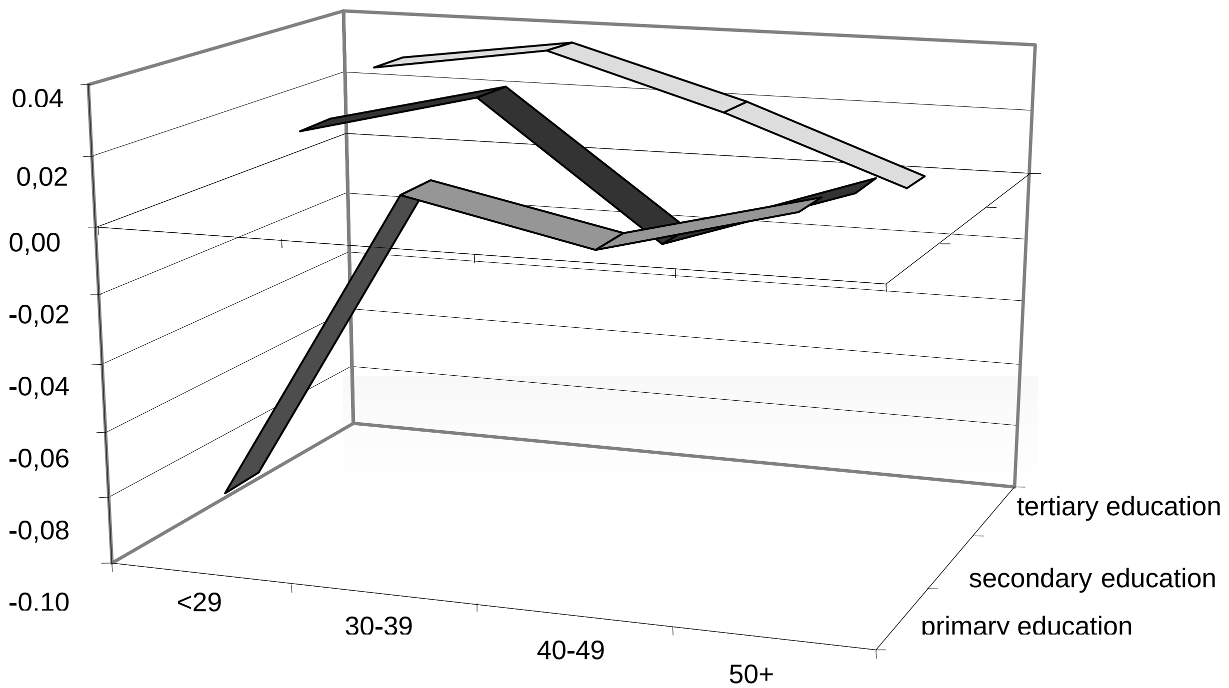


Figure 6.14(b):
Estimated coefficient values with disjunctive age-education shares, age-education shares, gender shares and firm attributes (age and size of firms and multi-plant dummy)



Productivity and ICT intensity

In the past decade, the European Union has fallen behind the USA with regard to the development of labour productivity. A recently published report of the European Commission (O'Mahony and van Ark 2003) identified lower production and use of information and communication technologies (ICT) in the European manufacturing sector as one of reasons for this development (see also Section 3 of our report). Production and the use of ICT are key factors for an increase in the productivity of labour. Therefore it is highly relevant to investigate the differences of productivity in firms working in branches, in which ICT is produced or used, and in all other branches.

The EU report breaks down the branches into three categories: ICT producing, ICT using and others (Table 6.13).

Table 6.13:
Classification of branches according to ICT category in manufacturing industries

Category	Branches according to NACE classification
ICT producing	30, 313, 321, 322, 323, 331
ICT using	18, 22, 29, 31 (without 313), 33 (without 331), 351, 352, 353, 359, 36, 37
Others	Other branches of manufacturing not mentioned

Source: O'Mahony and van Ark (2003), p. 49

In order to test whether there are any differences in the age structure effects between the industries (belonging to one of the categories mentioned in Table 6.13), two steps were pursued in the analysis. In a first step, descriptive statistics were used to show the age of staff working in one of the three categories mentioned above. In a second step, separate regressions for the value added per worker were conducted for the manufacturing sector. Results are displayed for each category, i.e., ICT producing, ICT using and other industries.

The results of the descriptive statistics reveal no significant differences in age profiles. In all three categories, the mean age of staff as well as standard deviations are very similar. Hence, all age groups are represented to the same extent in all three ICT categories.

The results of the regressions are presented in Table 6.14. The outcome shows that **no age pattern prevails in the ICT producing firms**. The age structure does not seem to matter. Education seems to play only a minor role in labour productivity. Skilled workers are the only category that has a significant (positive) influence. The size of the firm has a positive impact on labour productivity, which is a sign for economies of scale. Firms with a high share of apprentices exhibit a significantly smaller productivity relative to the average of all firms. The reason is that young people are in the process of education and hence not as productive as their experienced fellow workers. The coefficients of all other variables are insignificant. The reason for this could be the small sample size and the low number of observations in several categories.

When surveying the firms **using ICT**, a **slight hump-shaped pattern of age** can be observed, although the coefficient of the third age share is insignificant. The pattern of education is similar to that of the whole sample (see Table 6.11). The exception is the insignificant influence of lower secondary education. Size has a positive influence on productivity, which is a sign for economies of scale. Firms organised as multi-plant companies are once more at a disadvantage. The influence of the occupational structure corresponds to the one found in the previous tables where we did not distinguish between the three ICT categories.

According to the results in model 3 (see Table 6.11), the regressions for firms of branches **neither belonging to ICT producing nor to ICT using branches** have very similar coefficients. The only exception is the insignificant coefficient of the size variable.

Conclusions

Summing up the micro evidence for Austrian mining and manufacturing, a hump-shaped pattern is found for all age variables. Thus, productivity is lower in firms that have a higher share of younger or older workers as compared to firms whose share of workers in the middle age group is higher. These results prevail when we control for age, gender and education shares. Once the occupational structure and the share of part-time workers are included as additional control variables, the hump-shaped pattern of age on productivity declines further.

When splitting the sample into two subsamples—i.e., a sample of **small** firms (with less than 50 employees) and a sample of **large** firms (50 or more employees)— results differ from those obtained in Sweden; no clear pattern of age can be observed in large firms.

In order to test whether age structure effects differ between industries belonging to different **ICT** categories, separate regressions were conducted for the ICT producing and ICT using industries as well as for other industries. The results are as follows:

- No age pattern on productivity was found for the ICT producing industries.
- A weak age pattern prevails for ICT using industries.
- All other industries show a hump-shaped age profile.

In conclusion, these results support the hypothesis that other factors of production (e.g., ICT capital) are more important for ICT producing firms than their employees' age structure.

Table 6.14:
Basic regressions for manufacturing on enterprise level by ICT-classes

Variable	ICT producing	ICT using	Rest
Log share -29	0.03	0.05	0.06
	(1.19)	(4.39)**	(6.18)**
Log share 30-49	0.01	0.06	0.09
	(0.16)	(3.80)**	(6.46)**
Log share 50+	-0.01	0.02	0.02
	(-0.60)	(1.44)	(2.95)**
Log share academics	0.02	0.03	0.04
	(0.79)	(2.07)*	(4.01)**
Log share upper secondary	0.03	0.06	0.04
	(1.59)	(5.32)**	(5.26)**
Log share skilled workers	0.08	0.08	0.11
	(2.03)*	(4.29)**	(6.48)**
Log share lower secondary education	-0.01	0.02	0.04
	(-0,31)	(1.37)	(3.70)**
Log share male	-0.01	0.14	0.11
	(-0.17)	(7.64)**	(6.09)**
Log share female	-0.08	-0.01	-0.08
	(-2.54)*	(-1.15)	(-7.68)**
Size of firm	0.12	0.05	0.01
	(4.35)**	(3.96)**	(1.08)
Age of firm	-0.02	0.02	0.03
	(-0.86)	(2.14)*	(3.12)**
Multi-plant	0.08	-0.12	-0.04
	(1.11)	(-3.63)**	(-2.06)*
Log share self-employed	-0.02	-0.04	-0.05
	(-1.91)	(-7.16)**	(-11.61)**
Log share white collar	0.03	0.06	0.08
	(1.49)	(5.89)**	(11.52)**
Log share blue collar	0.02	-0.01	0.01
	(1.03)	(-0.71)	(0.88)
Log share apprenticeship	-0.04	-0.03	-0.04
	(-3.79)**	(-6.91)**	(-9.77)**
Log share home worker	0.08	-0.04	-0.04
	(1.20)	(-2.45)*	(-2.39)*
Log share part-time	-0.01	-0.01	-0.01
	(-0.65)	(-3.10)**	(-3.22)**
Constant	3.11	1.72	1.76
	(9.34)**	(12.44)**	(14.29)**
R square	0.25	0.29	0.29
F-test	8.31**	66.63**	121.25**
Observations	459	2,889	5,369

* significant at 5%, ** significant at 1%

Note: Absolute values on t-statistics are listed in parentheses.

7 Potential role of age in prospective analysis

Population ageing is a phenomenon that will affect all EU countries. However, the relative size of the cohorts in working age and entering working age in the next decades, as well as their educational attainments, vary substantially between countries. In this part of the report we will present productivity forecasts (based on the micro-based evidence of productivity effects of labour force ageing presented in part 6 of the report).

Equally important will be the sensitivity of those projections to various scenarios of the labour market institutions (where labour force participation and educational attainment is of central importance). Put differently, we **will use those simulations to evaluate various labour market policies wit h respect to their implications for productivity**.

Introduction

Our analysis of plant data for the **Swedish manufacturing** has shown that both **age structure** and **educational structure** of the workforce have important effects on productivity. In this section we analyse whether these micro-level relationships can be used to model the aggregate relationship between workforce change and productivity. The analysis is carried out in two steps. First, the model is applied to an out-of-sample data set of 14 EU countries. Then, for the 2005-2050 period, the model is combined with **population projections, educational assumptions and assumptions of activity rates in order to produce scenarios for the EU-25 economies**.

Preferred model

The estimates used for the prospective analysis are taken from column 5 in Table 6.1 with fixed plant effects. That is:

$$\begin{aligned} \textit{Log value added per worker} = \textit{intercept} \quad & - 0.023 * \textit{log share 15-29} \\ & + 0.138 * \textit{log share 30-49} \\ & + 0.081 * \textit{log share 50-64} \\ & + 0.201 * \textit{length of education} \qquad (1) \end{aligned}$$

This implies that we will be using a model estimated on only the manufacturing and mining sector of the economy to project change in the whole economy. An argument for this approach is that productivity measurements in manufacturing are less problematic than in the service sector.

Data and specification

To test if the above model, estimated on micro data, can be used to track movements in aggregate production we used data on the age composition and educational structure of the labour force for the members of **EU-14** (EU-15 excluding Luxemburg). Data on the new EU members were insufficient for this test. Our first check was carried out on data from **Sweden** where we have data on educational structure for a longer period than is available from Eurostat.

The aggregate variable that we model is **total GDP**, i.e., total value added in the economy plus depreciation. The model has a highly simplified structure:

Log GDP = *intercept* + β_1 * *log predicted productivity*+ β_2 * *log workers* (2)

where *predicted productivity* is obtained by applying (1) to aggregate age shares and aggregate mean length of education. *Workers* is the total number of employed in the economy (no intercept).

<u>Sweden</u>

Data on education levels of the labour force are available from 1985 onwards. Two major revisions were made in 1990 and 2000. This is clearly visible in the aggregate time series, see Figure 7.1.

Figure 7.1:
Mean length of education of the labour force, Sweden (observed values and quadratic trend)

To avoid undue influence of these breaks in data, a quadratic trend was substituted for the raw values. The quadratic trend was also used to provide estimated values for mean length of education for 2004.

The **proposed model fits the Swedish data almost too well**, with a near-perfect fit between predicted and observed GDP values. Since movements in the total number of employees (*workers*) capture influences from the business cycle this implies that our predicted productivity is closely correlated with the **GDP trend**. This is exactly the result that we want in order to be able to use the productivity model for forecasting purposes.

$$\underset{(1.63)}{\text{Log GDP} = 9.88} + \underset{(0.11)}{1.65} * \textit{log pred. prod.} + \underset{(0.18)}{0.94} * \textit{log workers}$$

Adj R2= 0.941, RMSE=0.029, N=19, standard errors in parentheses (3)

Also the estimated parameters are reasonable considering that we have not controlled for changes in the capital stock. The 1.65 parameter for *predicted productivity* implies that a one per cent increase in this variable translates into a 1.65 per cent increase in GDP. Although this is on the high side it is not too far away from unit elasticity. The parameter for *log workers*, on the other hand, is practically one. This is reassuring given that we have tried to control for changes in labour productivity.

This test on Swedish data is thus encouraging for the proposal to use the productivity model to forecast future influences of labour force change on movements in productivity.

Other EU countries

For the other **EU-14 countries** we have access to education data only for shorter periods. Moreover, for some countries, these education data demonstrate surprisingly large discontinuities. Nonetheless, it can be instructive to analyse to what extent the micro-based productivity model can account for the observed movements in GDP in the European Union during the last decade.

The procedure is the same we applied to Sweden with one exception. In the Swedish data that covers almost two full business cycles, *predicted productivity* is uncorrelated with *workers*. This is not the case in the EU-14 data where most of the data come from a business upturn. Here predicted productivity is positively correlated with total employment. The mean value for the country-wise correlation coefficient productivity and employment is 0.67, and for half the countries the correlation coefficient is above 0.88. It is desirable to minimise the effect of this correlation on the aggregate model. Therefore, the residuals resulting from a regression of log workers on log predicted productivity (and fixed country effects) was substituted for the original values in the model. The resulting model for the EU14 countries is

$$\text{Log GDP} = \textit{country spec. intercpt.} + \beta_1 * \textit{log pred. prod.} + \beta_2 * \textit{resid. log workers} \quad (4)$$

OLS estimation of this model on EU-14 data gives:

$$\text{Log GDP} = \textit{c.s. intercpt.} + \underset{(0.056)}{2.08} * \textit{log pred. prod.} + \underset{(0.056)}{1.40} * \textit{resid. log workers}$$

These estimates differ somewhat from those obtained using only Swedish data. Here the **parameter for predicted productivity is close to two** and the log workers parameter a little above one. As can be seen in Figure 7.2 there is a strong linear trend present in the GDP series. This raises some statistical concerns and serves to underline that the results presented above do not constitute forecasts in a strict sense of the term. Instead, our aim is to show what the impact of population ageing and different labour market trends on the productivity of the European economy could be, given that the age-productivity relationships of the estimated micro model are correct. In this context, therefore, we refrain from further econometric testing of the macro model.[26]

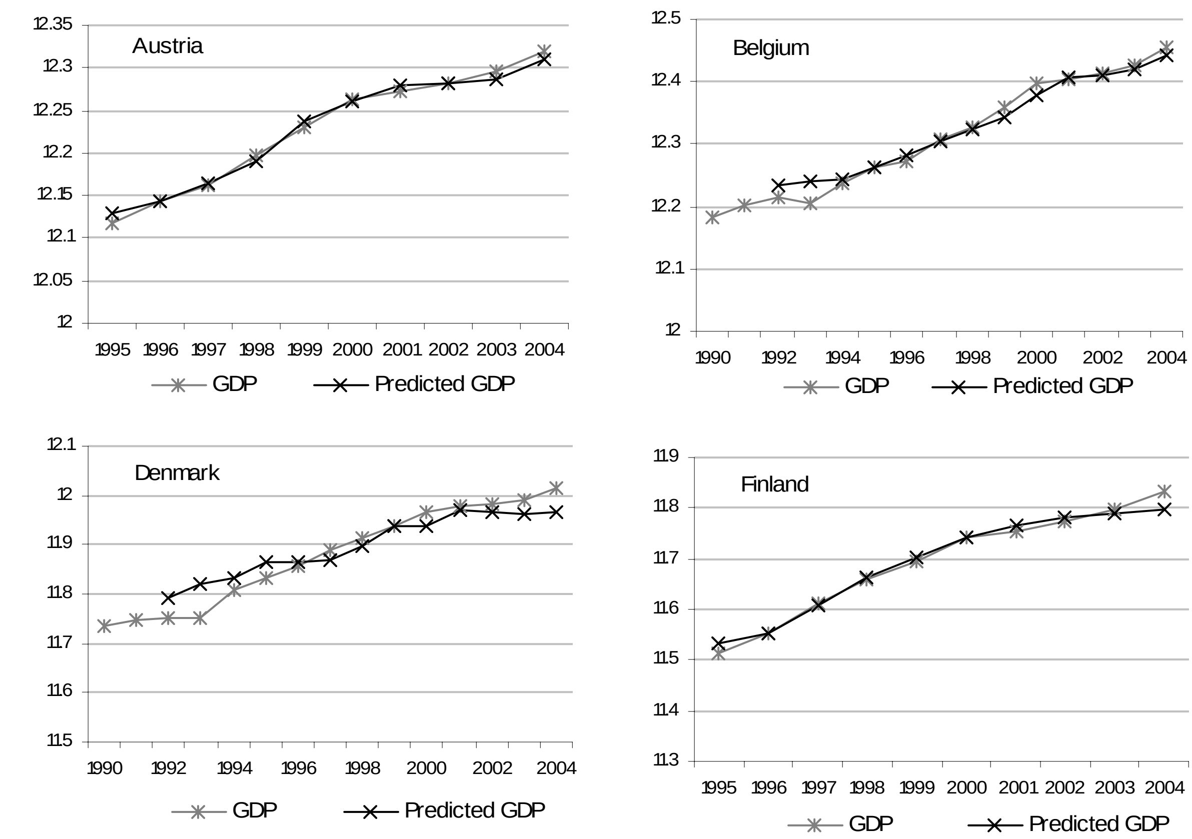
[26] The interested reader can consult Österholm, P. (2004) for the demonstration of a cointegrating relationship between age structure and GDP. Out-of-sample tests of age structure-based predictions of GDP are presented in Malmberg and Lindh (2004). A macro-based forecast of future growth in the EU

An illustration of how well the model is able to capture GDP movements in EU-14 is given in Figure 7.2, below. For *Austria, Finland*, *France*, *Ireland and the Netherlands* the **fit is very close**. Also for *Belgium* and *Greece*, there is a **good agreement**. The model **overpredicts** GDP growth in *Spain, Portugal, Luxembourg, Italy* and *Denmark* and **underpredicts** GDP change in the *United Kingdom* and *Sweden.* It is only for post-unification *Germany* that the model fails to capture the general trend in GDP.

