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Variations in Productivity over the Life Span: A Review and Some Implications

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Variations in Productivity over the Life Span: A Review and Some Implications

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Contents

Abstract

This paper presents a review of the literature on productivity differentials across adult age groups. The causes of age variations in productivity are addressed with special emphasis on the role of cognitive abilities and labor market performance. According to most findings, older workers tend to be overpaid relative to their productivity. The consequence can be difficulties in employing elderly workers.

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Variations in Productivity over the Life Span: A Review and Some Implications

Vegard Skirbekk

1. Introduction

In order to estimate how population changes affect economic growth, several studies have used population and workforce growth as explanatory variables (e.g., Bloom and Williamson 1998). But, if there are differences in productivity levels between workers of different ages, this approach may give inaccurate results. Studies that control for productivity differences between workers of different ages can reduce this problem (e.g., Blanchet 2001). However, also this approach could have weaknesses, if it does not take into account that age-productivity profiles can change over time. The sort of tasks tomorrow's labor force needs to carry out is likely to differ from the type of work carried out today. And when the type of skills demanded in the labor force changes over time, the relative productivity of old to young workers may change as well. If one adjusts for age-specific productivity and how it changes over time, one can make more accurate estimates of how changes in the age structure of the population affect economic growth.

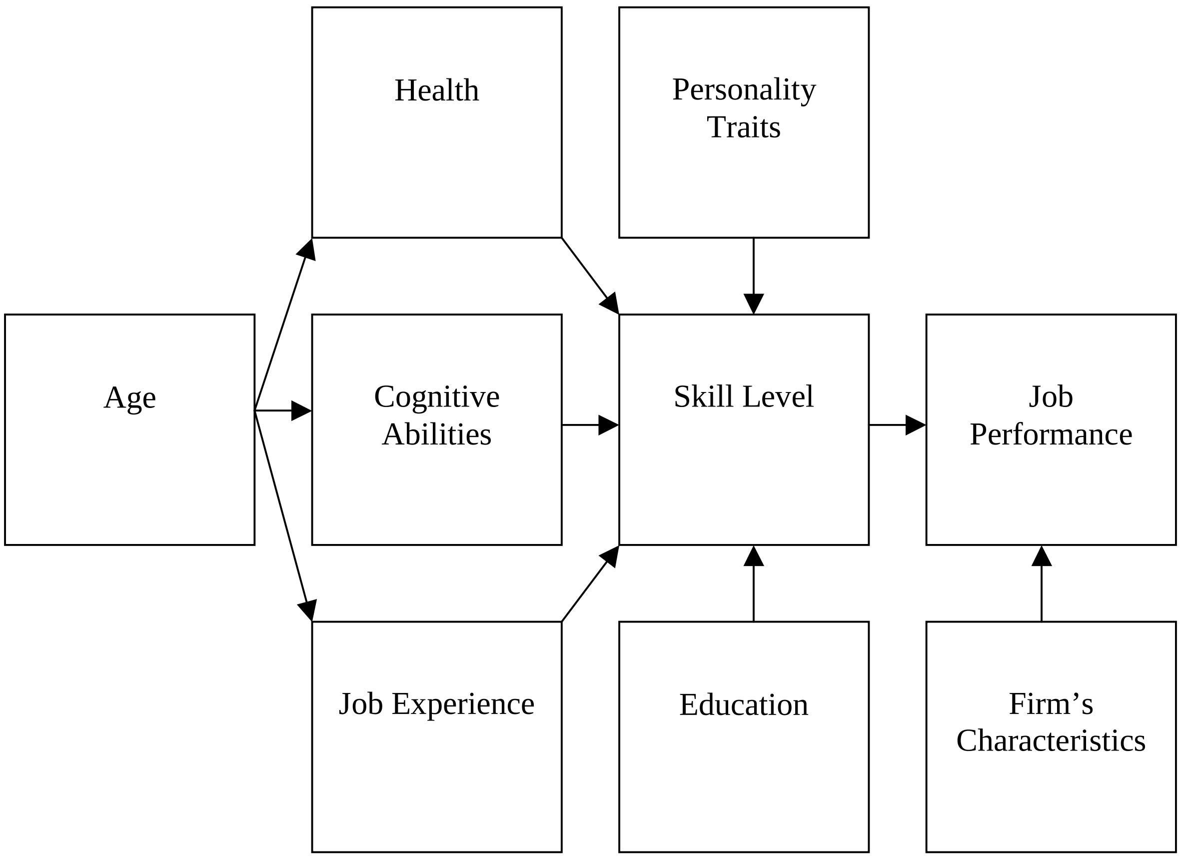
An important reason for the variation in productivity between age groups is the role of cognitive abilities[1]. Cognitive abilities are argued to be the most valid predictor of job performance (Hunter and Hunter 1984), and some evidence suggests that it has become increasingly related to job success in recent years (Murnane et al. 1995). Most studies find that mental abilities decrease substantially as people age (e.g., Salthouse 1992). Thus, the importance of cognitive abilities for the elderly worker's productivity is likely to be high, increasing over time, and its implication is that the workers' productivity is adversely affected as they get older.

Figure 1 presents a simplified outline of the main causal factors relating to the worker's productivity. The worker's physical and mental abilities, together with his training and job knowledge, forms the "skill" level, which represents the productivity potential of an individual. The skill level, combined with firm specific characteristics (e.g., capital, industry type, technology, region), determines how well the worker performs in a given job. This diagram can help provide an intuitive understanding of

[1] "Cognitive abilities" is a broad term, referring to aspects of intellectual functioning. These include reasoning, spatial orientation, numerical capabilities, verbal abilities and generally at which speed and accuracy individuals are able to solve problems. The most commonly used measurement of cognitive abilities is the IQ score.

how different factors, some of them strongly related to age, affect productivity among workers.

Figure 1. Factors affecting job performance



The present paper is organized as follows: First, studies that investigate age-related variation in mental abilities are reviewed. Second, the effect of cognitive abilities on productivity is discussed. Third, evidence on how productivity is affected by age is given, followed by how the role of experience influences work abilities. Fourth, data on age-earning profiles are shown, followed by a discussion on the implications of a gap between wages and productivity for older workers. Finally, the conclusion gives a brief summary, and outlines some policy recommendations for improving employment opportunities among the elderly.

2. Age and Cognitive Abilities

Studies on how cognitive abilities evolve over the life span tend to find age-related declines at some stage in adult life. But whether these reductions are evident already from young adulthood, or whether they decline only in late adulthood, is a debated issue. In any case, these reductions do not necessarily affect work behavior until late adulthood, since they are relatively small at first and since more experience can offset declining abilities until this stage. Another issue that affects how an individual benefits from experience at different stages in his life is the changing capacity to learn, and the willingness to adapt.

Whether age-related developments are general to all the components of intelligence or if they evolve in relatively unrelated patterns, is another ongoing debate. Salthouse (1996) argues that age-related declines lower the level of general intelligence, *g*, which again affects the evolution of specific abilities. An opposing view is presented by Schaie (1994), who argues that an overall index of intelligence does not suffice, since the patterns of age-related changes in specific abilities are not uniform enough.

One common method of disaggregating intelligence into specific abilities is termed the “Primary Mental Abilities” (e.g., Thurstone and Thurstone 1963). A brief description of these abilities follows:

- Perceptual Speed. Measures the preciseness and the time it takes for an individual to discriminate between visual stimuli.
- Verbal Meaning. A measurement of how well an individual understands ideas expressed in words. Measures the passive as well as the active size of a person's vocabulary.
- Word Fluency. Ability to memorize and recall words and semantic constructions. Measures how well individuals process information.
- Number. Measures how well individuals perform on basic math tests, such as multiplication and addition. Speed and accuracy of the answer is used as a measurement of this ability.
- Spatial Orientation. The ability to infer space-form relationships, such as visualizing an object from different angles.
- Inductive Reasoning. A measurement of how well an individual is able to identify patterns and links in a situation, and how well he manages to apply this to a related problem.
- Memory. The ability to recall verbal units, such as sentences.

Mental abilities can also be divided according to how they are affected by ageing, i.e., into those abilities that show large declines, fluid abilities, and those that tend to show no or only small decrements, crystallized abilities (Horn and Cattell 1966, 1967). The first group, fluid abilities, are those that measure how well one is able to solve tasks related to new material, in particular when there is a speed requirement. Examples include perceptual speed and, to some extent, reasoning. The second group, crystallized abilities, affect those tasks that are dependent on accumulated knowledge, and include verbal meaning and word fluency.

A study by Schwartzman et al. (1987) compared psychometric tests of young men during WWII, with re-tests of the same individuals at old age. They found that verbal abilities generally remained unchanged, while test scores related to reasoning and speed clearly declined. Similar results are given in Blum et al. (1970) in a test-retest study of twins. Blum et al. found that older twins showed clear decrements in most cognitive abilities at older ages, except in vocabulary tests. Another study, by Collins and Tellier (1994), investigated how well individuals are able to reorient themselves to new task requirements. They find a strong negative age-effect, where the older individuals were less able to adjust to new ways of solving a problem.

Most empirical studies on age and cognitive development use cross-sectional samples; which means they study ability levels of individuals from different age groups at one point in time. Some other studies are longitudinal, which means that they sample individuals more than one time during their lives. Cross-sectional investigations tend to find more age variation in cognitive abilities than longitudinal studies, which, to a large extent, can be explained by differences between cohorts in ability scores. This type of studies also tend to predict an earlier onset of the decline of mental abilities than longitudinal studies (Schaie 1994). Important reasons for these differences which affect measured intelligence levels include that later cohorts have more schooling, and have experienced better socio-economic standards. Furthermore, tests have become more commonplace during the last decades, both in magazines and newspapers as well as when firms choose job candidates (see, e.g., Jenkins 2001). Thus individuals will have more practice taking these tests, and may therefore score higher because they are better trained for them.

A comparison of psychometric test results from individuals born in different periods has shown that cohort effects matter. Studying individuals in a given chronological age, the results from those born in the first quarter of the 20th century were better on tests of inductive reasoning and verbal ability, but worse on numerical ability tests than prior cohorts. Similar changes in abilities were also found by comparing the baby boom cohorts of 1945, 1952 or 1959 with the 1924 cohort. The later born cohorts received higher scores on reasoning and verbal memory, perceptual speed remained constant, while numerical and vocabulary scores declined (Willis and Schaie 1998). Further evidence on cohort differences in psychometric test scores is found in Flynn (1987), who shows that test results from IQ scores have increased substantially over time.

These differences in test scores between cohorts may in part explain the differences between cross-sectional and longitudinal studies. Cross-sectional studies can give a good impression of the ability level of the population at a stage in time, while longitudinal studies can outline the evolution of abilities for individuals within different cohorts. The most important consideration with the use of longitudinal studies is their high levels of non-random attrition[2], where the respondents who drop out tend to be the less able. Further, individuals answering to the same test in subsequent waves may improve their scores as a result of practice. Thus, the relatively small decrements in abilities over the life span which longitudinal studies usually show, may understate the real impact of ageing on mental abilities (Willis and Baltes 1980).