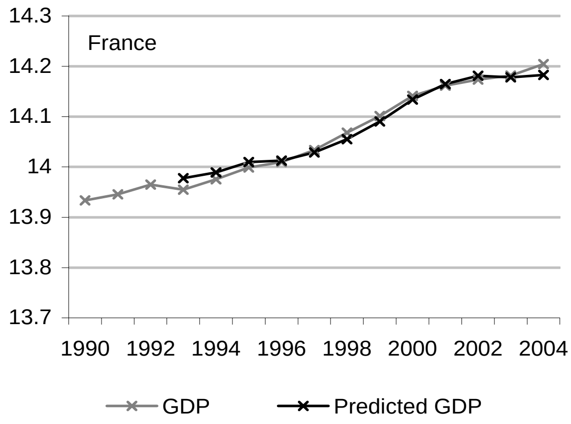
Our conclusion is that the crude model we have developed using plant-level data on the relation between labour force structure and productivity can be used to reproduce movements in GDP at the aggregate level. This provides us with a mechanism whereby assumptions about future changes in the structure of the active labour force can be transformed into different scenarios for GDP, GDP per worker, and GDP per capita scenarios.

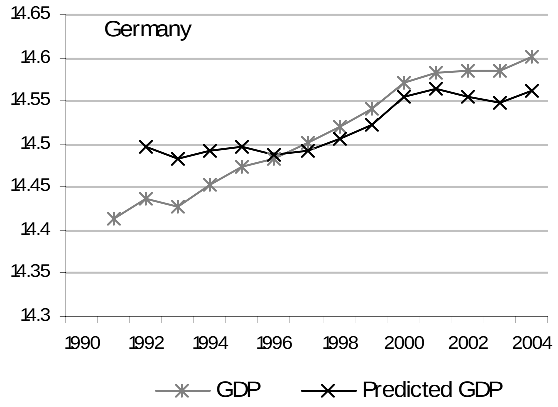
Before the results of these scenarios are presented, though, it is important to point out that more micro-empirical studies are necessary before we can be assured that the relations we have demonstrated in the Swedish data are stable and permit to generalise. Nonetheless, the calculations we present below are consistent with the micro relationships demonstrated in the Swedish data. And, as we have shown above, an aggregate model based on these relationships works pretty well both for the Swedish and EU-14 macro data.

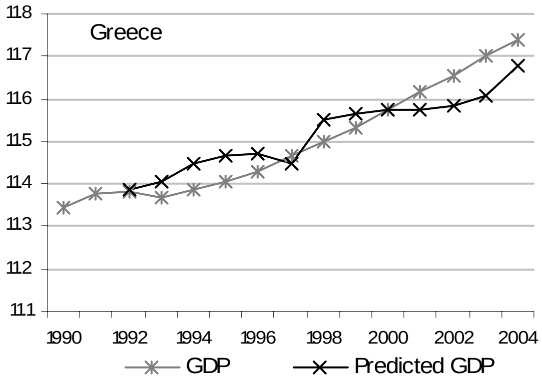
Figure 7.2:
Predicted and actual levels of log GDP

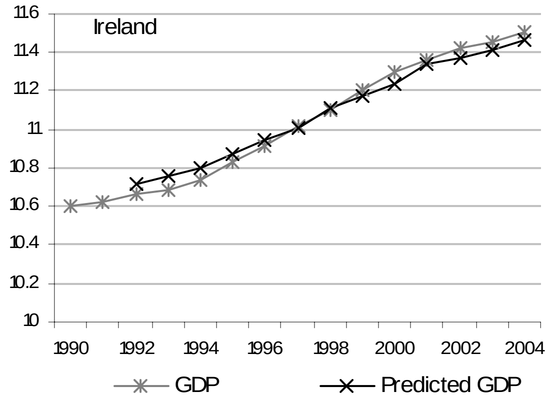


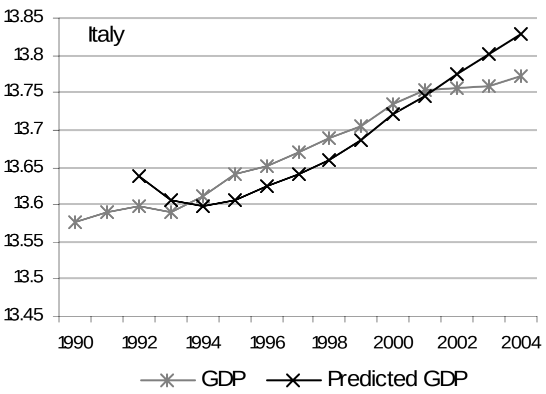
member states using a demographic approach is given in Institute for Futures Studies (2004).

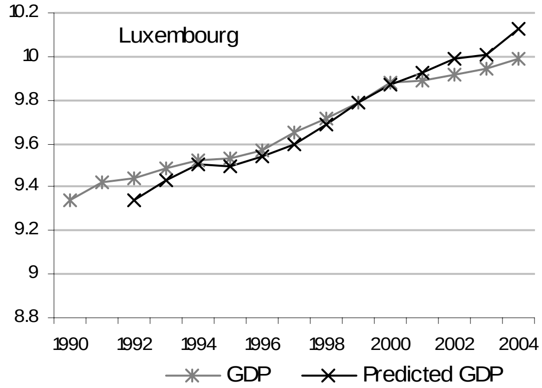

France
14.3
14.2
14.1
14
13.9
13.8
13.7
1990 1992 1994 1996 1998 2000 2002 2004
GDP
Predicted GDP

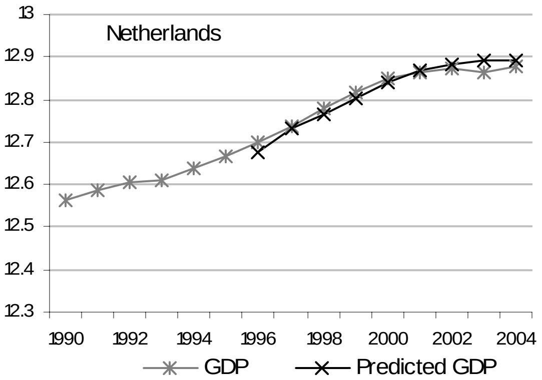

Germany
14.65
14.6
14.55
14.5
14.45
14.4
14.35
14.3
1990 1992 1994 1996 1998 2000 2002 2004
GDP
Predicted GDP

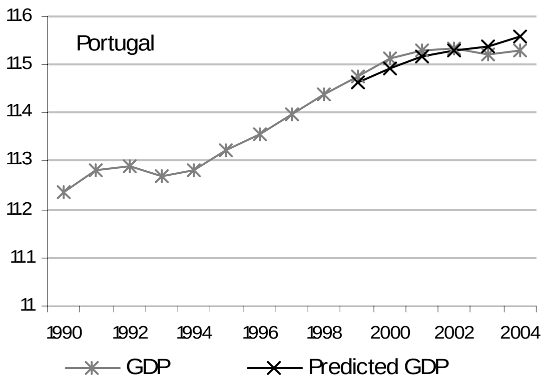

Greece
11.8
11.7
11.6
11.5
11.4
11.3
11.2
11.1
1990 1992 1994 1996 1998 2000 2002 2004
GDP
Predicted GDP

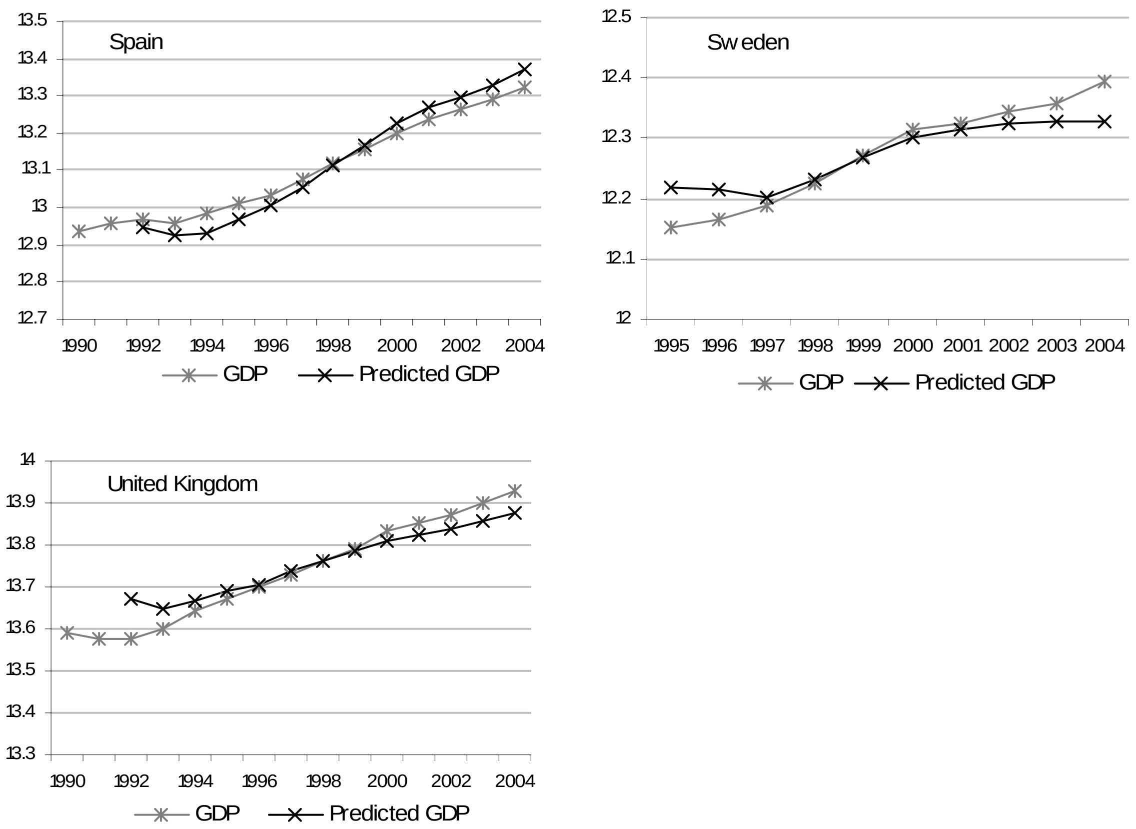

Ireland
11.6
11.4
11.2
11
10.8
10.6
10.4
10.2
10
1990 1992 1994 1996 1998 2000 2002 2004
GDP
Predicted GDP


Italy
13.85
13.8
13.75
13.7
13.65
13.6
13.55
13.5
13.45
1990 1992 1994 1996 1998 2000 2002 2004
GDP
Predicted GDP


Luxembourg
10.2
10
9.8
9.6
9.4
9.2
9
8.8
1990 1992 1994 1996 1998 2000 2002 2004
GDP
Predicted GDP


Netherlands
13
12.9
12.8
12.7
12.6
12.5
12.4
12.3
1990 1992 1994 1996 1998 2000 2002 2004
GDP
Predicted GDP


Portugal
11.6
11.5
11.4
11.3
11.2
11.1
11
1990 1992 1994 1996 1998 2000 2002 2004
GDP
Predicted GDP



Assumptions

Since our preferred model seems to be able to capture relatively well the effect on macro-level productivity of changes in age structure and educational structure it can be of interest to use the model to predict possible outcomes of future changes in the labour force.

The first input into these projections is **population forecasts** from the UN Population division for the EU member states. Although not the best available, the UN projections are a convenient standard based on the assumption of convergent fertility rates. This assumption implies that the GDP projections will primarily reflect the ageing of the current European population and not national differences in future fertility levels.

The second input is information by age group on **current educational attainment** of the working age population. Inspired by the method pioneered by Goujon and Lutz, these figures were used to project the future level of education. The assumption was that **after the age interval 25-34 the educational attainment of a cohort will stay constant**. Thus, if 40 % of the 25-34 age group have tertiary education in 2000 this will be the case also for the 55-64 age group in 2030.

The third input is assumptions about future levels of **labour force participation** and of the **educational attainment of future cohorts**. In each case two alternative assumptions have been used:

Education: (1) The educational attainment of future cohorts will be the same as that of the current 25-34 age group. Note that since the educational attainment of this group in general is much higher than for earlier cohorts this assumption implies that educational levels will increase quite rapidly in most EU countries in the next decades.

(2) The educational attainment of future cohorts will converge to current levels of the 25-34 age group in Ireland (with respect to tertiary education 43%), and Sweden (with respect to secondary education 57%)—that is, no one will finish school with only primary education). It is assumed that this level will be reached when the cohort born 1995-2004 has reached the 25-34 age group. Thus, in 2050 the whole working population will have achieved these attainment levels.

Participation: (1) Participation rates by age will **stay constant at today's levels**. This implies that current differences in participation rates will remain.

(2) **Convergence** in participation rates **to the Swedish level**.

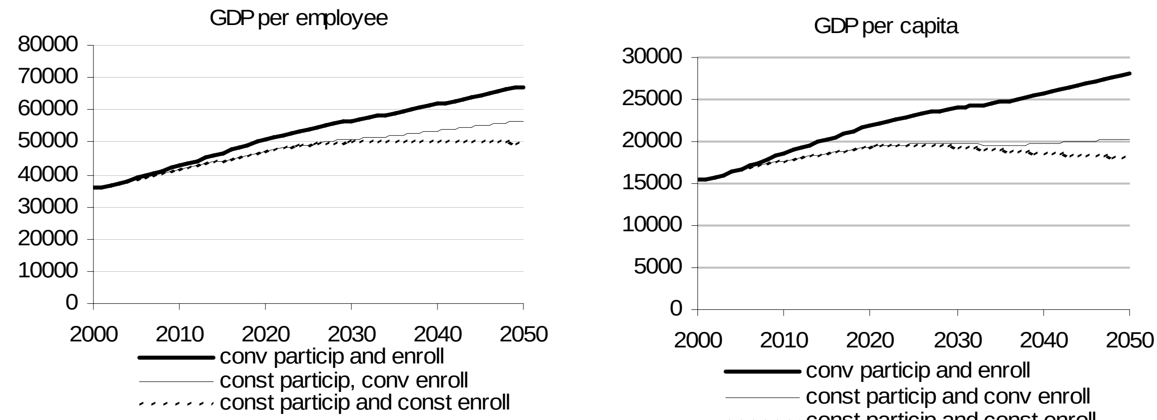
<u>Results</u>

Let us first look at the **effect of population on the mean levels of productivity and GDP per capita in the EU member states**. These results are given for EU-25 in Figure 7.3(a) (in order to make the graphs more legible, the convergent participation, constant enrolment alternative is not shown). As can be seen from these graphs the average prospects for productivity growth are not bad for the next 15 years. After 2025, though, there is a risk for stagnation if current participation rates and current education enrolment rates are constant. With increased enrolment a continuing increase in the education level of the labour force will give a continued increase in productivity.

A scenario with constant enrolment and constant participation rates will lead to **declines in GDP per capita**, as can be seen in Figure 7.3(a). Neither are rising enrolment rates alone enough to secure growth in GDP per capita. The reason is the high growth of the non-working age population. Here, on the other hand, an increase in **labour force participation** can ensure **continued growth**. Increasing labour force participation will also, as seen in Figure 7.3(a) (left panel), bring about higher growth in GDP per employee. The reason is that in our estimated model an increasing share of 30+ workers will increase labour productivity. By increasing participation rates among older workers it may thus be possible to raise the productivity of the European economy. On average between 2005 and 2025 this raises the growth rate from slightly below one per cent to over two per cent. And as seen in Figure 7.3(a), the effect will be even stronger on **per capita income growth**. Here growth is boosted through both an increasing productivity and an increase in the number of employed in relation to the total population. Thus, with increasing participation rates and enrolment rates a large increase in per capita income growth is within reach even in the face of a rapidly ageing population. Note that the growth promoting effect of convergence in education levels only comes with a considerable delay of more than 20 years while convergence to higher participation rates have more immediate effects.