Verhaegen and Salthouse (1997) present a meta-analysis of 91 studies, most of them cross-sectional, on how cognitive abilities (processing speed, primary working memory, episodic memory, reasoning, and spatial ability) evolve with age. On the basis of these studies, Verhaegen and Salthouse conclude that declines in speed, reasoning and episodic memory were significant before 50 years of age, and that the age-related

[2] In the Seattle Longitudinal Study, more than half of the initial sample was lost from every new sample by the time of the second wave (after 14 years). E.g., from the 500 individuals of the initial 1956 sample only 162 remained in the 1970 wave (Schaie 1994).

declines accelerated with age. They also argue that reductions in the speed of processing and primary working memory were the mediators of the declines in most of the other cognitive abilities[3]. This “common cause” view of age-related declines is also held by Baltes and Lindenberger (1997) and Welford (1958), who argue that variations in abilities over the life span could be attributed to changes in the nervous system causing a slower timing of perception and response, and a weakened short-term memory function.

The “Seattle Longitudinal Study” (e.g., Schaie 1994) applies both longitudinal and cross sectional approaches. The first wave in the longitudinal study was administered in 1956, and the sample was extended and examined every 7th year thereafter. Using the longitudinal approach, only perceptual speed is found to declines from an early age, while number, spatial orientation and inductive reasoning increases weakly until a peak is reached at around 40 years of age, and declines slowly but in an accelerating way thereafter. Verbal meaning and verbal ability are found to decline only from the 60s. The cross-sectional approach finds that number and verbal abilities remain relatively stable up to the last test at 81 years of age, while reasoning and perceptual speed start declining early in life.

Evidence on how universal reductions in mental performance take place, is provided in Park et al. (1999). Their findings suggest that age-related decrements are independent of culture, since the declines tend to follow similar patterns across different countries.

There is some evidence that intervention may halt the reduction in mental abilities over the life cycle. Schaie and Willis (1986a, 1986b) conclude, on the basis of a training program evaluation, that age-specific declines in certain cognitive abilities can be stabilized or even reversed among many individuals. The cognitive abilities studied are inductive reasoning and spatial orientation. The authors find that among many of those who are subjected to training, cognitive skills are enhanced relative to those who do not undergo training. On the other hand, evidence found in Sharit and Czaja (1994) contradicts this statement, and suggests that declines in cognitive abilities can neither be eliminated nor stabilized even when subject to training.

3. Cognitive Abilities, Productivity and Income

Scores on psychometric tests are found to vary significantly by age. But how relevant is this to how much an employee adds to the production value in a firm? This section surveys literature on the relation between test scores and productivity. Little direct evidence on the relation between productivity and measured abilities exists. Therefore, many of the studies presented in this section concern how cognitive abilities relate to income, which is used as a proxy for productivity. As demonstrated in other parts of this paper, wages fail to completely reflect the value of a person's marginal productivity, particularly at young and old ages. But even if the wage level is not accurately matched by variations in the productivity level, evidence indicates that wage variations tend to match productivity differentials relatively well along most

[3] Verhaegen and Salthouse (1997), by studying a large comparison of age-skill studies, show that all cognitive skill variables share substantial parts of their age-related variance.

dimensions. Hægeland and Klette (1999) find that higher wages generally reflect higher productivity for most variables. For example, they conclude that gender differences in wages are almost entirely explained by productivity differences (measuring productivity by the marginal impact of workers on a firm's value-added).

Notably the types of tasks performed in laboratory studies can sometimes be weak predictors of workplace performance. Salthouse (1984) shows that declines in perceptual speed do not always relate to reduced job performance. He shows that older workers type as effectively as younger ones, despite slowed perceptual speed. The types of psychometric tests analyzed with respect to income are typically measures of IQ, numerical abilities, reasoning or other cognitive abilities. Working behavior is only adversely affected when the reduction passes a threshold where the skills are below what is needed in the job situation. And the threshold differs according to the type of job. Warr (1994, p 501-529) outlines a categorization of job types, based on whether age-related declines in cognitive abilities affect work performance and whether this is alleviated through experience.

Most available evidence suggests that cognitive abilities are a strong predictor of job performance. Barrett and Depinet (1991) show that those who score high in tests of intelligence, undergo more years of schooling and experience greater job success. Altonji and Blank (1999) review studies on how group differences in wages are reflected in test scores. Their review indicates that group differences in wage levels are largely explained by variations in test scores, also after controlling for schooling, industry, region and experience. Currie and Thomas (1999) find significant correlations between test results for individuals of only 7 years of age and their adult income levels, also after adjusting for socio-economic influences. Tyler et al. (2000) analyzed the effect of scores on a test measuring math, writing, reading, social studies and science skills, which is used for high school dropouts. They take into account gender, race and region of residence, though controls for most other socio-economic influences are lacking. Better cognitive abilities are associated with higher income, and increasingly so with age, a result found to hold for all groups studied. Additional demonstrations of the link between test scores and wages are given in Bishop (1991), Grogger and Eide (1993) and Murnane et al. (2000).

Boissiere et al. (1985), using evidence from developing countries, found that some cognitive abilities seem to be more important to wage premiums than others. Reasoning abilities are found to have a small impact on salaries, while literacy and numerical abilities are those which have the highest impact on income levels. The number of years in school have a moderate effect on earnings.

An increasingly strong correlation between test scores and income is found by Murnane et al. (1995), who studied the relation between performance in basic mathematics tests at the end of high school and hourly wages in the US. The analysis accounted for whether the individual was raised in a single-parent household, for the number of siblings, parental education, race, work experience, and whether the type of work the individual had was part-time. This analysis showed that math scores predicted income levels in the 1980s better than in the 1970s, and that the relation between wages and test scores was stronger six years after graduation than two years after graduation. There is also a research result showing that performance in advanced mathematics can give pay-offs as well, according to a British study of secondary school mathematics specialists (Dolton and Vignoles 2000). It is found that the math competence was strongly linked to adult earnings.

Hunter and Hunter (1984) generalize the findings of thousands of studies on how cognitive abilities relate to job performance. They conclude that a test of cognitive ability is a measure with high validity for labor market performance. They present a meta-analysis based on 515 studies showing that cognitive abilities have validity on training success, as measured by the correlation coefficient, ranging from .27 to .61 across job categories.[4] Cognitive abilities are found to have a higher correlation with measures of job performance than other predictors for most job types. In a comparison of predictive studies Hunter and Hunter find that that a composite ability test has a higher correlation with supervisor ratings than other ways of predicting job performance, including education, experience and job tryout.

One element which could interact with the cognitive abilities and productivity relation is whether cognitive skills evolve differently as individuals age. If the patterns of age-variation in mental abilities differ between individuals with high and low ability levels, then the link to productivity might also be more or less strong as individuals grow older. Empirical evidence provided by Deary et al. (2000) contradicts this, and shows that the rank-ordering of intelligence remains relatively constant. They found that intelligence levels at the age of 11 are closely correlated to levels at the age of 77, with a correlation coefficient of 0.6.

4. Experience and Vintage Effects

The ‘human capital vintage effect’ means that the skills individuals have learned when they were young can be outdated and no longer productivity-enhancing when they are older. This effect, driven by technical change, is likely to be particularly evident in industries strongly affected by technology growth (such as the information and communication technology and the electronics industries). The cause of the vintage effect may be reductions in cognitive abilities over the life cycle, most prominently those related to memory and speed abilities. The elderly learn at a slower pace than younger individuals, especially if what they learn is qualitatively different from what they have already mastered[5], and they also tend to get less flexible as they age.[6]

Evidence from a Finnish dataset (Ilmakunnas et al. 1999) shows that the positive effect of experience on productivity is evident for only a limited number of years[7]. The productivity gains from experience are found to peak after 3.8 years, and to decline thereafter. When workers have more than 13 years of experience, productivity falls below that of those without experience. The reason why this productivity gain from

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[4] These numbers are adjusted for range restriction and measurement error, and are taken from the original work done by Ghiselli (1973). Ghiselli’s study found a mean validity of .24 for these professions.

[5] A discussion of how learning capabilities evolve with age can be found in Hoyer (1998).

[6] Schaie (1958) gives evidence that old people are more rigid than younger persons. Since flexibility is a demanded attribute in the labor market, older workers may have a disadvantage over younger workers and may experience more problems adjusting to new work situations.

[7] Ilamkunnas et al. (1999) control for the age of the plant in their study in order to reduce causality problems caused by new high-productive firms having younger, less experienced workers.

experience is so short term might be that some of the individuals are employed at more adult ages and consequently benefit less from new experience, and are therefore understating the overall productivity gains from the experience of younger individuals. Rybash et al. (1986) argue that, as people grow older, they undergo an *encapsulation* of job know-how, so that the workers' skills become domain- or a firm-specific. Age-related cognitive limitations may cause problems when one seeks to perform work tasks in unfamiliar areas. Since accelerating technical change may force more frequent changes in working patterns, difficulties in acquiring new knowledge may be a particular problem for older workers. This implies that senior employees are able to uphold relatively high levels of productivity within a type of job, in comparison with how well other tasks would be performed.

Another reason which can explain why productivity declines at older ages is that firms take into consideration the age of the worker when they decide who they would like to train or promote. When older workers are close to retirement, they have fewer chances of being selected for the most productive jobs, since companies prefer workers with longer work prospects. If the company knows that retirement is approaching, the company will be less interested in training the worker, since the benefits of higher productivity will remain for a shorter period. Furthermore, the worker may be less motivated to learn, since acquiring new insights may only slightly improve income levels, when only few years remain in the workforce. Additionally, if hiring younger individuals extends the duration of employment, hiring young instead of old workers may reduce retraining costs.

5. Productivity and Age

Since there is a strong link between mental abilities and job performance, one might expect that productivity declines similarly to cognitive abilities at older ages. But since declines in cognitive abilities are for several years offset by experience and more on-the-job training, the evolution of productivity does not necessarily mirror the decline in cognitive skills. The workers' potential for job success is affected by several influences, and although cognitive abilities may be the most important factor, they are not the only one.

This section reviews the literature on productivity measured for workers of various ages, and discusses the validity of different methodological approaches. Ratings from colleagues and managers tend not to show a clear link between age and job performance, while piece rate samples predict a declining or a small effect of seniority on productivity. But these methods may contain weaknesses which reduce their validity when investigating how productivity develops with respect to age. Many of these problems have been overcome with the use of large-scale datasets that investigate the marginal productivity of an extra worker on aggregate productivity. Most of these studies predict that workers have an inverted U-shaped productivity curve, where workers of older ages create less value-added.

Among the many ways one can estimate productivity, the common measures of supervisory ratings and piece-rate work may contain serious fallacies, in particular when studying the impact of the worker's age. Using the supervisors' evaluations can give a wrong impression of the employee's true capabilities, especially for senior workers. Elements typically associated with older workers such as past achievements, loyalty, reliability and experience can induce supervisors to give inflated evaluations of their seasoned employees (e.g., Salthouse and Maurer 1996). Empirical evidence which supports a supervisory bias towards experienced workers is found in Rothe (1949) with regard to blue collar workers, and Stockford and Bissell (1949) for administrative personnel. Even if supervisors do not necessarily attribute lower efficiency levels to their own senior employees, surveys suggest that they believe there exists a general negative link between age and a worker’s productivity.[8]

A study by Waldman and Avolio (1986), reviewing studies on sales records, peer ratings and supervisor assessments, illustrates that the way productivity is measured may lead to opposite results. Their overview showed that whether age affected productivity positively or negatively depended on the measurement method, and that only a relatively small part of productivity variation could be attributed to age. A meta-analysis by McEvoy and Cascio (1989) investigated the impact of the worker's age on the supervisor’s assessment, or sales records, by examining 96 existing studies. They found productivity coefficients in the range of -.44 to .66, implying that no generalizations on age related productivity developments could be drawn.