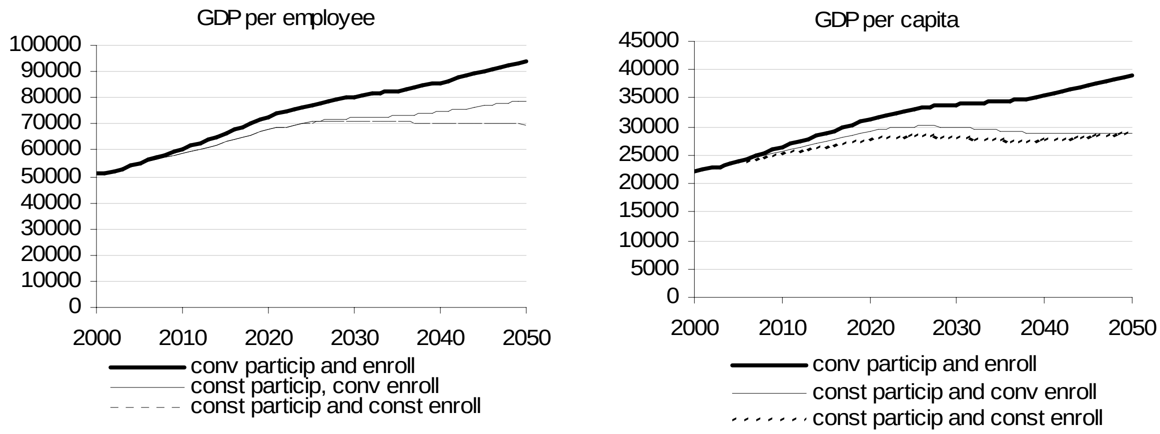
Figure 7.3(b), instead, shows the **development in EU-15**. With respect to GDP per employee, the development is similar to the EU-25 with the difference that the overall level is higher and that growth in the double convergence scenario is reduced after 2025. In the EU-25 double convergence scenario productivity growth is more linear. This same difference between EU-15 and EU-25 is also, to some extent, the case with the double convergence scenario for GDP per capita. Moreover, for EU-15 our model does not predict a continued fall in GDP per capita in the no-convergence alternative. One reason could be that EU-15 contains most of the EU countries that already have high participation rates.

Figure 7.3(a):
EU-25 mean GDP in 1995 EUR fixed prices



Source: Eurostat

Figure 7.3(b):
EU-15 mean GDP in 1995 EUR fixed prices



Source: Eurostat

This is the general picture. Depending on current participation rates and educational attainment rates, and on differences in age structure, the national trends can diverge considerably (see Figure 7.4). On the one extreme is Sweden, see the following graphs for countries. In **Sweden**, increasing education levels will bring about some increase in per capita GDP but this is not enough to give a continued increase in per capita GDP. The reason is that participation rates are already at the convergence level as it is defined here. If Sweden would be able to raise participation rates also in age groups that traditionally have been in retirement, such as the **65-74 age group**, this could help to generate improved prospects for per capita income growth.

Austria represents another extreme. **Austria** per employee GDP will increase thanks to increasing education levels and some initial positive age structure effects. The great potential, however, resides in a change in labour force participation. Currently, the **participation rate of the 50-64 age group is 43 % in Austria in comparison to 71% in Sweden**. An increasing participation of older adults would decrease the youthfulness of the Austrian labour force and, hence, according to our estimates increase productivity. In combination with the accounting effect on per capita GDP of increased participation, the effect would be strong enough to counter the long-run negative effect of an older population. The effect of a convergence to high levels of educational attainment would, however, not be very large since Austria already is near the convergence level.

The **Italian** picture is different in this respect. An increase of Italian educational attainment towards the convergence level could bring about very substantial increases in productivity above the base scenario. This big effect is due to currently **low rates of educational attainment** in Italy. If educational attainment were to remain low and there were no change in participation, Italy could foresee a 25% reduction in per capita income after 2025. The effects of a policy aimed at increasing participation and enrolment rates, on the other hand, can generate substantial per capita income growth. According to our estimates, a doubling of GDP per capita would be within reach, although this would require very determined policy efforts.

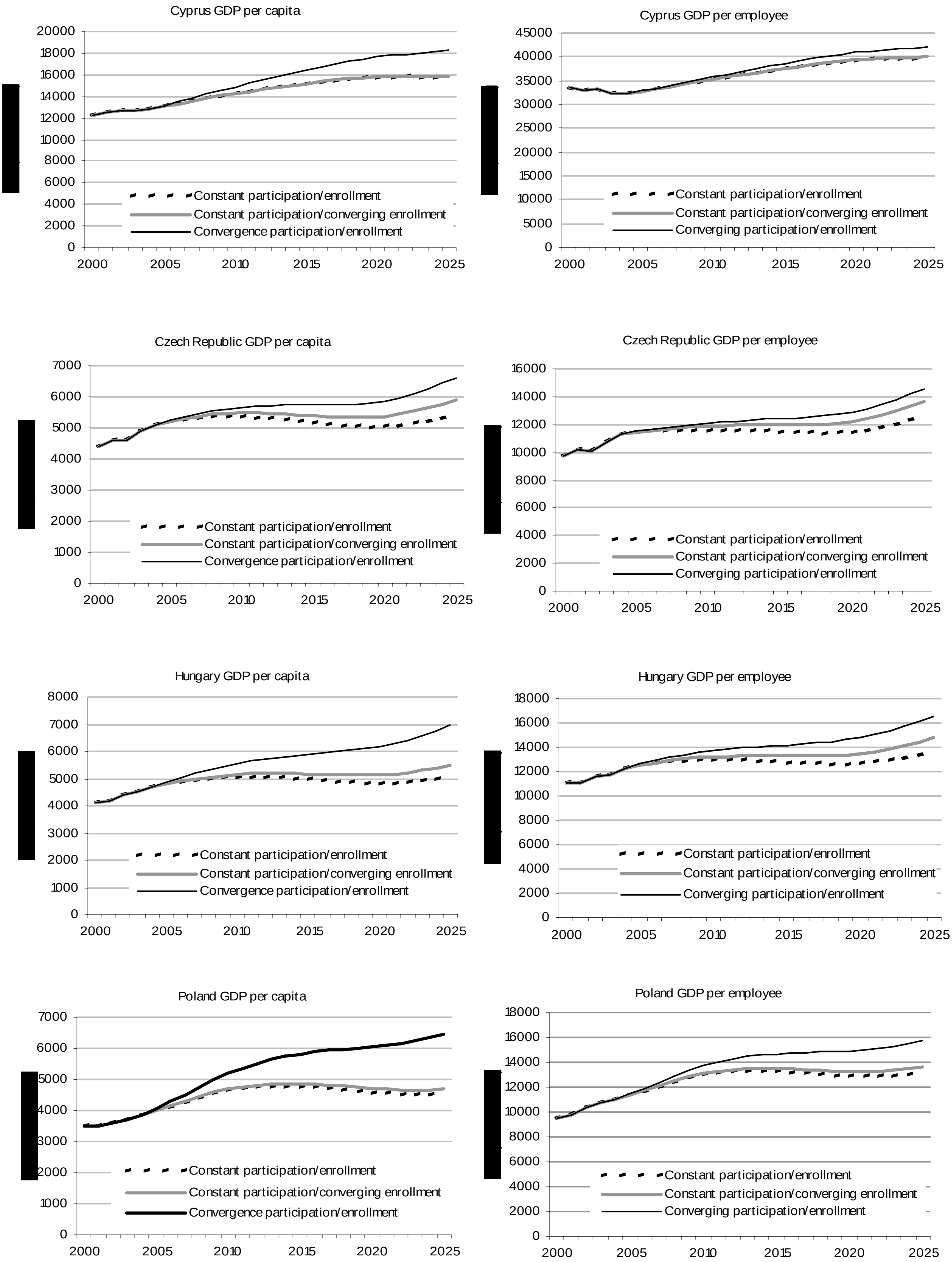
For **Spain** the growth prospects for the two decades look good. A maturing labour force in combination with highly educated young cohorts can stimulate productivity growth and contribute to healthy per capita income increases. After 2030, however, per capita income can be expected to decline if there is no increase in the labour force participation of older adults.

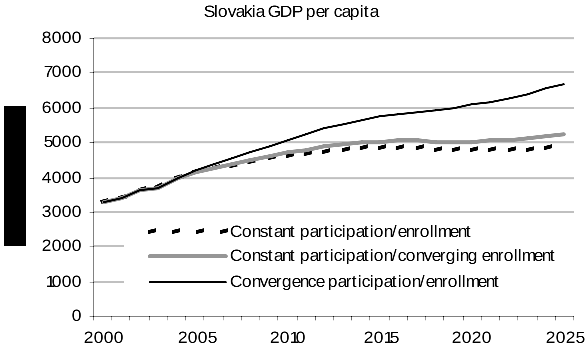
France is another interesting case. Here there will be some productivity growth thanks to rising education and a maturing working-age population. But there will be no per capita income growth unless there is an increase in participation rates among older workers. If participation rates increase, however, the reward can be a strong per capita income increase.

For the **Baltic States**, the current analysis does not hold very big expectations. Some increase in per GDP per capita levels are projected but these are not enough to allow a convergence to West European levels. It must be emphasised here, however, that our model does not capture pure income convergence or, for example, the effect of infrastructure investments. Increasing participation rates seems to be of importance especially for Latvia and Lithuania as population ageing will set in after 2030. For the **Czech Republic**, both education and participation will become important issues to encourage productivity growth. Raising participation rates also seems like a necessity to generate per capita income growth in **Slovakia** over the next decade. With an increase in participation rates, on the other hand, the potential for growth looks substantial.

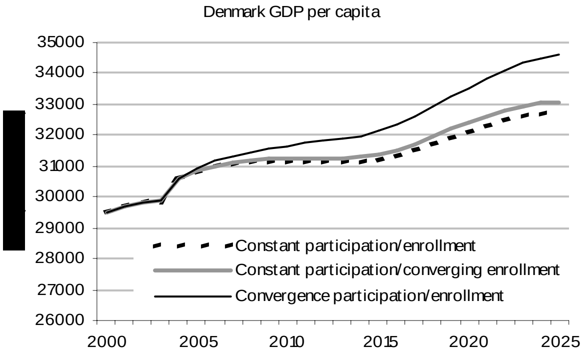
This applies even more strongly to **Belgium** where the growth potential is large but per capita income may stagnate after 2015 unless there is an increase in participation.

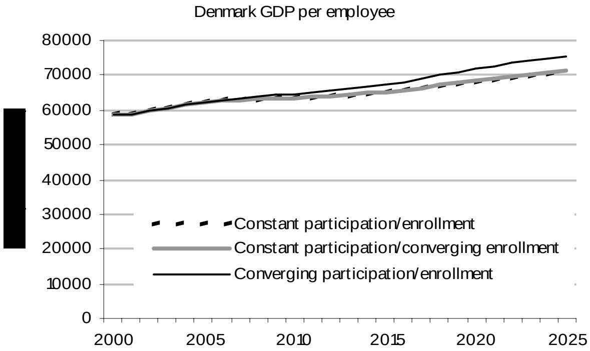
Figure 7.4:
Projected GDP per capita and GDP per employee for EU

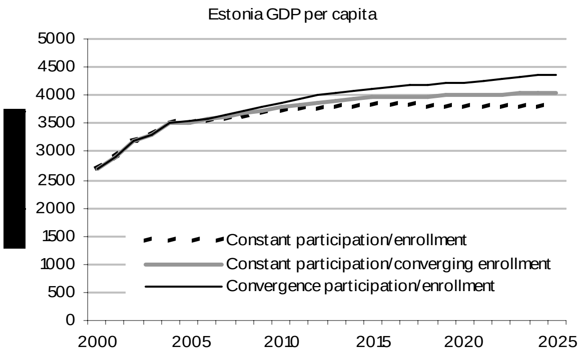


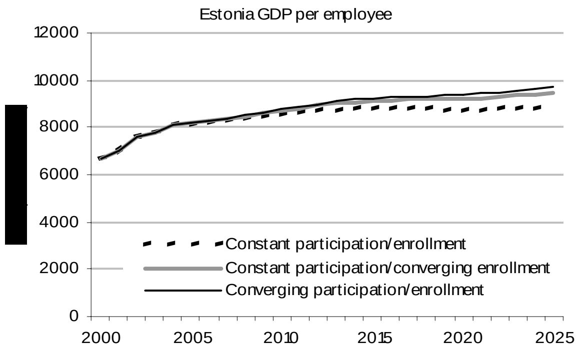

Slovakia GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

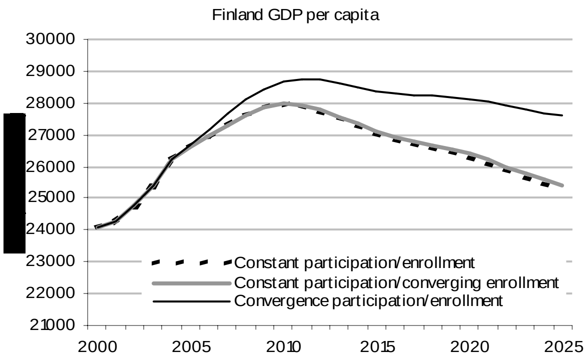

Slovakia GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

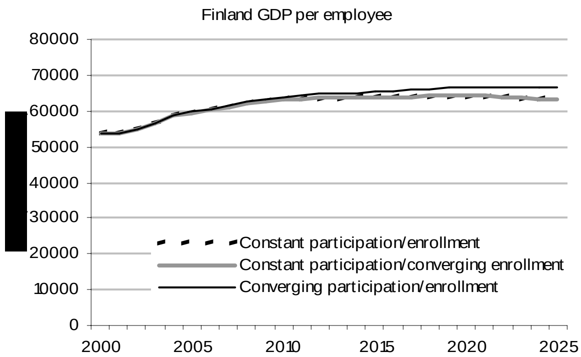

Denmark GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

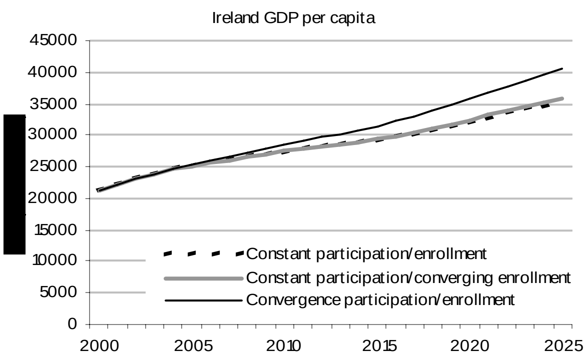

Denmark GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment


Estonia GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

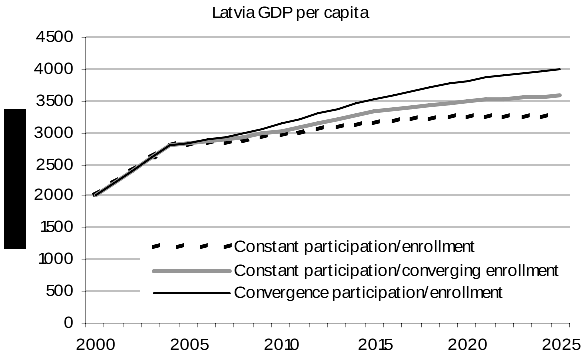

Estonia GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

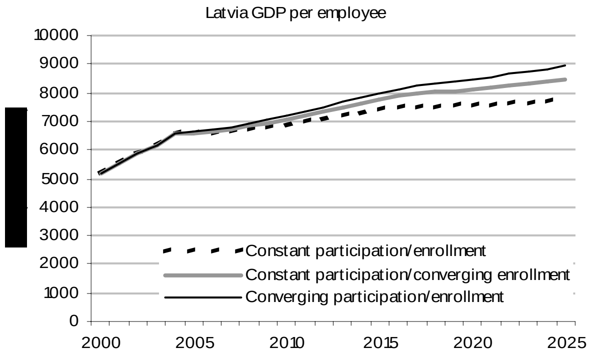

Finland GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

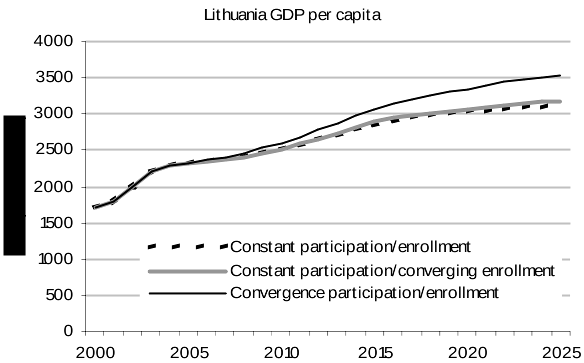

Finland GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment


Ireland GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

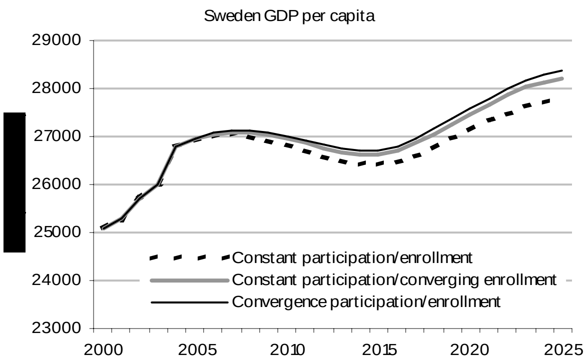

Ireland GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

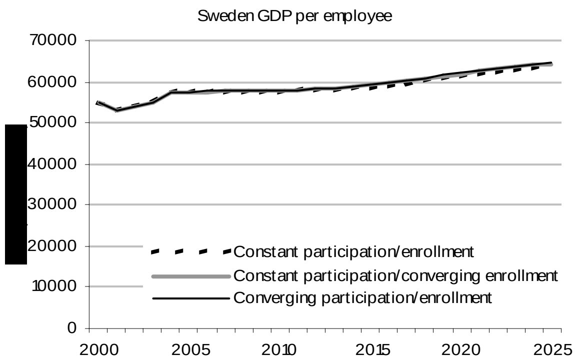

Latvia GDP per capita
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2000
2005
2010
2015
2020
2025
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

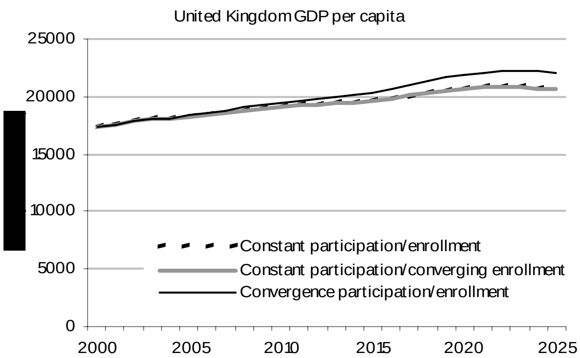

Latvia GDP per employee
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2000
2005
2010
2015
2020
2025
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