Other examples of attempts to measure productivity by analyzing supervisor’s assessments include Medoff and Abraham (1981), who examined how white collar workers at a large corporation were rated, and found that long experience does not enhance productivity, despite of increased wage levels. A study by Hunter and Hunter (1984) also finds no relation between supervisor’s assessment and the age of the employee.

In a comprehensive study, Dalton and Thompson (1971) investigate age-ratings for engineers, using evaluations from both employers and employees. Their dataset consisted of 6 firms in a field of rapid technical progress, with 2500 engineers and managers. Both the engineers and their managers answered that workers around their 30s put in the most effort and performed the most sophisticated technical work. They also agreed that productivity falls as the engineers move into their 40s and beyond.

A second approach to measure age-related impacts on worker productivity is based on piece rate performance, where the speed and accuracy in work-sample tasks are examined (e.g., Shearer 1996). However, task-quality/speed tests can also be biased, in particular towards elderly employees. First, these typically simple work tasks examinations do not necessarily reflect the productivity of workers in a real job situation. Second, studies that examine worker's performance of piece-rate work are often time limited. This may give age-biased results, since older employees may not be able to uphold a high speed of work for longer than the short period studied (Salthouse and Maurer 1996, p 357). Third, piece rate workers may be a selected group of workers, which questions how general the validity of the findings are. As shown by Kate and Perloff (1992), workers in piece-rate work tend to be different in terms of earnings profiles and as to which age groups they belong to, in comparison to those who work for time-rates.

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[8] A survey from the US showed that 88% of corporate executives thought that there is a relationship between age and productivity. They believed that productivity peaks around the age of 43 (Wall Street Journal, 24. March, 1998).

De la Mare and Shephard (1958) found that older shoe leather cutters worked more slowly at higher ages, though this was partly compensated by a better quality of their products until they turned 60. 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 had a drop in productivity after age of 55.

A third way of measuring productivity over the life span is based on the analysis of large-scale employer-employee matched datasets. The marginal effect of a worker on a company's output or value added is used as a proxy for employee productivity. This method overcomes several of the disadvantages associated with other measures of productivity. First, the dataset is usually not subject to personal judgment, which increases its objectivity. Second, in addition to experience, education and human capital vintage effects, it can capture the effect of personal characteristics that could contribute to productivity but are often hard to measure. These personal traits, although potentially productivity enhancing, are usually difficult to disentangle. These include social skills, intuition, problem solving, tacit knowledge, flexibility, creativity, wisdom, motivation, patience, as well as cognitive abilities. By estimating the workers' effect on firm productivity, the effect of these traits are taken into account.

On the other hand, there are also considerations regarding the use of this method, i.e., that it may be subject to causality problems. First, young age structures could be a consequence of the firm's high productivity rather than the cause. This problem is partially solved by including variables on industry type, size of firm and the age of the plant, or by using lagged measures of worker age profiles. Second, capital levels vary between firms, which, in turn, affects worker productivity. Given that workers of certain age groups are non-randomly distributed to firms with high or low capital levels, age-productivity estimates could be biased. However, extensive controls for capital levels used in most studies reduce this problem. Third, the estimated productivity effects may also be affected by the age-composition of the workers, e.g., certain shares of older and younger workers may be beneficial or detrimental to productivity levels.

Hellerstein and Neumark (1995) analyze 933 Israeli firms, where the workers are categorized in four occupational (unskilled, engineer, technical or academic) and three age groups (up to 34, 35-54, 55 or older). On the basis of the firms' output and labor composition, the workers' productivity is estimated. This is done by taking into account the type the of industry, the number of employees, the firm's capital and material input, as well as spending on research and development. The analysis suggests that worker productivity increases over the life span in a similar way as wages develop. However, weaknesses of the data, large estimate variations and a bias in the language skills and productivity levels of some age groups due to high immigration are likely to affect the results. Therefore, as the authors emphasize, no clear conclusion about age and productivity can be drawn.

Hellerstein et al. (1999) present a model for evaluating productivity on the company level, and employ it to analyze matched employer-employee data from the US, consisting of 3,102 plants and 128,460 workers. Productivity is measured as the log of the firms' output and value added. Age is disaggregated into three groups: 34 years or less, 35-54, and 55 or older. The model also controls for gender, race, type of profession, if a person was ever married, and whether a person has at least some college education. Covariates are the number of employees in the company, region, the age of the establishment, as well as the type of industry.

Hellerstein et al. show that wages are increasing for most of the working life, but they found that the effect of worker's productivity by age is not clear. When output is used as a productivity index, workers of 55 years or older are found to be more productive than those of less than 34 years, approximately reflecting the increase in wages. However, when the value added of the plant is used instead, productivity levels for those older than 55 were somewhat lower than the productivity levels of the two younger age groups.

Applying an extended version of the theoretical framework developed in Hellerstein et al. (1999), Crépon et al. (2002) study the development of wages and productivity in France. After discarding 62% of the plants in the original dataset, their final sample consists of 23,292 companies in manufacturing, 54,576 companies in the non-manufacturing sector and more than 3 million workers, which probably makes it the largest dataset ever used in age-productivity studies. The analysis took into account workers' gender, age, occupation class, number of hours worked and wages. Plant variables included age, size, industry type, several capital variables and output (which was used as a proxy for productivity). Wages in France are shown to be monotonically increasing with age. In spite of higher wages, older workers were found to be 10-20% less productive (depending on the type of industry) than 25-34 year olds.

Hægeland and Klette (1999) also base their study of productivity in Norway on an extended version of Hellerstein et al.'s (1999) model. They use information from the Norwegian census of manufacturing plants and personal register data to construct a dataset that included detailed information on companies' and workers' characteristics. 29% of the original plant sample was dropped, leaving 7,122 plants with an average of 38 employees. Worker variables included length of education, gender, experience and number of hours worked. Productivity was measured as value added, net of taxes and subsidies, while wages included salaries and other payments (most importantly social security) paid by the company. Age of the workers was proxied by the variable "Experience", which simply states the number of years in the labor force. E.g., an individual with medium experience (who left school 8-15 years ago), and medium length of education (13 or 14 years), is 28-36 years old. A weakness with this approach is that the authors do not measure age directly, and although "experience" can be used as a proxy for age, this measure is too wide to capture productivity differences between older age groups.

Hægeland and Klette find that wages increase substantially as workers move from short- to medium-term experience, and for those with long-term experience, wages remain relatively stable. Productivity declines markedly for those with more than 15 years of experience. Thus, the oldest age group continues to receive high wages, even if they have significantly lower productivity levels. The wage-productivity gap is most strongly pronounced for 1990-93, the most recent period studied, and weaker for the years 1986-89.

Ilmakunnas et al. (1999) study how age affects productivity among Finnish plants. The employer-employee dataset comprises 3,882 companies, with relatively detailed information on both workers and firms. The authors analyze how the plants' value added is influenced by the age composition of the workers. Their analysis shows that productivity in companies peaks when the average age of workers is 40, and declines thereafter, when controlling for the age of the plant as well as for education and experience levels among the workers.

Andersson et al. (2002) study Swedish mining and manufacturing plants with a minimum of 50 employees for the years 1985-96. The applied dataset consisted of a sample of 2874 plants. They analyze the impact of the plant workers' age and education structure on productivity, controlling for type of industry. They use the producer-price value added per person as a measurement for workers' productivity. Using 40-49 year olds with primary education as their reference group, they find that tertiary education, especially technical or economic, increases value added in almost all age groups. 16-29 and 40-49 year olds affect productivity positively regardless of education, while 30-39 year olds are found to be increasing productivity significantly only when they have tertiary education[9]. For 50-59 and 60-69 year olds, those with tertiary education enhance productivity, while those with primary and secondary education reduce it.

A problem with this and similar studies is to determine the direction of causality between age structure and productivity. When companies are highly productive, they are more likely to hire new young workers; therefore the young age structure is not necessarily the cause of high productivity. Andersson et al. (2002) try to control for this by regressing with lagged values of age categories in order to see how earlier age structures affect plant productivity. In doing so, they find that workers with primary and secondary education over the age of 50 years have negative effects on productivity, while all individuals with tertiary education have significant positive effects on productivity, except for those above 60, where no effect is found.

A fourth type of studies use aggregate population variables, such as workforce growth, to estimate the macro-economic impact. Productivity changes are estimated either at the industry or the national level. Most of these studies do not disaggregate the workforce by age (e.g., Bloom and Williamson 1998). One exception is Nishimura et al. (2002), who investigated technical progress and value-added growth in Japanese industries for the years 1980-1998. The workers in the sample are divided in four categories. There are two groups for age; those older or younger than 40; as well as two groups for education; those with college education or more and those with secondary school or less. They found that technological progress was positively associated with the share of workers of 40 years or older in the 1980s, while this relationship turned negative in the 1990s. No association was found for workers with low education.

Due to the aggregation level of the data, these studies are likely to contain larger measurement errors than, e.g., the matched employee-employer datasets (e.g., the share of workers from the different categories within each industry is estimated based on survey data). Furthermore, for the case of Nishimura et al.'s study, having only two age categories is not likely to capture the differences in age-specific productivity very well. Given that productivity peaks around 40 years of age, the result of categorizing age as younger or older than 40 may conceal age differences. The 40 years or younger group consists of both inexperienced labor market entrants as well as experienced, highly

[9] Andersson et al. (2002) propose that the reason why 30-39 year olds are not affecting productivity is that they are likely to be in a family raising situation.

productive workers, while the group of above 40 contains those who still have high productivity, as well as elderly workers with lower productivity.

There are also other approaches to measuring productivity. Kotlikoff and Gokhale (1992) assume that the present value of wages and pensions equals the actual productivity of newly hired workers. From data of a firm with 300,000 employees and observations from 1969 to 1983, they use the expected compensation for workers hired at different ages to construct a productivity profile. They find that the older workers are overpaid relative to their job performance, since their productivity declines while their wages rise. Some professions, such as sales workers, have compensation levels which are relatively close to their productivity, while managers are at the other end of the scale, with wages much higher than their productivity levels. This analysis contains some weaknesses, in particular those hired at older ages may be negatively selected.

6. Age-Earnings Profiles

The wage data presented in OECD (1998) show that for 17 out of the 19 countries observed[10], gross wages are found to reach peak levels for the 45-54 year old age group. The age-earnings profile is characterized by a relatively steep increase in wage levels until the peak is reached, followed by a mild reduction in earnings in the last years before retirement. The 25-29 year olds earn on average 0.72 of what the 45-54 year olds earn, while the 55-64 year olds earn 0.91 of the 44-54 year olds[11].

Age-specific wage differences increase with educational level. For individuals with less than upper secondary education, 25-29 year olds earned 0.81 times of what the 45-54 year olds earned, while for those with university education, 25-29 year olds earned only 0.53 times of what the 45-54 year old earned. A detailed presentation of how wages differ according to length of education is found in Willis (1986, p. 530). Here it is shown that an extra year of education causes the wage differentials over the life cycle to differ increasingly higher.