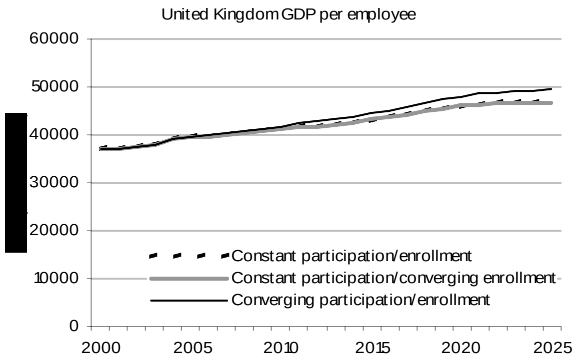

Lithuania GDP per capita
4000
3500
3000
2500
2000
1500
1000
500
0
2000
2005
2010
2015
2020
2025
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

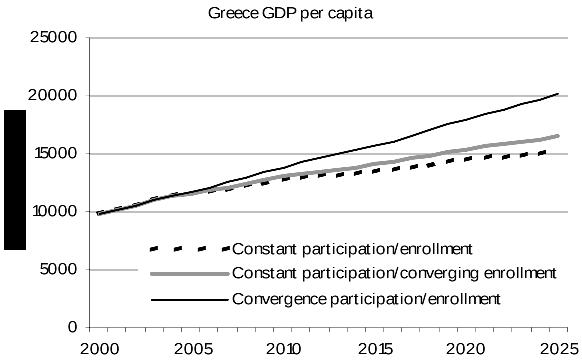

Lithuania GDP per employee
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2000
2005
2010
2015
2020
2025
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

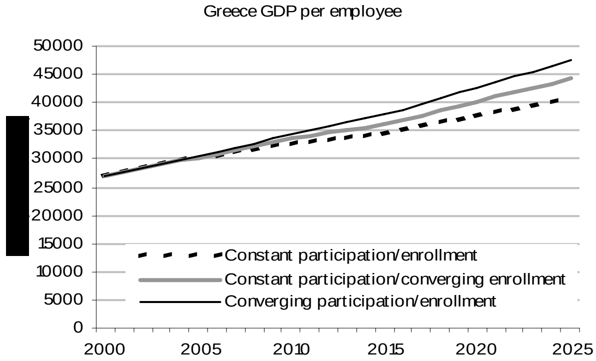

Sweden GDP per capita
29000
28000
27000
26000
25000
24000
23000
2000
2005
2010
2015
2020
2025
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

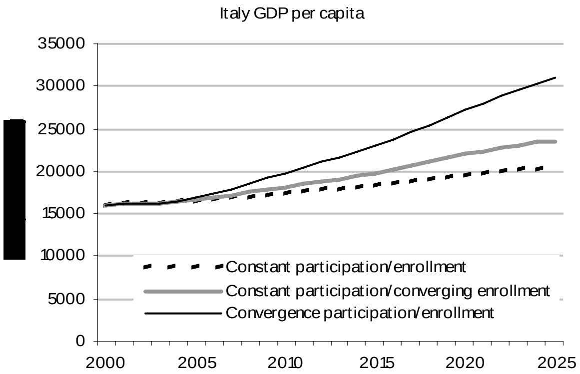

Sweden GDP per employee
70000
60000
50000
40000
30000
20000
10000
0
2000
2005
2010
2015
2020
2025
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

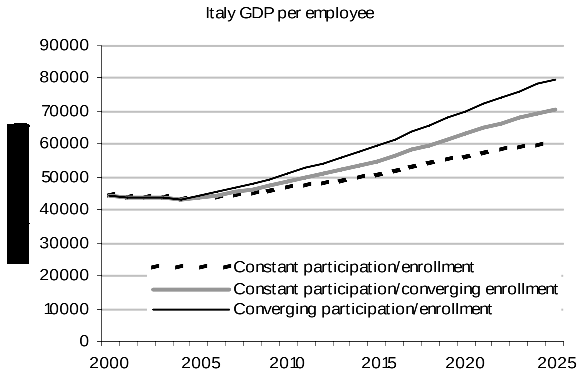

United Kingdom GDP per capita
25000
20000
15000
10000
5000
0
2000
2005
2010
2015
2020
2025
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

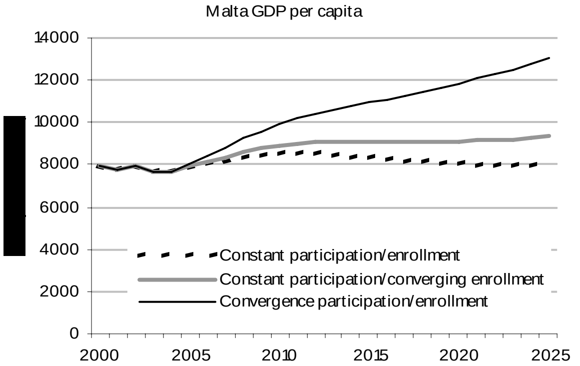

United Kingdom GDP per employee
60000
50000
40000
30000
20000
10000
0
2000
2005
2010
2015
2020
2025
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

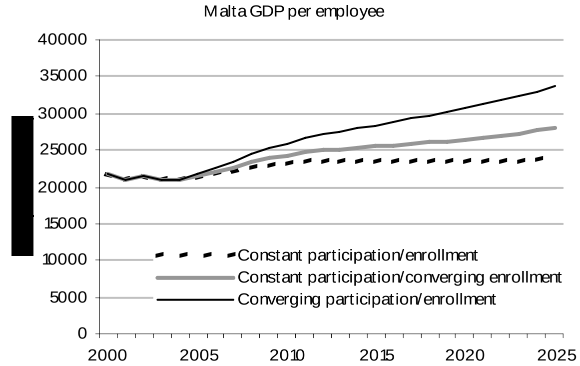

Greece GDP per capita
25000
20000
15000
10000
5000
0
2000
2005
2010
2015
2020
2025
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

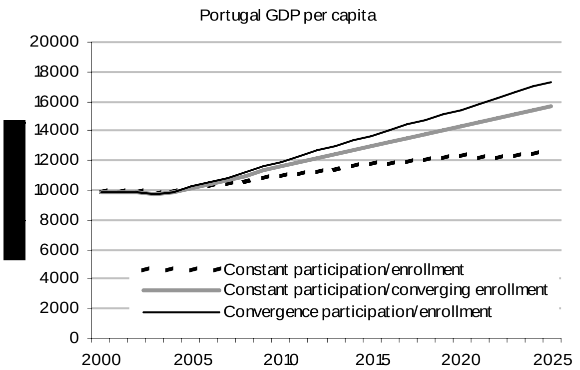

Greece GDP per employee
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
2000
2005
2010
2015
2020
2025
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

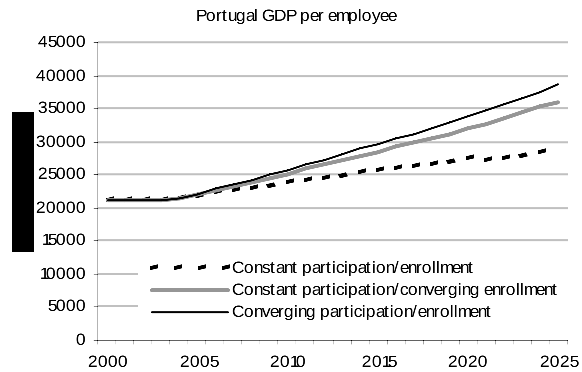

Italy GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

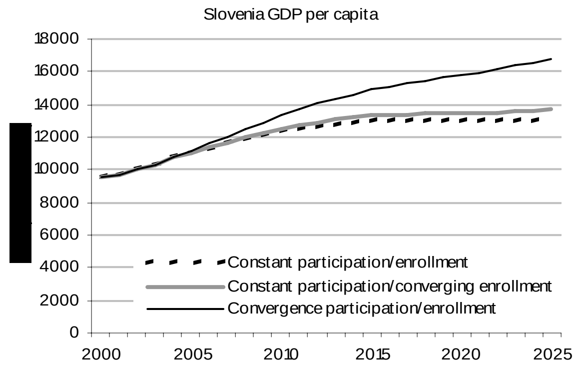

Italy GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

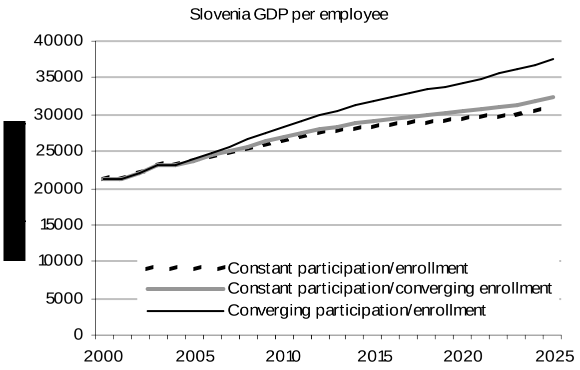

Malta GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

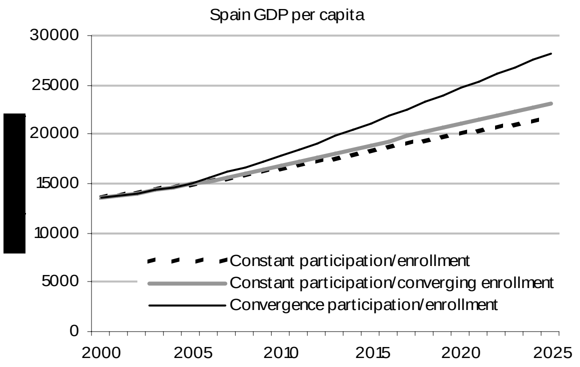

Malta GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

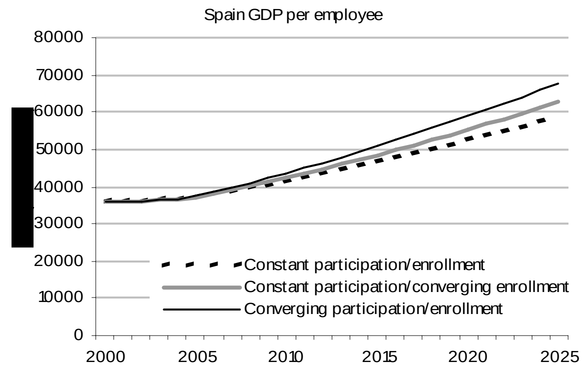

Portugal GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

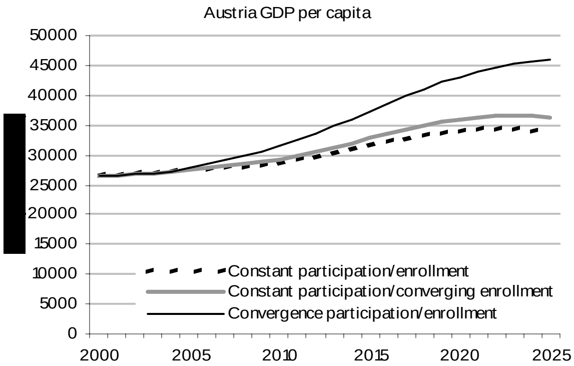

Portugal GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

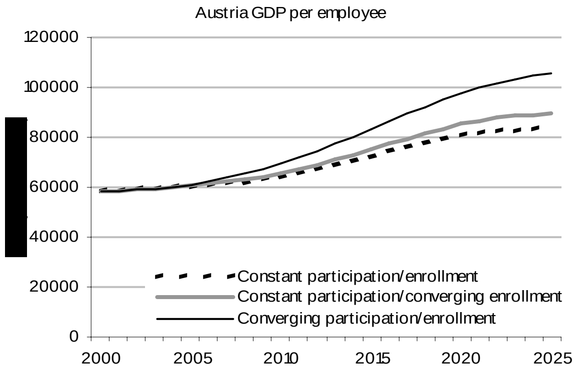

Slovenia GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

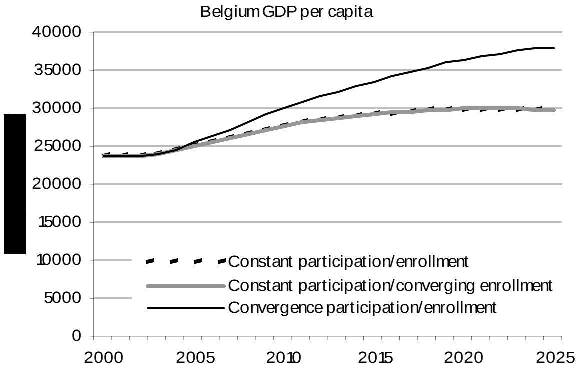

Slovenia GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

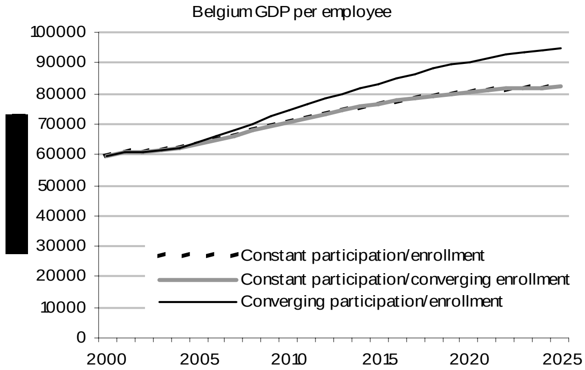

Spain GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

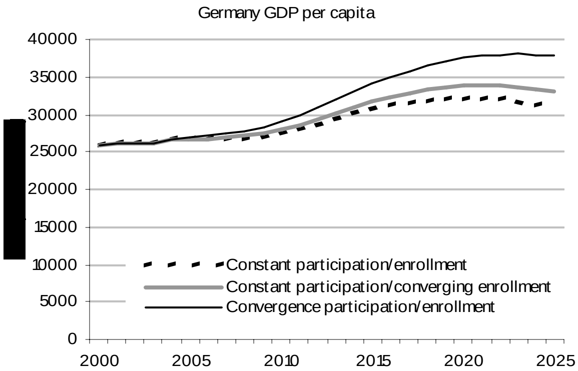

Spain GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

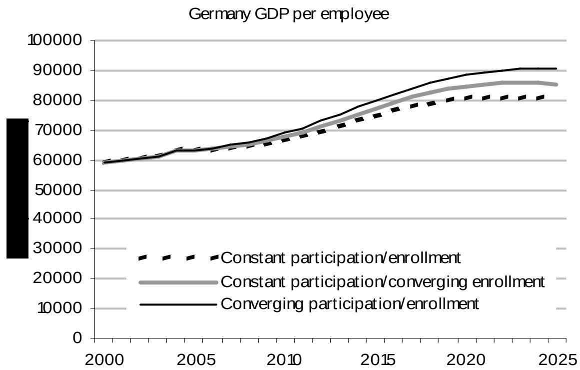

Austria GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

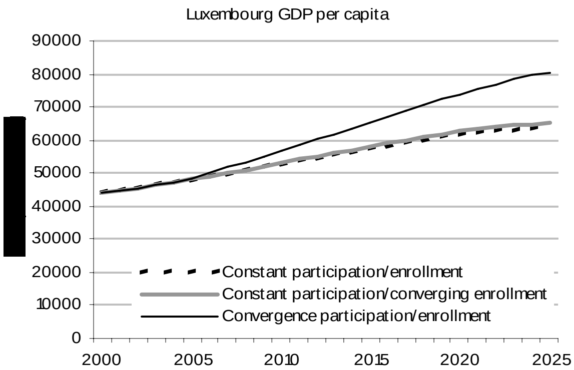

Austria GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

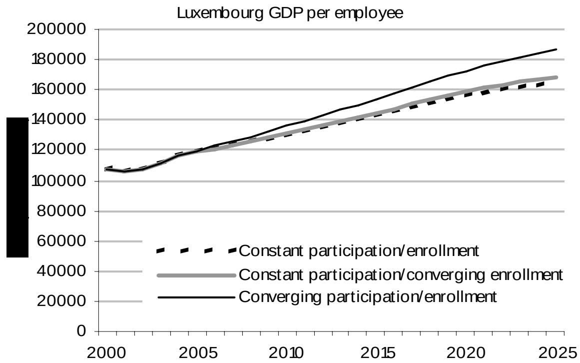

Belgium GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

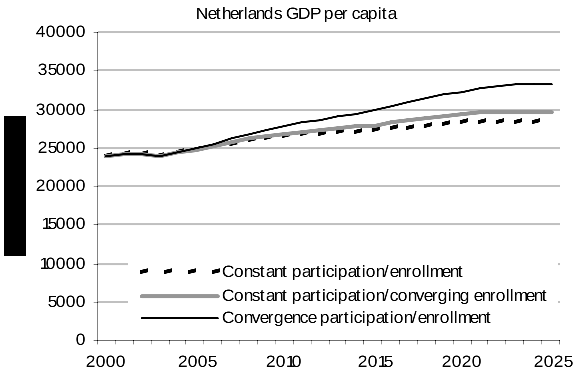

Belgium GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

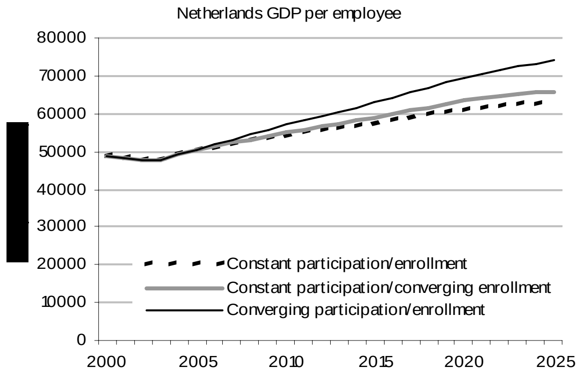

Germany GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment

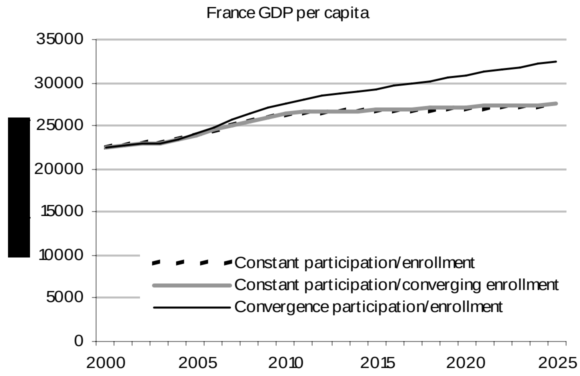

Germany GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment

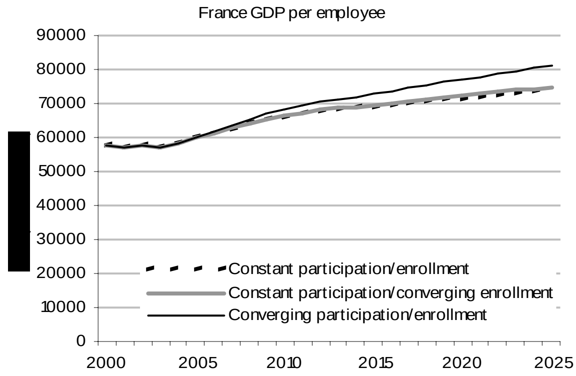

Luxembourg GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment


Luxembourg GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment


Netherlands GDP per capita
Constant participation/enrollment
Constant participation/converging enrollment
Convergence participation/enrollment


Netherlands GDP per employee
Constant participation/enrollment
Constant participation/converging enrollment
Converging participation/enrollment





In Table 7.1 and 7.2 we summarise the contribution of educational and labour force scenarios to **growth in GDP per employee** and **GDP per capita**.