The general pattern is one with increasing wages from the entrance in the labor market until a peak of around 50 years of age is reached, followed by a modest decrease. This pattern seems quite robust, though the size of new cohorts entering the labor market has its effect, i.e., a relatively high number of new entrants tends to have a detrimental impact on the wages of young workers, since workers of different ages are imperfect substitutes[12].

According to labor market theory unemployment rates could increase in the short run, when the influx of new labor is relatively high. Martin and Ogawa (1988) present evidence which shows that the wage ratios of 20-29 to 40-49 year olds in Japan is reduced by 1% when the share of the former increases by 10%. But Shimer (2001) contradicts this study, by writing that an expected increase in the influx of new workers

[10] The countries in the study were Australia, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Sweden, Switzerland and the US. For the Czech Republic and the UK the wages peak for the 35-44 year olds.

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

[12] For an overview of the literature on the substitutability between workers from different age groups, see Disney (1996, pp 159-174).

can be beneficial even for young workers. He argues that the entry of relatively high numbers of new workers into one US state in comparison with other states is associated with increased labor force participation rates and decreased unemployment levels. Further, OECD (1998) provides evidence that the wages of 25-29 year olds relative to 45-54 year olds have decreased in the period 1980-1995, despite of smaller entry cohorts.

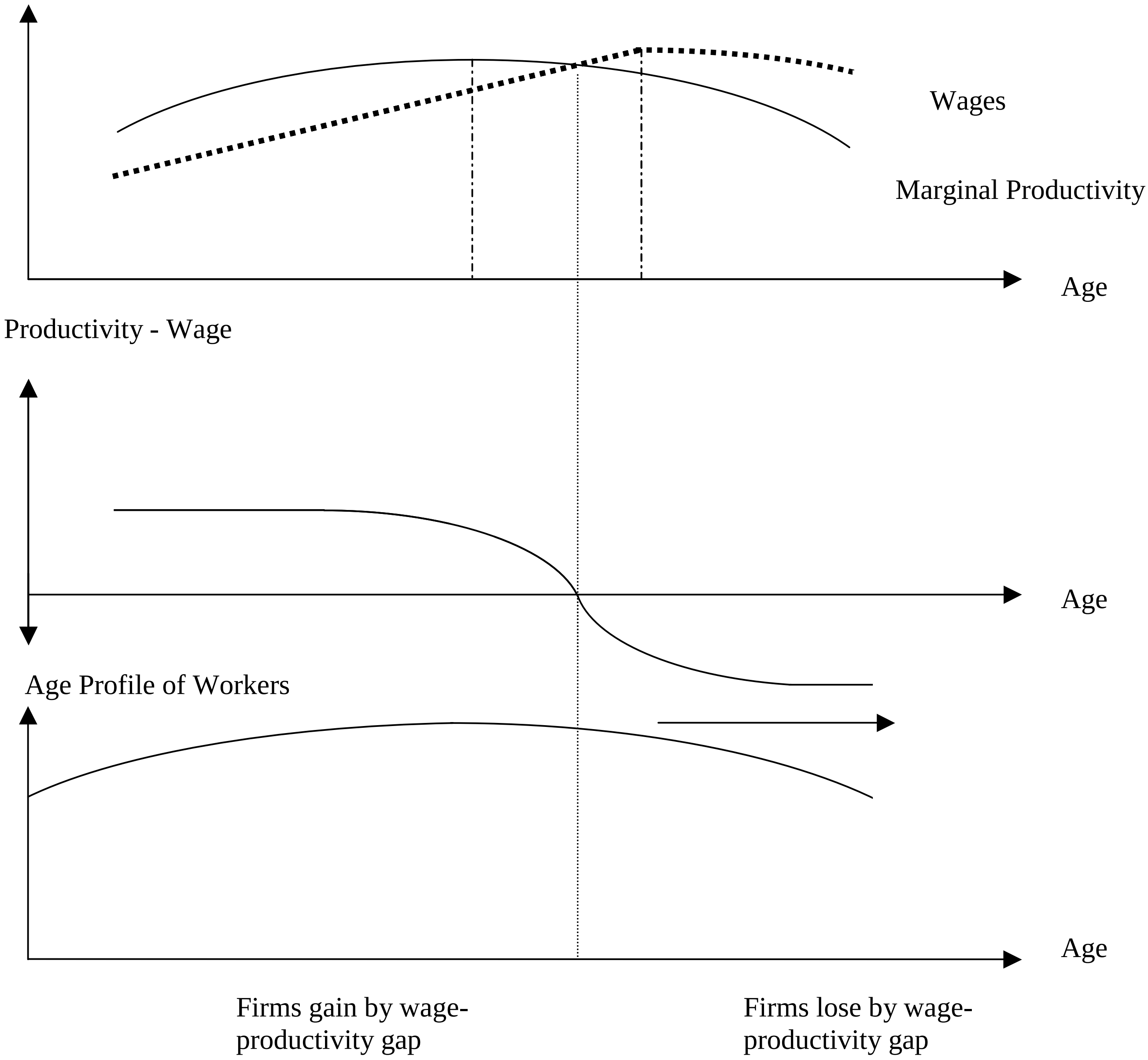
7. A Wage-Productivity Discrepancy

Based on the findings from the previous sections, a gap between productivity and wages in later adulthood seems to be evident, where wages continue to rise after productivity has fallen. In a labor market where there are short-term employment contracts, this discrepancy may be a symptom of inefficiency, since productivity levels are not matched by the wages.