To illustrate how these tables can be read we discuss the results for Austria. We start with Table 7.1 In the **base scenario**, column g, productivity in Austria will grow by 1.9% per year between 2005-2020, decline by 0.2% annually between 2020-2035 and increase by 0.1% per year between 2035 and 2050. The productivity increase between 2005 and 2020 is mainly due to labour force ageing (1.85, column d) and to some extent assisted by rising educational levels (0.2%, column a). Declining productivity growth after 2020 is mainly due to the disappearance of the ageing effect (see column d). In the **educational convergence** alternative, column h, there is higher productivity after 2020 and this difference increases in the last period even further. With **total convergence**, column i, there is also a convergence in participation rates. As shown in column e and f, this implies a large increase on the productivity growth rate for Austria. In the total convergence alternative, Austria will have sustained productivity growth in all three periods (column i).

Table 7.2 focuses on prospects for per capita income given the productivity growth rates presented above. Two new factors enter the determination of per capita income. (1) The share of people in working ages (15-64 years) in the total population, and (2) the employment rate among people in working ages. This can be shown through the following decomposition:

Per capita GDP = GDP per employed * employed / total population
= GDP per employed * (employment rate*working age pop)/total pop
= GDP per employed * employment rate * share of people in working age

In our projections the share of the **working age population** is given from the demographic forecast. For all three periods it gives a negative contribution to per capita growth rates because of an increasing number of elderly (column j). Changes in the age distribution of the working age population will also have an effect since participation rates vary by age. This is shown in column k, for the assumption that **employment rates remain the same**. The effect here will be negative in the first period because of an increase in the 50-64 age group with lower employment rates than the 30-49 year age group. If Austrian **employment rates were to converge** to the higher Swedish level, this negative effect would vanish and indeed turn positive after 2020 (column l). Column n, o, and q, summarise the effects on per capita income growth of the different scenarios. Column n shows the **base scenario** with constant enrolment rates and constant employment rates. The positive effect of rising productivity in the first period (column g, Table 7.1) is reduced here by the decreasing share of the working-age population (column j) and a negative effect of declining employment rates due to workforce ageing (column k). Because of the strong projected productivity growth, per capita income growth rates will stay positive though. This is not the case in the second and third period. Here, weak or negative productivity growth in combination with negative effect of declining working age shares will result in declining per capita income growth rates. In comparison, the total convergence alternative (column q) will give positive per capita income growth in all periods thanks to higher productivity growth (column i) and higher employment rates (column l). The total difference in relation to the base alternative are, as can be seen in column r, substantial.

Table 7.1:
Contributions to annual growth in GDP per employee

		a	b	c	d	e	f	g	h	i
Country	Period	Rising ed. level, constant enrolment	Rising ed. level, converging enrolment	diff (b-c)	Labour force age, constant participa-tion rates	Labour force age, converging participa-tion rates	diff (e-d)	Base GDP/emp (a+d)	Educational convergence (b+d)	Total convergence (b+e)
Austria	2005-2020	0.2%	0.2%	0.0%	1.8%	2.6%	0.8%	1.9%	1.9%	2.8%
Austria	2020-2035	0.2%	0.5%	0.4%	-0.4%	0.3%	0.7%	-0.2%	0.1%	0.9%
Austria	2035-2050	0.0%	0.7%	0.7%	0.1%	0.7%	0.6%	0.1%	0.8%	1.3%
	-									
Belgium	2005-2020	0.4%	0.4%	0.0%	1.2%	1.9%	0.7%	1.6%	1.6%	2.3%
Belgium	2020-2035	0.4%	0.4%	0.0%	-0.4%	0.2%	0.6%	0.0%	0.0%	0.6%
Belgium	2035-2050	0.0%	0.4%	0.4%	0.0%	0.5%	0.4%	0.0%	0.4%	0.8%
	-									
Cyprus	2005-2020	0.5%	0.5%	0.0%	0.7%	1.0%	0.2%	1.2%	1.2%	1.4%
Cyprus	2020-2035	0.5%	0.5%	0.0%	0.4%	0.6%	0.2%	0.8%	0.8%	1.0%
Cyprus	2035-2050	0.0%	0.5%	0.5%	0.4%	0.6%	0.1%	0.4%	0.9%	1.0%
	-									
Czech Republic	2005-2020	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.0%	0.0%	0.4%
Czech Republic	2020-2035	0.0%	0.5%	0.4%	1.6%	1.7%	0.2%	1.6%	2.1%	2.2%
Czech Republic	2035-2050	0.0%	0.6%	0.6%	-0.5%	-0.3%	0.3%	-0.5%	0.1%	0.4%
	-									
Denmark	2005-2020	0.3%	0.3%	0.0%	0.3%	0.6%	0.3%	0.6%	0.6%	0.9%
Denmark	2020-2035	0.3%	0.4%	0.0%	-0.4%	-0.1%	0.3%	-0.1%	0.0%	0.2%
Denmark	2035-2050	0.0%	0.4%	0.4%	0.1%	0.4%	0.3%	0.1%	0.5%	0.8%
	-									
Estonia	2005-2020	-0.1%	-0.1%	0.0%	0.5%	0.7%	0.1%	0.5%	0.5%	0.6%
Estonia	2020-2035	-0.1%	0.3%	0.3%	0.8%	0.8%	0.1%	0.7%	1.0%	1.1%
Estonia	2035-2050	0.0%	0.4%	0.4%	-0.1%	0.0%	0.1%	-0.1%	0.3%	0.4%
	-									

		a	b	c	d	e	f	g	h	i
Country	Period	Rising ed. level, constant enrolment	Rising ed. level, converging enrolment	diff (b-c)	Labour force age, constant participa-tion rates	Labour force age, converging participa-tion rates	diff (e-d)	Base GDP/emp (a+d)	Educational convergence (b+d)	Total convergence (b+e)
Finland	2005-2020	0.3%	0.3%	0.0%	0.2%	0.4%	0.2%	0.5%	0.5%	0.7%
Finland	2020-2035	0.3%	0.3%	0.0%	-0.3%	-0.1%	0.2%	0.0%	0.0%	0.3%
Finland	2035-2050	0.0%	0.3%	0.3%	0.2%	0.4%	0.2%	0.2%	0.5%	0.7%
	-									
France	2005-2020	0.5%	0.5%	0.0%	0.7%	1.1%	0.4%	1.2%	1.2%	1.6%
France	2020-2035	0.5%	0.5%	0.0%	-0.1%	0.2%	0.3%	0.4%	0.4%	0.8%
France	2035-2050	0.0%	0.6%	0.6%	-0.1%	0.2%	0.3%	-0.1%	0.5%	0.8%
	-									
Germany	2005-2020	0.1%	0.1%	0.0%	1.6%	1.8%	0.3%	1.6%	1.6%	1.9%
Germany	2020-2035	0.1%	0.4%	0.3%	-0.8%	-0.5%	0.3%	-0.7%	-0.3%	-0.1%
Germany	2035-2050	0.0%	0.5%	0.5%	0.2%	0.4%	0.2%	0.2%	0.7%	0.9%
	-									
Greece	2005-2020	0.3%	0.3%	0.0%	1.2%	1.6%	0.4%	1.5%	1.5%	1.8%
Greece	2020-2035	0.3%	0.7%	0.4%	1.0%	1.2%	0.2%	1.2%	1.6%	1.9%
Greece	2035-2050	0.0%	0.8%	0.8%	-0.7%	-0.4%	0.3%	-0.7%	0.2%	0.4%
	-									
Hungary	2005-2020	0.1%	0.1%	0.0%	0.0%	0.6%	0.6%	0.1%	0.1%	0.7%
Hungary	2020-2035	0.1%	0.5%	0.4%	1.5%	1.8%	0.3%	1.5%	1.9%	2.2%
Hungary	2035-2050	0.0%	0.6%	0.6%	-0.3%	0.0%	0.3%	-0.3%	0.4%	0.7%
	-									
Ireland	2005-2020	0.5%	0.5%	0.0%	1.4%	1.7%	0.3%	1.8%	1.8%	2.2%
Ireland	2020-2035	0.5%	0.5%	0.0%	1.0%	1.3%	0.3%	1.5%	1.5%	1.8%
Ireland	2035-2050	0.0%	0.5%	0.5%	-0.5%	-0.2%	0.3%	-0.5%	0.0%	0.3%
	-									
Italy	2005-2020	0.2%	0.2%	0.0%	1.5%	2.2%	0.6%	1.7%	1.7%	2.3%
Italy	2020-2035	0.2%	0.9%	0.7%	0.1%	0.6%	0.5%	0.3%	1.1%	1.5%
Italy	2035-2050	0.0%	1.2%	1.2%	-0.6%	-0.2%	0.5%	-0.6%	0.6%	1.0%
	-									
Latvia	2005-2020	0.0%	0.0%	0.0%	1.0%	1.2%	0.3%	0.9%	0.9%	1.2%
Latvia	2020-2035	0.0%	0.5%	0.5%	0.7%	0.9%	0.2%	0.7%	1.2%	1.4%
Latvia	2035-2050	0.0%	0.6%	0.6%	0.3%	0.4%	0.1%	0.3%	0.9%	1.0%
	-									

		a	b	c	d	e	f	g	h	i
Country	Period	Rising ed. level, constant enrolment	Rising ed. level, converging enrolment	diff (b-c)	Labour force age, constant participa-tion rates	Labour force age, converging participa-tion rates	diff (e-d)	Base GDP/emp (a+d)	Educational convergence (b+d)	Total convergence (b+e)
Lithuania	2005-2020	0.2%	0.2%	0.0%	1.4%	1.5%	0.2%	1.6%	1.6%	1.7%
Lithuania	2020-2035	0.2%	0.3%	0.1%	0.4%	0.5%	0.1%	0.6%	0.7%	0.8%
Lithuania	2035-2050	0.0%	0.3%	0.3%	0.9%	0.9%	0.0%	0.9%	1.2%	1.2%
Luxembourg	2005-2020	0.6%	0.6%	0.0%	1.2%	1.7%	0.5%	1.8%	1.8%	2.3%
Luxembourg	2020-2035	0.6%	0.6%	0.1%	-0.1%	0.3%	0.4%	0.5%	0.6%	1.0%
Luxembourg	2035-2050	0.0%	0.7%	0.7%	0.0%	0.3%	0.3%	0.0%	0.7%	1.0%
Malta	2005-2020	0.4%	0.4%	0.0%	0.2%	1.1%	0.9%	0.6%	0.6%	1.5%
Malta	2020-2035	0.4%	1.2%	0.8%	0.8%	1.4%	0.6%	1.2%	2.0%	2.6%
Malta	2035-2050	0.0%	1.5%	1.5%	0.1%	0.5%	0.5%	0.1%	1.6%	2.0%
Netherlands	2005-2020	0.3%	0.3%	0.0%	1.0%	1.6%	0.6%	1.3%	1.3%	1.9%
Netherlands	2020-2035	0.3%	0.5%	0.2%	-0.6%	-0.1%	0.5%	-0.3%	-0.1%	0.5%
Netherlands	2035-2050	0.0%	0.6%	0.6%	0.2%	0.7%	0.5%	0.2%	0.8%	1.3%
Poland	2005-2020	0.3%	0.3%	0.0%	0.6%	1.3%	0.7%	0.9%	0.9%	1.6%
Poland	2020-2035	0.3%	0.4%	0.2%	1.5%	1.8%	0.3%	1.8%	1.9%	2.3%
Poland	2035-2050	0.0%	0.5%	0.5%	0.0%	0.3%	0.3%	0.0%	0.5%	0.8%
Portugal	2005-2020	0.4%	0.4%	0.0%	1.1%	1.5%	0.3%	1.5%	1.5%	1.8%
Portugal	2020-2035	0.4%	1.2%	0.9%	0.7%	1.0%	0.3%	1.1%	1.9%	2.2%
Portugal	2035-2050	0.0%	1.8%	1.8%	-0.7%	-0.3%	0.3%	-0.7%	1.1%	1.4%
Slovakia	2005-2020	0.1%	0.1%	0.0%	0.8%	1.5%	0.6%	0.9%	0.9%	1.5%
Slovakia	2020-2035	0.1%	0.4%	0.4%	1.6%	1.9%	0.3%	1.7%	2.0%	2.4%
Slovakia	2035-2050	0.0%	0.6%	0.6%	0.0%	0.3%	0.3%	0.0%	0.6%	0.9%
Slovenia	2005-2020	0.3%	0.3%	0.0%	1.2%	1.9%	0.8%	1.4%	1.4%	2.2%
Slovenia	2020-2035	0.3%	0.5%	0.2%	0.9%	1.4%	0.5%	1.2%	1.4%	1.9%
Slovenia	2035-2050	0.0%	0.6%	0.6%	-0.5%	0.0%	0.5%	-0.5%	0.1%	0.6%

		a	b	c	d	e	f	g	h	i
Country	Period	Rising ed. level, constant enrolment	Rising ed. level, converging enrolment	diff (b-c)	Labour force age, constant participa-tion rates	Labour force age, converging participa-tion rates	diff (e-d)	Base GDP/emp (a+d)	Educational convergence (b+d)	Total convergence (b+e)
Spain	2005-2020	0.4%	0.4%	0.0%	1.8%	2.2%	0.4%	2.3%	2.3%	2.7%
Spain	2020-2035	0.4%	0.8%	0.3%	1.0%	1.3%	0.2%	1.5%	1.8%	2.0%
Spain	2035-2050	0.0%	0.9%	0.9%	-1.4%	-1.1%	0.4%	-1.4%	-0.6%	-0.2%
Sweden	2005-2020	0.3%	0.3%	0.0%	0.1%	0.1%	0.0%	0.4%	0.4%	0.4%
Sweden	2020-2035	0.3%	0.4%	0.1%	-0.2%	-0.2%	0.0%	0.1%	0.2%	0.2%
Sweden	2035-2050	0.0%	0.4%	0.4%	0.3%	0.3%	0.0%	0.3%	0.7%	0.7%
United Kingdom	2005-2020	0.3%	0.3%	0.0%	0.7%	1.0%	0.3%	1.0%	1.0%	1.3%
United Kingdom	2020-2035	0.3%	0.3%	0.0%	-0.4%	-0.2%	0.3%	-0.2%	-0.2%	0.1%
United Kingdom	2035-2050	0.0%	0.3%	0.3%	0.3%	0.6%	0.2%	0.3%	0.6%	0.8%

Table 7.2:
Contributions to annual growth in GDP per capita

		j	k	l	m	n	o	p	q	r
Country	Period	Share of working age population	Age of working age pop, constant emp rates	Age of working age pop, converging emp rates	Diff	Base GDP/cap (g+j+k)	Edu conv GDP/cap (h+j+k)	Diff edu conv GDP/cap (o-n)	Total conver-gence GDP/cap (i+j+l)	Diff total GDP/cap (q-p)
Austria	2005-2020	-0.2%	-0.3%	0.0%	0.3%	1.4%	1.4%	0.0%	2.6%	1.1%
Austria	2020-2035	-0.9%	0.1%	0.3%	0.2%	-1.0%	-0.6%	0.4%	0.3%	1.3%
Austria	2035-2050	-0.3%	-0.1%	0.2%	0.3%	-0.2%	0.5%	0.7%	1.3%	1.5%
	-									
Belgium	2005-2020	-0.2%	-0.2%	0.3%	0.5%	1.2%	1.2%	0.0%	2.4%	1.2%
Belgium	2020-2035	-0.6%	0.1%	0.5%	0.4%	-0.5%	-0.5%	0.0%	0.5%	1.0%
Belgium	2035-2050	-0.1%	-0.1%	0.4%	0.4%	-0.1%	0.3%	0.4%	1.1%	1.2%
	-									
Cyprus	2005-2020	-0.1%	0.1%	0.6%	0.4%	1.2%	1.2%	0.0%	1.9%	0.7%
Cyprus	2020-2035	-0.3%	0.0%	0.4%	0.4%	0.5%	0.5%	0.0%	1.1%	0.6%
Cyprus	2035-2050	-0.3%	-0.1%	0.4%	0.4%	0.1%	0.5%	0.5%	1.1%	1.0%
	-									
Czech Republic	2005-2020	-0.5%	0.3%	0.5%	0.2%	-0.2%	-0.2%	0.0%	0.3%	0.6%
Czech Republic	2020-2035	-0.3%	-0.3%	0.1%	0.3%	1.1%	1.5%	0.4%	2.0%	0.9%
Czech Republic	2035-2050	-0.9%	0.0%	0.2%	0.2%	-1.4%	-0.8%	0.6%	-0.3%	1.1%
	-									
Denmark	2005-2020	-0.2%	-0.1%	-0.2%	-0.1%	0.3%	0.3%	0.0%	0.5%	0.2%
Denmark	2020-2035	-0.5%	0.1%	0.0%	-0.1%	-0.5%	-0.4%	0.0%	-0.2%	0.2%
Denmark	2035-2050	0.1%	0.0%	-0.1%	-0.1%	0.2%	0.6%	0.4%	0.8%	0.6%
	-									
Estonia	2005-2020	-0.3%	0.3%	0.6%	0.2%	0.5%	0.5%	0.0%	0.9%	0.4%
Estonia	2020-2035	-0.2%	-0.2%	0.1%	0.3%	0.3%	0.7%	0.3%	1.0%	0.7%
Estonia	2035-2050	-0.5%	0.0%	0.3%	0.2%	-0.6%	-0.2%	0.4%	0.1%	0.7%
	-									

Country	Period	j Share of working age population	k Age of working age pop, constant emp rates	l Age of working age pop, converging emp rates	m Diff	n Base GDP/cap (g+j+k)	o Edu conv GDP/cap (h+j+k)	p Diff edu conv GDP/cap (o-n)	q Total conver-gence GDP/cap (i+j+l)	r Diff total GDP/cap (q-p)
Finland	2005-2020	-0.5%	0.0%	0.1%	0.2%	-0.1%	-0.1%	0.0%	0.3%	0.4%
Finland	2020-2035	-0.4%	0.0%	0.2%	0.2%	-0.3%	-0.3%	0.0%	0.0%	0.4%
Finland	2035-2050	0.0%	0.0%	0.1%	0.2%	0.2%	0.5%	0.3%	0.8%	0.7%
France	2005-2020	-0.3%	-0.1%	0.3%	0.4%	0.8%	0.8%	0.0%	1.6%	0.8%
France	2020-2035	-0.4%	0.0%	0.4%	0.4%	0.0%	0.0%	0.0%	0.7%	0.7%
France	2035-2050	-0.2%	0.0%	0.4%	0.3%	-0.2%	0.4%	0.6%	1.0%	1.2%
Germany	2005-2020	-0.2%	-0.2%	0.2%	0.4%	1.3%	1.3%	0.0%	1.9%	0.6%
Germany	2020-2035	-0.8%	0.1%	0.4%	0.3%	-1.5%	-1.1%	0.3%	-0.5%	0.9%
Germany	2035-2050	0.0%	-0.1%	0.2%	0.3%	0.0%	0.6%	0.5%	1.1%	1.1%
Greece	2005-2020	-0.1%	0.1%	0.7%	0.6%	1.5%	1.5%	0.0%	2.4%	1.0%
Greece	2020-2035	-0.5%	-0.2%	0.4%	0.6%	0.6%	1.0%	0.4%	1.8%	1.2%
Greece	2035-2050	-0.7%	0.0%	0.5%	0.5%	-1.3%	-0.5%	0.8%	0.3%	1.6%
Hungary	2005-2020	-0.3%	0.2%	0.8%	0.6%	0.0%	0.0%	0.0%	1.2%	1.2%
Hungary	2020-2035	-0.3%	-0.2%	0.5%	0.7%	1.1%	1.5%	0.4%	2.5%	1.4%
Hungary	2035-2050	-0.7%	0.0%	0.5%	0.5%	-1.0%	-0.4%	0.6%	0.4%	1.5%
Ireland	2005-2020	-0.2%	0.0%	0.3%	0.3%	1.7%	1.7%	0.0%	2.3%	0.6%
Ireland	2020-2035	-0.2%	-0.1%	0.2%	0.3%	1.1%	1.1%	0.0%	1.7%	0.6%
Ireland	2035-2050	-0.7%	0.1%	0.3%	0.3%	-1.1%	-0.6%	0.5%	-0.1%	1.0%
Italy	2005-2020	-0.3%	-0.3%	0.4%	0.7%	1.1%	1.1%	0.0%	2.4%	1.3%
Italy	2020-2035	-0.8%	-0.1%	0.6%	0.6%	-0.6%	0.2%	0.7%	1.2%	1.8%
Italy	2035-2050	-0.5%	0.1%	0.5%	0.5%	-1.1%	0.1%	1.2%	1.0%	2.1%
Latvia	2005-2020	-0.2%	0.2%	0.5%	0.3%	1.0%	1.0%	0.0%	1.5%	0.5%
Latvia	2020-2035	-0.3%	-0.2%	0.2%	0.3%	0.2%	0.7%	0.5%	1.2%	1.0%
Latvia	2035-2050	-0.7%	0.0%	0.3%	0.3%	-0.5%	0.2%	0.6%	0.6%	1.1%

		j	k	l	m	n	o	p	q	r
Country	Period	Share of working age population	Age of working age pop, constant emp rates	Age of working age pop, converging emp rates	Diff	Base GDP/cap (g+j+k)	Edu conv GDP/cap (h+j+k)	Diff edu conv GDP/cap (o-n)	Total conver-gence GDP/cap (i+j+l)	Diff total GDP/cap (q-p)
Lithuania	2005-2020	0.0%	0.2%	0.5%	0.4%	1.8%	1.8%	0.0%	2.3%	0.5%
Lithuania	2020-2035	-0.5%	0.0%	0.4%	0.4%	0.1%	0.2%	0.1%	0.7%	0.6%
Lithuania	2035-2050	-0.5%	-0.2%	0.3%	0.4%	0.2%	0.5%	0.3%	1.0%	0.8%
Luxembourg	2005-2020	0.1%	-0.2%	0.3%	0.5%	1.7%	1.7%	0.0%	2.7%	1.0%
Luxembourg	2020-2035	-0.5%	0.0%	0.5%	0.5%	0.1%	0.2%	0.1%	1.0%	0.9%
Luxembourg	2035-2050	-0.2%	0.0%	0.4%	0.5%	-0.2%	0.5%	0.7%	1.3%	1.5%
Malta	2005-2020	-0.5%	0.0%	0.8%	0.7%	0.1%	0.1%	0.0%	1.8%	1.6%
Malta	2020-2035	-0.3%	-0.1%	0.6%	0.7%	0.7%	1.5%	0.8%	2.8%	2.1%
Malta	2035-2050	-0.4%	0.0%	0.6%	0.6%	-0.4%	1.1%	1.5%	2.2%	2.6%
Netherlands	2005-2020	-0.3%	-0.2%	-0.1%	0.0%	0.9%	0.9%	0.0%	1.5%	0.6%
Netherlands	2020-2035	-0.7%	0.1%	0.1%	0.0%	-0.9%	-0.7%	0.2%	-0.1%	0.8%
Netherlands	2035-2050	0.0%	0.0%	0.0%	0.0%	0.2%	0.8%	0.6%	1.3%	1.1%
Poland	2005-2020	-0.3%	0.3%	1.2%	0.8%	0.9%	0.9%	0.0%	2.5%	1.6%
Poland	2020-2035	-0.3%	-0.3%	0.6%	0.9%	1.1%	1.3%	0.2%	2.6%	1.4%
Poland	2035-2050	-0.9%	0.0%	0.7%	0.7%	-0.9%	-0.4%	0.5%	0.6%	1.5%
Portugal	2005-2020	-0.2%	0.0%	0.1%	0.1%	1.3%	1.3%	0.0%	1.8%	0.5%
Portugal	2020-2035	-0.5%	-0.1%	0.1%	0.2%	0.4%	1.3%	0.9%	1.7%	1.3%
Portugal	2035-2050	-0.6%	0.0%	0.1%	0.1%	-1.2%	0.6%	1.8%	1.0%	2.2%
Slovakia	2005-2020	-0.2%	0.2%	0.8%	0.5%	1.0%	1.0%	0.0%	2.1%	1.2%
Slovakia	2020-2035	-0.4%	-0.3%	0.4%	0.7%	1.0%	1.4%	0.4%	2.4%	1.3%
Slovakia	2035-2050	-0.9%	-0.1%	0.5%	0.5%	-1.0%	-0.4%	0.6%	0.5%	1.4%
Slovenia	2005-2020	-0.4%	0.0%	0.3%	0.2%	1.1%	1.1%	0.0%	2.1%	1.0%
Slovenia	2020-2035	-0.6%	-0.3%	0.1%	0.4%	0.3%	0.5%	0.2%	1.4%	1.1%
Slovenia	2035-2050	-0.7%	0.1%	0.3%	0.2%	-1.2%	-0.6%	0.6%	0.1%	1.3%

		j	k	l	m	n	o	p	q	r
Country	Period	Share of working age population	Age of working age pop, constant emp rates	Age of working age pop, converging emp rates	Diff	Base GDP/cap (g+j+k)	Edu conv GDP/cap (h+j+k)	Diff edu conv GDP/cap (o-n)	Total conver-gence GDP/cap (i+j+l)	Diff total GDP/cap (q-p)
Spain	2005-2020	-0.3%	0.0%	0.6%	0.6%	2.0%	2.0%	0.0%	3.0%	1.0%
Spain	2020-2035	-0.6%	-0.3%	0.3%	0.6%	0.6%	0.9%	0.3%	1.8%	1.2%
Spain	2035-2050	-1.1%	0.2%	0.6%	0.4%	-2.3%	-1.4%	0.9%	-0.7%	1.6%
	-									
Sweden	2005-2020	-0.4%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%
Sweden	2020-2035	-0.3%	0.0%	0.0%	0.0%	-0.2%	-0.1%	0.1%	-0.1%	0.1%
Sweden	2035-2050	0.0%	0.0%	0.0%	0.0%	0.2%	0.6%	0.4%	0.6%	0.4%
	-									
United Kingdom	2005-2020	-0.1%	-0.1%	0.0%	0.1%	0.8%	0.8%	0.0%	1.2%	0.3%
United Kingdom	2020-2035	-0.5%	0.0%	0.1%	0.1%	-0.6%	-0.6%	0.0%	-0.3%	0.3%
United Kingdom	2035-2050	0.0%	-0.1%	0.0%	0.1%	0.3%	0.6%	0.3%	0.9%	0.6%

8 Conclusion

What an ageing workforce will mean for future European productivity growth depends on what we mean by productivity. We have followed the common convention and defined the concept as **value added based labour productivity**, and we argue that productivity is a **system attribute** rather than a property in the individual inputs.

Reviewing trends in EU aggregate productivity growth over the periods 1979-1990, 1990-1995 and 1995-2001 indicates that the EU productivity growth fell behind US growth rates in the second half of the 1990s and at the same time within-EU disparities of productivity growth increased. This has spread concern, in particular with a view to the future when European welfare systems will be forced by demographics to finance the care and support of a much larger elderly non-working population. The focus of our report is to address the concern that an older workforce will make this task even more difficult than it already is. The main original contribution of our study is a micro-meso analysis at the firm/plant level of the relation between productivity and the age and educational composition of the workforce in Sweden and Austria. This is set within the framework of a comprehensive survey of both macro and micro studies, relating to aggregate productivity as well as individual productivity and its dependence on technological and social context.

Since the Lisbon target not only relates to productivity growth but also aims to raise employment rates and to improve labour market performance, our report also summarises **trends in labour force structure** in the past and discusses future projections of productivity growth as they will depend on alternative projections of the labour force. Our study on five OECD countries (France, UK, Germany, Spain and US) clearly indicates that decreases/increases in the crude labour force rate (the total labour force divided by the population of working age) for males/females between 1985 and 2000 were dominated by changes in age-specific labour force participation rates (as opposed to changes in the age distribution of the total population). Our study indicates that there is considerable scope for attenuating labour force ageing and labour force shrinkage through policy interventions aimed at changing labour force participation rates. Of course, for countries where labour force participation rates for women and men are already high the margin for such behavioural changes is smaller than for countries still faced with low female and male participation rates. Regarding the EU-15 as a whole, the largest potential to raise overall employment lies within those countries with lower employment rates and/or larger working-age populations. Low employment rates in the new member states strengthen the challenge towards the Lisbon target while their larger growth potential may facilitate these aims.

Static comparative analysis implies that employment and productivity growth are negatively related (arguing that less productive and less skilled people are integrated in the workforce), but the long-run effect of boosting employment is argued to be positive, not least from a fiscal perspective since it broadens the tax base. The much discussed “jobless growth” phenomenon may, however, be peculiar to how the labour market reacts to the age composition of the working population. The result from Sweden in chapter 6.1 of this report, which shows that the expansion of the group 50-59 years old on local labour markets depresses employment and enhances productivity, is a clear indication that matching processes on the labour market are crucial for the relation. Since the results at the plant level indicate that this group is less positive for productivity than the 30-49 age group, this apparent contradiction is an important challenge for future research to illuminate in more detail. There are non-trivial estimation problems with these results, first and foremost the fact that plants will adapt their age structure in order to achieve desired productivity, thus variation in age structure is not an independent determinant of productivity at the plant level. Interpreting the estimated effects as direct causal factors for plant productivity may therefore be problematic. However, in the case of local labour market results this can be controlled for. Our attempts to assess the problem in the Swedish panel estimations point in the direction that it is unlikely to be a serious problem for those estimates as well.

While the relation between age and individual productivity is less clear-cut, there has been recent evidence of a significant relation between changes in the adult population and aggregate productivity at the **macro level**. Based on recent empirical findings which have shown that input accumulation cannot explain the majority of cross-country differences in output per worker and hence total factor productivity (TFP) must account for the differences, various studies have tested **whether demographics do exert an influence on TFP**. Empirical evidence based on pooled cross-country data over the period 1960-1990 indicates that workers aged 40-49 have a large positive effect on productivity (as measured by the Solow residual). A study based on Japanese industries, however, indicates that the positive effect of educated workers older than 40 on technological progress turned from positive in the 1980s to negative in the 1990s. The higher rate of technological change and capital-biased technological change during the 1990s may have shifted the productivity peak towards younger ages, opening for the speculation that it may shift again as this slows down with the maturation of ICT technologies..

An important **cause of age-related productivity declines** for individuals is likely to be age-specific reductions in **cognitive abilities**. Some abilities, such as perceptual speed, show relatively large decrements already from a young age, while others, like verbal abilities, exhibit only small changes throughout the working life. **Experience** boosts productivity up to a point beyond which, however, additional tenure has little effect. Ageing implies that one learns at a slower pace and has reductions in memory and reasoning abilities. In particular, senior workers are likely to have difficulties in adjusting to new ways of working. This is often compounded by socially suboptimal firm choices and institutional arrangements that give few incentives to invest in training when there are few years remaining in the work life.

Earlier studies tend to neglect the causes of age-related job performance differences and the impact of **changing labour market demands** when measuring age differences in productivity. In this report we **estimate the productivity potential by weighing age-specific ability levels against the labour market demand for these abilities**. Evidence from both employment shifts between industries and changes caused by relative wage levels of unskilled and skilled employees suggests that there has been an increase in the demand for cognitive abilities over a long period of time. Physical strength and bodily coordination have lost much of their importance, while analytic, numerical and interpersonal abilities are increasingly in demand. Basing the estimates on the causes of productivity differences allows an assessment of the impact of structural changes in the labour market. The **age-productivity profile** is found to vary over time, in accordance with changing labour market needs (see Section 5.4, Figure 5.6 of this report). Assuming a reasonably strong effect of experience, we estimate that **individual productivity peaks for the 35-44 year old age group**. If having long experience becomes less relevant and the ability to learn and adjust becomes more important, the productivity peak shifts towards younger ages. Conversely, if the minimum ability requirement should drop over time, age differences in productivity would decrease. The estimations of the productivity profile reflect that job performance on average tends to decrease in the second half of the working life, given almost any calibration of the model. The only exception to this would be if an individual's productivity gains from experience continues for several decades and if this effect more than outweighed the functional decreases with respect to other job-related factors. Given available empirical evidence on how additional work experience affects productivity, this may seem unlikely. Hence, these findings support the theory of delayed payment contracts, where the relatively high wages of older workers create loyalty to the firm and represent a compensation for high productivity earlier in the career. Since other employers would be unwilling to pay for this compensation such a seniority pay scheme also obstructs reallocation of elderly people and may constitute a barrier for the optimal use of elderly labour.

As these various studies on age-productivity differentials show, productivity is a system attribute and cannot be understood in isolation of its social context. However, the hump-shaped pattern of age-productivity differentials seems to be ubiquitous across various studies although there is considerable variation in the exact age of the peak. Our own studies on Austrian and Swedish data are no exceptions in this respect. To investigate **the relation between age and productivity**, taking into account firm-level-specific factors, we refer to **two matched employer-employee data sets** (a longitudinal one in Sweden and a recently generated cross-sectional one in Austria).

Summing up the micro evidence from **Swedish mining and manufacturing**, we find a **hump shape in the age effects on productivity** where the peak is estimated to lie **in the age group 30-49**. **Education** quite clearly has substantial effects on productivity and for the purpose of this report indicates that even if an ageing workforce would tend to become less productive **this can very likely be compensated in the long run by increased education of the future workforce**. We also find that, possibly due to good matching in the **local labour market**, overall productivity improves when there are higher numbers of 50-59 years old. As a general rule, young people are much more mobile and searching for good job matches. Ageing of the workforce also implies that appropriate job matches for its older members are achieved to a higher extent. There are considerable costs associated with hirings and separations—not least in terms of low productivity during the first time on a new job, Note that such an effect is necessarily temporary since ageing sooner or later destroys the good match either by decreased capacity of the employee, retirement or by technological change making the match obsolete.

Thus another tentative conclusion with respect to the purpose of this report is that well-functioning **labour markets** may be just as crucial as education for maintaining productivity and maybe especially so with an ageing workforce. Results on **worker and job**

flows for manufacturing establishments in Sweden with 50 or more employees between 1986/87 to 1995/96 shows that many more jobs were created and destroyed than needed to match the net change in employment. We found a sharp decline in employment for those with the lowest education while net employment on average rose for those with a university degree. Similarly, job creation rates for those with higher education were more than twice as high as for those with only a pre-upper secondary educational level. Job and worker flows by age groups indicate that employment among the oldest workers fell rather dramatically during the whole period and almost no jobs were created for oldest workers.

The cross-sectional firm-level analysis for **Austrian mining and manufacturing** enterprises gave similar findings as the Swedish data set, as well as the estimates based on causal variation in productivity and findings from earlier studies presented in the review section. The age-productivity curve shows a **hump-shaped pattern with a peak for mid-life workers in ages 30-49**. Similar to the Swedish results, the productivity dispersion is much wider than wage dispersion and there is hardly any relation between a firm's productivity and the average wage level in that firm. Regression of value added per worker on age and gender shares indicates a hump-shaped pattern for the age variable, i.e., firms in which the share of younger or older workers is higher, have a lower productivity compared to firms where the share of the middle age group is higher. By adding firm-specific factors like the size and age of the firm, etc. we still find a hump-shaped pattern of the age profile. Once we include the occupational structure and the part-time share of workers in firms as additional control variables, the hump-shaped pattern of age on productivity is further reduced. Splitting the sample into two subsamples of **small** (less than 50 employees) versus **large firms** (50 or more employees) yields different conclusions than found for Sweden. For small-sized firms the results on the age pattern and other covariates are similar as for the whole sample. By contrast, age variables become all but insignificant in the sample containing only large firms. This means that **no clear pattern of age can be observed in large firm**s. From these results one might conjecture that large-sized firms—through their workers' councils—restrict worker flows more than in Sweden. But another, possibly related, reason could be that large-sized firms, because of their market power, are not that much forced to optimise the age structure of their staff. The Austrian data set allows decomposing firms by type of industry. We find **no age pattern on productivity for ICT producing industries**, a **weak age pattern for ICT using industries** and a **hump shaped age profile for all remaining industries**. These results lend support to the hypothesis that other factors of production (e.g., ICT capital) are more important than the age structure of employees for ICT producing firms.

Based on our analysis of plant data for the Swedish manufacturing (which showed that both age structure and educational structure of the workforce have statistically significant effects on productivity), we conduct a **prospective analysis** on workforce change and productivity in the last part of the report. If these Swedish patterns are valid in the wider EU context, and our analysis indicate that they may be, the **average prospects for productivity growth are not bad for the next 15 years**. **After 2025, though, there is a risk for stagnation if participation rates and education enrolment rates remain at current levels**. Rising enrolment rates alone are not enough to secure a long-run growth in GDP per capita since the high growth rate of the non-working age population dominates. **Only by increasing**

labour force participation rates, a productivity growth of the European economy will be possible. On average our results indicate that between 2005 and 2025 growth rates of labour productivity may rise from slightly below one per cent to over two per cent by raising participation rates to the best-practice level. To maintain growth after that requires raising education rates also to the best-practice levels. The effect will be even stronger on per capita income growth since the number of employed in relation to the total population will increase as well, in addition to rising productivity levels.

Depending on current participation rates and educational attainment rates, and on differences in age structure, the national trends will differ. For instance, in **Sweden** the increase in educational levels will help to increase GDP per capita during the next years but this may not be enough for continued increase. Labour force participation rates are already high in Sweden and the growth potential that operates through increased labour force participation is therefore more difficult to achieve for Sweden. On the other extreme, **Austria** has a very high educational level but labour force participation rates among older workers are among the lowest in the EU. The growth potential with respect to labour market reforms aimed at increasing the participation rates is therefore high for Austria. For **Italy**, both policies (increasing educational levels and labour force participation) are timely and would help to increase GDP per capita over the next decades.

While many questions are still unanswered this study points out some clear directions for future policy discussion in this area. **First**, it confirms the common belief that raised education levels are important for maintaining growth in ageing economies, but it also indicates that for reasonable levels of education to be attained the delay in productivity effects is quite substantial, as in most cases appreciable effects do not occur until twenty years after initiation of such efforts. In many countries labour force participation rates offer a much faster road to increased productivity growth.

Increasing education levels can provide an important stimulus for European productivity growth. The micro-level results that we present here indicate that an **increase of one year in the mean length of education can give as much as a 20% increase in productivity**. Using this result to explain growth rates confirms that the rate of increase in the educational level of the labour force can explain a substantial part of the GDP performance in many EU countries since the early 1990s. Increasing enrolment levels in those EU countries which lag behind with respect to education could therefore help to improve economic performance. But conditions differ vastly between countries, average length of education being nearly twice as long in for example Germany as in Portugal. The catch-up potential as judged from current enrolment rates also varies considerably among the EU members.

From the **Swedish mining and manufacturing data**, however, there are indications that **education at the tertiary level may have decreasing returns**. This prompts the caution that going beyond current best-practice levels may yield disappointing returns. There is, of course, a problem when education tends to expand at the expense of the effective working life. A window of opportunity may be to increase the efficiency of education in such a way that the same quantity of productive human capital requires less years of schooling. How large that window may be is uncertain but the length of tertiary education to formally identical levels is achieved at vastly different ages in the EU. Since the length of education has also started to infringe upon the prime fertility period and thus potentially threatens the reproduction of the population the potential for **a more efficient education** becomes ever more important to investigate.

Our measures in terms of attainment levels in education also do not take into account most of the training and education that takes part later in life as part of personnel programs or re-schooling programs, making it difficult to assess its importance. Again, however, if employees are investing in future human capital it must carry a cost in terms of actually produced value added. Hence, while education undoubtedly constitutes one of the major prerequisites to sustain productivity growth by increasing human capital, there are also trade-offs to consider like in any other investment plan.

Second, the study shows that productivity growth is a more complex phenomenon than just adding up the individual capacity of the available labour supply. Individual productivity age profiles vary with the technological context and content of the work. **Industrial restructuring and reallocation of labour within the current social context is quite likely to be quantitatively much more important than the age composition of labour per se.** Matching properties of the labour market that depend to a very high degree on idiosyncrasies of national labour market institutions most likely are important in order to explain differences between the Swedish and Austrian results, e.g., the difference in productivity age profiles for large and small firms. The Swedish results at the local labour market level (that 50-59 year old persons are associated with high productivity but with high unemployment as well) also indicate that such properties may be directly crucial for the explanation of "jobless growth" and, combined with macro evidence, indicate that ageing may enhance productivity growth at the national level in spite of individual productivity peaking at middle age.

We should also emphasise that we do not take into account the possibility that there could exist bifurcation points, where for example having a slightly lower aggregate output could lead to large negative effect. Finally, start-ups (as the General Entrepreneurship monitor suggests) and innovation seem to be carried out to a large extent by individuals below age 40. Hence, ageing could have different effects than what we foresee in this analysis.

While there are many questions left to resolve by future research these results indicate that heterogeneity within the EU is pervasive with respect to what measures different member states need to take in order to ensure future productivity growth.

If, as this study indicates, reallocation of jobs and workers across industries, firms, plants and places are crucial to the productivity performance of the population in ageing economies, then serious issues are raised with respect to current EU policies for social, industrial and regional protection. **Alleviating the problems caused by declining industries or regions by subsidies that prevent this reallocation may then carry a very high cost for the future sustainability of European welfare**. Lock-in mechanisms in the labour market designed for social security today may undermine the social security of the future. From our results we can only raise this issue and not prescribe how to avoid it. Due to a lack of data on previous labour flows, the workings of these reallocation mechanisms are still uncharted research territory where knowledge is scarce and opinions are many.

Comparative research in this area is still underdeveloped but attracting more and more attention. Our study demonstrates that a better understanding of the matching processes at the labour market is crucial for the formulation of sustainable industrial and labour market policies.

Third, one main conclusion of this report is **rising labour force participation in conjunction with increasing education levels can alleviate the negative effects of population ageing**. In this respect, the report points to a clear-cut policy agenda, where increased female labour force participation (at least for some countries) and a reversal of the trend of declining participation rates among older workers becomes one of the most important means for the EU to be able to meet the increasing needs of old-age people.

However, the empirical evidence underlying this conclusion is not clear-cut when it comes to the effect on productivity of an older workforce. Studies of productivity on the individual level and on cross-sections of firm data indicate that old workers may have a lower productivity than workers in younger age groups. Such results may have been important in supporting policies of early retirement in the 1980s and 1990s, under the slogan of "leaving room for the young". This is an incorrect argument, as there is no evidence that decreasing retirement ages have increased labour market participation of the young. Furthermore, even if individual productivity in a specific job should drop by age, this does not imply that a higher proportion of older workers has a negative effect on aggregate productivity. This is so for a number of reasons: older workers may change the tasks they do, their presence may affect the productivity of younger workers, they use more capital, etc. Therefore the large flows from worker to pensioner status are not justified from a productivity-maximising point of view. Moreover, as we have shown there are indications that the effects from the composition of the workforce cannot be evaluated by simply adding up these age profiles for individuals. The Swedish study which followed plants over time indicate that **older workers may be nearly as productive as prime-aged workers and clearly more productive than the youngest workers**. Our results at the level of local labour markets point out high shares of 50-59 years old as the **only age group** with important effects on productivity. If these results are correct, policies of early retirement might have been disastrous for the aggregate productivity of European firms. The **evidence gathered in this report clearly justifies that productivity will increase if labour force participation increases.**

How should these seemingly contradictory results be weighed? From a statistical point of view, studies using panel data and local labour market data are preferable since they are, at least to some extent, capable of controlling for some endogeneity in the age structure of firms. Thus, for instance, high-productivity firms can have many young workers because they are expanding, not because high shares of young workers are more productive. In a cross-section it is close to impossible to achieve any efficient control for this direction of causality. Control variables may help but the results will remain open to interpretation since the controls themselves are correlated with the age composition. The results presented in this report should therefore at least serve as **a warning that earlier assumptions of low productivity effects from older workers might have been incorrect, even though further research is needed to establish whether this is a fact or an artefact of some other statistical difficulty**.

Moreover, even if it were the case that older workers have a lower productivity, raising participation rates would still increase per capita income simply because the **elderly earn their own keep to a larger extent**. However small their contribution to value added it would still be positive, and, from a fiscal viewpoint increase the revenues rather than the expenditures. Only if they actually crowded out younger more productive persons would it pay (if productivity of the young is indeed sufficiently much higher) to buy them out of production, as it were. It hardly needs to be pointed out that for the firm, productivity of the young need not even be higher than for the old workforce members since they are paid less (especially if there are seniority pay scales), so the social optimum will in this case clearly be different from the market solution. A decrease in differential treatment by age that does not reflect productivity differences; phasing out fixed retirement ages and shifting from seniority-based to performance-based wage systems may increase employment of both older and younger individuals.

Finally, it bears emphasising that the Austrian results show that technology differences between industries also modify what we can expect from changing age and education structure in the workforce. The demand for individual capability bundles shift with the technological progress and since this capability bundle also changes over the life course the impact of age structure on productivity is liable to change as well. As evidenced in this report, the changes in capabilities over the life course may be quite dramatic. Innovation and imitation require rather different capabilities and thus (as pointed out in the prospective analysis) transferring conclusions from Swedish age and education patterns in mining and manufacturing, first to the Swedish economy, then to **EU-15** and finally to the **new member states** certainly requires a leap of faith. While our validation against Swedish GDP and GDP within EU-15 does suggest that it may still be a useful exercise where the projections seem rather in line with the development other information and previous results lead us to expect, the **projections for the new members seem overly pessimistic**. The prime reason for that evaluation is that the **catch-up effect** which cross-country studies would imply within the European context has not been part of our analyses.

The theory behind a catch-up effect, i.e., a faster growth rate as a country starts from an initially lower level of GDP per capita, is that such a country is farther away from the steady-state GDP level that current technology growth would allow and thus can grow faster since part of the progress is made by imitation and a faster rate of capital accumulation. **The catch-up potential is higher in the new member states and thus we would expect their growth rates to be higher in spite of an ageing population and the level of education being already high**. As has been argued above, the capacity to absorb technological progress may be higher with a younger age structure and more recent education in the workforce. If that mechanism is strong enough to be important it could indicate that the trend of fast ageing (which the new member states share) could stifle the catch-up of new members to EU-15. To our knowledge there is no systematic study of this possibility with its disturbing implications for the future coherence of the Union.

In the literature (Crespo-Curesma et al. 2004) there are indications that the technology-absorptive capacity of Europe may play a role in the recent trend of falling behind the US in terms of productivity growth and that ageing may play a role in this respect, but again we are not aware of any systematic evaluation of the quantitative importance of such a mechanism.

Summing up, the conclusions from this study clearly indicate that more education and in particular increased labour force participation, especially for the older part of the population and in some countries also for females and the young, are crucially important when it comes to maintain European productivity growth. The efficiency of labour market matching has been implicated as a prime factor behind different age patterns of productivity at more aggregate levels than studies on individual productivity indicate. This puts the focus on labour market institutions which differ considerably across the European Union. From another angle, type of technology has been shown to be important for the impact of age and education on productivity. What is inherent in these latter results is that there is a strong possibility (underlined by recent increases in the spread of productivity growth within the EU) that the policy focus should be on national policies rather than on common targets for the Union.

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APPENDIX A

ICT Taxonomy

1. *ICT Producing - Manufacturing* (ICTPM): Office machinery (30); Insulated wire (313); Electronic valves and tubes (321); Telecommunication equipment (322); Radio and television receivers (323); Scientific instruments (331).

2. *ICT Producing – Services* (ICTPS): Communications (64); Computer & related activities (72).

3. *ICT Using – Manufacturing* (ICTUM): Clothing (18); Printing & publishing (22); Mechanical engineering (29); Other electrical machinery & apparatus (31-313); Other instruments (33-331); Building and repairing of ships and boats (351); Aircraft and spacecraft (353); Railroad equipment and transport equipment nec (352+359);Furniture, miscellaneous manufacturing; recycling (36-37).

4. *ICT Using – Services* (ICTUS): Wholesale trade and commission trade, except of motor vehicles and motorcycles (51); Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52); Financial intermediation, except insurance and pension funding (65); Insurance and pension funding, except compulsory social security (66); Activities auxiliary to financial intermediation (67); Renting of machinery & equipment (71); Research & development (73); Legal, technical & advertising (741-3).

5. *Non-ICT Manufacturing* (NICTM): Food, drink & tobacco (15-16); Textiles (17); Leather and footwear (19); Wood & products of wood and cork (20); Pulp, paper & paper products (21); Mineral oil refining, coke & nuclear fuel (23); Chemicals (24); Rubber & plastics (25); Non-metallic mineral products (26); Basic metals (27); Fabricated metal products (28); Motor vehicles (34).

6. *Non-ICT Services* (NICTS): Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel (50); Hotels & catering (55); Inland transport (60); Water transport (61); Air transport (62); Supporting and auxiliary transport activities; activities of travel agencies (63); Real estate activities (70); Other business activities, nec (749); Public administration and defence; compulsory social security (75); Education (80); Health and social work (85); Other community, social and personal services (90-93); Private households with employed persons (95); Extra-territorial organizations and bodies (99).

7. *Non-ICT Other* (NICTO): Agriculture (01); Forestry (02); Fishing (05); Mining and quarrying (10-14); Electricity, gas and water supply (40-41); Construction (45)

Source: O'Mahony and van Ark (2003), p. 49

APPENDIX B:

Decomposing the change in labour force indicators over time

We apply a new decomposition method of the change in an average as introduced by Vaupel and Canudas Romo (2002). We denote *average_v(t)* as the average of a variable over the characteristic *x* (e.g., age) at time *t*:

$$\text{average\_v}(t) = \frac{\int_0^\infty v(x,t)w(x,t)dx}{\int_0^\infty w(x,t)dx}$$

where *w(x,t)* denotes a weighting function.

In Vaupel and Canudas Romo (2002) it is shown that the change of the average over time, i.e., *d/dt average_v(t)*, can be decomposed into two components:

d/dt [average_v(t)] = average [d/dt v(t)] + cov(v,prime_w). (B.1)

In the above equation *d/dt* indicates the time derivative and prime expresses the relative derivative or intensity:

prime_w = [d/dt w(x,t)] / w(x,t) = d/dt ln [w(x,t)].

The first component on the right hand side of equation (B.1) gives the average change of the function of interest while the second component measures the covariate between the variable of interest and the intensity of the weighting function.

More intuitively: the first term, the average change, accounts for the change observed in the population produced by a **direct change in the characteristic of interest**. The second term, the covariance term, accounts for the **structural or compositional component of change** (i.e., the change in population heterogeneity). Similar to Vaupel and Canudas Romo (2002) we refer to the first term as the direct change or level-1 effect of change and to the second term as the compositional component or levle-2 effect of change.

Applying formula (B.1) to the crude labour force rate yields the expression for the change in the crude labour force rate over time

d/dt [CLF(t)] = average [d/dt l(t)] + cov(l,prime_N). (B.2)

The first term in equation (B.2) captures the direct effect, i.e., the **average change in age-specific labour force participation rates**. If, for example, the average duration of education increases due to a higher fraction of people obtaining a university degree then the time derivative d/dt l(t) is negative for the respective groups. If, on the other hand, the average age of retirement increases, then the time derivative might be positive for the age groups concerned. The sign of the average of the time derivative depends on the intensity of these two changes and also the size of the involved age groups. The second term in equation (B.2) is the structural or compositional component of change, it relates to **changes in the age composition of the population**.

APPENDIX C

A new measure of the age-productivity profile

The productivity measurement is based on the functional level of cognitive and non-cognitive abilities at different stages across the life span. The strength of impact for each ability on the productivity level is determined by the demand for the ability in the labour market. This may be a strong assumption, since many jobs are not affected by ability variation unless, for example, the ability level drops below a certain threshold.

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

$$\hat{a}_{X,S,g} = \frac{\bar{a}_{X,S,g} - \bar{a}_{X,S,25\text{-}34\text{ year olds}}}{\sigma(a_{X,S,25\text{-}34\text{ year olds}})} \qquad \text{(C.1)}$$

In Equation (C.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 the average ability score for each age group and the difference is divided by the standard deviation of ability *X* for the 25-34 years 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 age group 25-34 years, in proportion of the standard deviation.

$$\hat{a}_{X,D(t)} = \frac{a_{X,D(t)}}{\sum_X a_{X,D(t)}} \qquad \text{(C.2)}$$

Equation (C.2) gives the estimate for the demand for ability *X* at time *t.* By dividing the importance of ability *X*, $a_{X,D(t)}$, with the sum of all task scores, $\sum_X a_{X,D(t)}$, we get a measurement of the relative importance of task input *X* in the economy, $\hat{a}_{X,D(t)}$.

$$\hat{a}_{X,g,t} = \hat{a}_{X,S,g} * \hat{a}_{X,D(t)} \qquad \text{(C.3)}$$

In Equation (C.3), the supply of each ability by age group *g* is multiplied by its demand at time *t*. This equilibrium index, $\hat{a}_{X,g,t}$, is used to give an estimate of the market value of what each age group possess of ability *X*.

$$\hat{a}_{g,t} = \sum_X \hat{a}_{X,g,t} \qquad \text{(C.4)}$$

Equation (C.4) shows that $\hat{a}_{g,t}$ is the sum of the equilibrium index scores. The variable $\hat{a}_{g,t}$ is the *potential productivity index*, an aggregate equilibrium index, for age group *g* at time *t*. If one of the abilities is less demanded than the others, its impact on the potential productivity index is lower.

To illustrate the way the potential productivity index is constructed, an example follows: 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 year old 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 year olds. If there should be 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.

APPENDIX D

Definitions for annual job and worker flows on the Swedish laboUr market

<u>The concept of job flows</u>
We follow the conventions adopted by Davis and Haltiwanger (1990, 1992) as regards the definitions of job creation and job destruction rates. A job means an employment position occupied by a worker.

Let $E_{(i,t)}$ be employment at establishment *i* at year *t*. Then "**job creation"** (JC) and "**job destruction**" (JD) can be defined as:

$$JC_{(i,t)} = E_{(i,t)} - E_{(i,t-1)} = \Delta E_{(i,t)} \quad \text{if } \Delta E_{(i,t)} > 0$$
$$JD_{(i,t)} = E_{(i,t)} - E_{(i,t-1)} = \Delta E_{(i,t)} \quad \text{if } \Delta E_{(i,t)} < 0$$

The **size of the establishment** in year *t* is defined as the average employment of the two years *t* and *t*-1. That is

$$\text{Establishment size} = X_{(i,t)} = ½(E_{(i,t)} + E_{(i,t-1)})$$

Dividing JC and JD by the average employment, X, gives us the "**job creation rate**" (JCR) and "**job destruction rate**" (JDR) at whatever level we want. We can define it for each establishment (with the proper adaptation for entries and exits where we cannot average employment over 2 years). Here we will use the industry level of manufacturing, but the same concepts can be defined regionally or at more detailed industry levels.

JCR is the share of created jobs to the share of total jobs. JCR is the sum of all jobs created by new establishments (ENTRY) and by expanding establishments (EXP), that is establishments that increase the number of employees between *t*-1 and *t*, divided by total employment. The JCR is defined as:

$$JCR_{(t)} = \sum_{i \in I_t} \left(\frac{\Delta E_{(i,t)}}{X_{(t)}} \right) \text{if } \Delta E_{(i,t)} > 0$$

$$X_{(t)} = \sum_{i \in I_t} X_{(i,t)}, \; I_t = \text{all establishments at year } t.$$

JDR is the share of destroyed jobs to the share of total jobs. JDR is the sum of all jobs destroyed by closing establishments (EXIT) and by contracting establishments (CONT), that is, establishments that reduce their number of employees between *t*-1 and *t*, divided by total employment. The JDR is defined as:

$$JDR_{(t)} = = \sum_{i \in I_t} \left(\frac{-\Delta E_{(i,t)}}{X_{(t)}} \right) \text{if } \Delta E_{(i,t)} < 0$$

The ***net employment growth*** (NET) is the difference between the job creation rate and job destruction rate:

$$NET_{(t)} = JCR_{(t)} - JDR_{(t)}$$

The ***job reallocation rate*** (JRR) is the sum of the creation and destruction rates:

$$JRR_{(t)} = JCR_{(t)} + JDR_{(t)}$$

The concept of worker flows

Worker flows are important.[27] The flows of workers are measured as the number of workers moving in and out of establishments, i.e. "**hirings**" and "**separations**". Note that there may be hires and separations even if the net job change at the establishment is zero.

Both individuals employed to replace separations, and employed at "new" jobs are defined as hirings. Let $H_{(i,t)}$ denote the number of workers at the establishment at year *t* who did not work there at year *t*-1. The ***hiring rate*** ($HR_{(t)}$) can then be defined as:

$$HR_{(t)} = \sum_{i \in I_t} \left(\frac{H_{(i,t)}}{X_{(t)}} \right)$$

"Separations" includes voluntary (quits) and involuntary (layoffs) leaves. Let $S_{(i,t)}$ denote the number of workers at the establishment at year *t* -1 who do not work there at year *t.* The ***separation rate*** ($SR_{(t)}$) can then be defined as:

$$SR_{(t)} = \sum_{i \in I_t} \left(\frac{S_{(i,t)}}{X_{(t)}} \right)$$

The difference between the hiring and separation rates is the same as the difference between job creation and job destruction rates, which is the net employment change. That is:

$$JCR_{(t)} - JDR_{(t)} = HR_{(t)} - SR_{(t)} = NET_{(t)}$$

The ***worker reallocation rate*** ($WRR_{(t)}$) is defined as:

$$WRR_{(t)} = HR_{(t)} + SR_{(t)}$$

The relation between worker flows, job flows, and changes in employment can be described as follows:

$$WRR_{(t)} \geq JRR_{(t)} \geq NET_{(t)}$$

The so-called ***churning rate*** (ChR) is the difference between worker flows and job flows. It shows the volume of worker flows in excess of that is needed to meet job flows and can be initiated by the employer or the employee. The churning rate can be defined as:

$$ChR_{(t)} = \sum_{i \in I_t} \left(\left[HR_{(t)} + SR_{(t)} \right] - \left[JCR_{(t)} + JDR_{(t)} \right] \right) = WRR_{(t)} - JRR_{(t)}$$

The first term on the right hand side is the worker reallocation rate, and gives the total amount of workers that are hired or separated at establishments. The second term on the right

[27] We follow the definitions by Burgess et al. (2000)

hand side is the job reallocation rate, and gives the amount of worker flows that is necessary to accomplish the establishment growth or decline.

Flows across educational groups and age groups

So far, jobs and workers have been treated as homogeneous. But job and worker flows are not evenly distributed across groups. In order to take this heterogeneity into account, we examine the educational level and age of workers who get new jobs and of those who lose old ones. We break the flows further by four educational groups; pre-upper secondary, upper secondary, university less than 3 years, and finally university 3 years or more. The flows are also broken down further into three age groups; 16-29, 30-49 and 50-64 years old.

For each group of individuals, the sum of the changes in employment between two consecutive years at an establishment is divided by the total employment for the same group of individuals. The aggregate job creation rate for worker group j is the aggregate increase in jobs of worker group j for establishments expanding in worker group j, divided by the level of jobs of worker group j. The job destruction rate is defined in a similar way by the aggregate reduction of worker group j using the mean of the present and previous size of worker group j as the denominator.

$$\mathrm{JCR}_{(j,t)} = \sum_{i \in I_t} \left(\frac{\Delta E(i,j,t)}{X(j,t)} \right) \text{if } \Delta E(i,j,t) > 0$$

$$\mathrm{JDR}_{(jet)} = = \sum_{i \in I_t} \left(\frac{-\Delta E_{(i,j,t)}}{X_{(j,t)}} \right) \text{if } \Delta E_{(i,j,t)} < 0$$

$$X_{(i,j,t)} = ½(E_{(i,j,t)} + E_{(i,j,t-1)}) \,, \qquad X_{(j,t)} = (\sum_{i \in I_t} X_{(i,j,t)})$$

The hiring rates and separation rates for group j of workers is defined in the similar way:

$$\mathrm{HR}_{(j,t)} = \sum_{i \in I_t} \left(\frac{H_{(i,j,t)}}{X_{(j,t)}} \right)$$

$$\mathrm{SR}_{(j,t)} = \sum_{i \in I_t} \left(\frac{S_{(i,j,t)}}{X_{(j,t)}} \right).$$

APPENDIX E

Definitions of statistical terms and variables for Austrian data

Key facts of structural business statistics

- Cover all enterprises, working groups, establishments and local units that carry out an activity allocated to the sections C to K (NACE Rev. 1.1)
- Population for the selection of sample units consisted of all the enterprises of NACE Rev. 1.1 divisions 10 to 74 (excl. 66) that were active at the end of the year under review (2001) in the business register of Statistics Austria
- Sampling process corresponds to a stratified random selection
- Data is collected by direct poll
- Sector-specific survey forms were used in each case for the sectors manufacturing, services and financial intermediation
- Survey forms were sent in August 2002; deadline for returning the forms was 30.9.2002, two written reminders in October 2002 and November 2002
- Response rate: 92.5%
- Sampling size was set at around 15,500 units for the manufacturing sector and around 27,300 units for the service sector. These 42,800 or so enterprises (approx. 18% of the population) cover 79.6% of the gross value added at factor cost of NACE sections C to K

Key facts for population census

The population census is carried out every ten years by Statistics Austria. The corner points are:

- Latest census was held on Mai 15th 2001
- 3.3 Mio. households with 8.1 Mio. persons
- Survey by questionnaire

Definitions

- **Enterprise (firm)**: The enterprise corresponds to a legal entity that forms an organisational unit for the manufacture of goods and services and has a certain freedom of decision in particular regarding the use of the current funds it accrues. An enterprise carries out one or more activities at one or more locations.
- **Local unit (plant)**: The local unit of employment (local unit) is a part of an enterprise that is situated in a fixed location (e.g., sales outlet, office, warehouse and workshop). In this location or from this location, economic activities are carried out for which—with exceptions—one or more persons work (possibly also part-time) on behalf of one and the same enterprise.
- **Total persons employed (employees):** “Total persons employed” includes active owners (including co-owners and tenants), unpaid family workers and gainfully employed persons. “Gainfully employed persons” are employees, workers, apprentices

and outworkers, who had a valid employment contract with the enterprise on the reference date of the survey.

All persons belonging to the enterprise (survey unit) were to be reported, irrespective of whether they worked in or outside the enterprise (e.g., persons temporarily posted abroad, personnel working on assembly sites, as long as payment of their remuneration was effected by the enterprise). Also to be specified were persons on sick leave, holiday, temporarily assigned to military exercises, women on pregnancy and maternity leave, seasonal and auxiliary workers, trainees, part-time workers, short-time and marginal workers. Persons employed did not include persons performing military or substitute military service, persons on leave (even if they had a valid employment contract with the enterprise), workers not belonging to the enterprise (e.g., temporary workers, persons seconded with contracts to work on specific projects) or supervisory boards.

- **Value added at factor cost:** The main objective of any survey of economic statistics is to determine a valid summation coefficient of performance capable of ascertaining the way in which individual economic sectors contribute to gross domestic product. The sales proceeds of an enterprise are not suitable as such as they include the intermediate inputs of other enterprises and would cause double and multiple counts due to the addition of the proceeds. However, as the survey had to take account of the accounting records of the enterprises, coefficients known to the respondents such as sales proceeds were initially taken into account.

  A broad figure of how the performances of enterprises can be determined based on receipts would be:

  Sales proceeds minus intermediate inputs = performance of the enterprise. The gross value added at factor costs is then obtained by adding the subsidies and subtracting the taxes and duties.
- **Production value:** The production value measures the amount actually produced by the unit, based on sales, including changes in stocks and the resale of goods and services.

  The production value is defined as turnover, plus or minus the changes in stocks of finished products, work in progress and goods and services purchased for resale, minus the purchases of goods and services for resale, plus capitalised production, plus other operating income (excluding subsidies). Income and expenditure classified as financial or extra-ordinary in company accounts is excluded from production value. Included in purchases of goods and services for resale are the purchases of services purchased in order to be rendered to third parties in the same condition.
- **Home worker:** Home workers are a sub-division of persons employed by the observation unit who carry out their professional activity from their own home.[28]
- **Part-time employees:** Part-time employees are considered to be those who, in accordance with a contract with the employer, did not perform a full day's work or did

[28] http://forum.europa.eu.int/irc/dsis/coded/info/data/coded/en/gl007077.htm

not complete a full week's work within the local unit.[29] According to Statistic Austria, part-time employees work 35 hours or less a week.

Educational variables

Lower secondary education (ISCED level 2)

The contents of education at this stage are typically designed to complete the provision of basic education, which began at ISCED level 1. In many, if not most countries, the educational aim is to lay the foundation for lifelong learning and human development, on which countries may expand, systematically, further educational opportunities. The programmes at this level are usually on a more subject-oriented pattern using more specialised teachers and more often several teachers conducting classes in their field of specialisation. The full implementation of basic skills occurs at this level. The end of this level often coincides with the end of compulsory education where it exists.

Level 2 includes also:

- In countries where primary education is part of 'basic education', the second stage of 'basic education' should be included in level 2. If 'basic education' is not officially divided into stages, the years after the sixth should be classified as level 2.
- This level includes special needs education programmes and all adult education, which are similar in content to the education given at this level, e.g., the education that gives to adults the basic skills necessary for further learning.

Source: UNESCO (1997)

Skilled workers

Skilled workers are all workers who completed an apprenticeship. During apprenticeship, all employees do not participate fully in the production process of the unit, because they are working under an apprentice's contract or because they are undertaking vocational training, which impinges significantly on their productivity. In contrast to upper secondary education programs, the apprenticeship does not provide an university entrance diploma. This combined program, which unites education and professional experience, is unique for Austria and Germany.

Upper Secondary education (ISCED level 3)

This level of education typically begins at the end of full time compulsory education for those countries that have a system of compulsory education. More specialisation may be observed at this level than at ISCED level 2 and often teachers need to be more qualified or specialised than for ISCED level 2. The entrance age to this level is typically 15 or 16 years. The educational programmes included at this level typically require the completion of some 9 years of full-time education (since the beginning of level 1) for admission or a combination of education and vocational or technical experience and as minimum entrance requirements the completion of level 2 or demonstrable ability to handle programmes at this level.

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[29] http://forum.europa.eu.int/irc/dsis/coded/info/data/coded/en/gl008905.htm

Level 3 includes also:

- This level includes also special needs education programmes and adult education.

Level 3 excludes:

- Remedial programmes that are designed for participants who have pursued a programme at ISCED level 2 but who have not attained the objectives of ISCED level 2 programmes (and which can therefore not be regarded as equivalent in content to any of the ISCED 3 programmes described below) should not be classified at ISCED level 3 but at ISCED level 1 or 2 depending on the content of the programmes.

Source: UNESCO (1997)

Academics

This level of education comprises first and second stage of tertiary education.

First stage of tertiary education (ISCED level 5)

This level consists of tertiary programmes having an educational content more advanced than those offered at levels 3 and 4. Entry to these programmes normally requires the successful completion of ISCED level 3A or 3B or a similar qualification at ISCED level 4A. All degrees and qualifications are cross-classified by type of programmes, position in national degree or qualification structures (see below) and cumulative duration at tertiary.

Level 5 includes also:

- This level includes all the research programmes, which are not part of a doctorate, such as any type of Master's degree.
- In some countries, students beginning tertiary education enrol directly for an advanced research qualification. In this case, the part of the programme concentrating on advanced research should be classified as level 6 and the initial years as level 5.
- Adult education programmes equivalent in content with some ISCED 5 programmes could be included at this level.

Source: UNESCO (1997)

Second stage of tertiary education (ISCED level 6)

This level is reserved for tertiary programmes, which lead to the award of an advanced research qualification. The programmes are therefore devoted to advanced study and original research and are not based on course-work only.

Level 6 includes also:

- - The part concentrating on advanced research in those countries where students beginning tertiary education enrol directly for an advanced research programme.

Source: UNESCO (1997)