But in the case of long-term contracts, the wage productivity gap may be efficient. The discrepancy between wages and productivity, where the young are underpaid and the old are overpaid, is not necessarily a market failure when firms are uncertain about their employer's true productivity, when they seek to increase loyalty or when they seek to reduce their moral hazard. Both Harris and Holmstrom (1982) and Lazear (1979) present theories that attempt to explain why marginal productivity may differ from wage rates in models with perfect competition. Harris and Holmstrom argue that the wage-productivity gap is caused by uncertainty about the workers' capabilities, and that the gap narrows as the employees prove their actual capacity by working. According to Lazear, the wages of older workers are higher than their marginal productivity since older workers should not under-perform due to moral hazard. If their income levels is reduced, they will "cheat", i.e., perform below their potential, since they are less worried about losing their job. If the wages are sufficiently high, workers will remain in their jobs and perform better also at older ages, since the costs of cheating increases, as they risk losing their well-paid jobs.

Salop and Salop (1976) argue that higher wages due to seniority are an outcome of successful matching in the labor market (a productive worker gets a particular job). In order to keep costs associated with turnover and training low, the firm will pay higher wages to those with long tenure. Another argument is that it would be in the company's interest to keep good workers. When workers expect a long period of income increases, their employer loyalty increases. Wage rates that are lower than productivity levels at young ages and higher at older ages make the workers stick to their company, since they know that their wages will eventually be higher than the value of what they produce.

Figure 2. Productivity and wages across the life span. Based on Lazear (1979) and Jackson (1998).



···· = Wages

—— = Marginal Productivity Value (MPV)

A = Ability Peak

M = Wage Peak

In the stylized situation of Figure 2, wages are lower than productivity levels at young ages and higher at older ages. This leads to a situation where firms will loose from hiring older workers, and profit from employing the young.

If the average age of the workforce is sufficiently young, firms will benefit from the wage-productivity gap. But when the labor force is ageing, the profit decreases and eventually becomes negative. Therefore, firms have incentives to tighten the wage-productivity gap for older workers. But because of rigidity in the labor market, and since paying older workers' high wages levels can increase the loyalty of younger workers, it will be in the firm’s interest to uphold the implicit contract between employers and employees. Therefore, retiring the older workers prematurely may be the solution firms will opt for.

To sum up, one can argue that the discrepancy between wages and productivity may reduce the employment opportunities of elderly workers. It generates pressure to exclude older workers from the labor market, since they cost more than they produce. Furthermore, this can make it harder to increase the age of exit from the labor force, since employers will prefer to get workers with a more beneficial productivity to wage ratio.

8. Conclusion

Different studies that analyze the influence of age on individual productivity use different indices to assess the performance of the workers. Some studies that are solely based on supervisors' opinions are argued to show low credibility, in particular when assessing the impact of the worker’s age. Other approaches, such as measuring the marginal effect on the firms’ value-added of workers from various ages, can be more valid. Most studies find either a relatively flat productivity profile, or one which indicates a decrease in performance for senior workers. This is contrasted by age-earnings profiles, which tend to increase through most of the working life. These findings suggests that the trend in wage growth is similar to the trend in productivity growth for young employees (though the wage levels are probably below productivity levels), but that wage increases cease to reflect productivity changes at later stages in the working life.

An important cause of these age-related productivity declines is likely to be the development of the cognitive abilities over the life span. Key findings from literature indicate that declines in several cognitive abilities take place for adult individuals, but whether the onset of the decline happens early or late in adulthood is a debated issue. Some abilities, such as perceptual speed, are found to be show large decrements even from a younger age, while others, such as verbal abilities, do not decline for most of the adult life.

Increases in life expectancy and better health at older ages have, for the last decades, been accompanied by earlier retirement ages[13]. Thus, there has been an

[13] For most OECD countries the approximate retirement age, or the “average age of transition to inactivity”, was found to lie between 57.6 to 63.6 years for men in 1995. For women, the retirement age was in the range of 54.1 to 62.1 years. Exceptions are Japan and Iceland, where the retirement age for men was 66.5 and 69.5 years, respectively. In Turkey and Japan the retirement age for women was 66.6 and 63.7 years, respectively (Blöndal and Scarpetta, 1999).

increase in the number of years that healthy individuals spend outside the workforce. This represents a massive reduction in aggregate productivity for the nations affected, even if older workers produce less than younger workers. Output is decreased by not employing elderly workers, and the higher fiscal spending associated with ageing populations increases, since elderly individuals working expand the tax base and decrease pension payments. Estimates of reductions to output caused by low labor force participation rates are found in Herbertsson and Orszag (2001). They apply a simple model to investigate the economic costs of low labor force participation among the elderly, and find that potential GDP was reduced by an OECD average of 6.3% in 1998 due to early retirement ages.

Encouraging 'active ageing'; increasing labor market participation of older individuals, is an emphasized policy in most aging economies. The productivity loss associated with early retirement indicates that this emphasis is entirely justified. However, active aging policy should take into account that older individuals tend to be different than younger ones with regards to job performance. The former may learn at a slower pace, be less flexible, and have reduced memory as well as reasoning abilities. Furthermore, they may have particular difficulties in learning new ways of working as well as adjusting to new fields. The likelihood that active ageing policies will be successful increases with the awareness of these issues.

Retirement ages decreased between 2.7 to 7.3 years for men and 2.6 to 8.4 for women in the period 1950-95, with some exceptions (in Japan and Iceland the male retirement age changed by -0.7 and 0.7, respectively, while for females the Irish retirement age changed by -10.7 years, the Japanese by –0.9 and the Swedish retirement age by -1.3 years).

References

Andersson, B., B. Holmlund and T. Lindh (2002): "Labor Productivity, age and education in Swedish mining and manufacturing 1985-96" (Preliminary Results), Uppsala, Sweden.

Altonji, J. G. and R. M. Blank (1999): "Race and Gender in the labor market", Ch. 48 in Ashenfelter, O. and D. Card: *Handbook of Labor Economics*, Vol. 3, Elsevier Science B.V.

Baltes, P.B. and U. Lindenberger (1997): "Emergence of a powerful connection between sensory and cognitive functions across the adult life span: A new window to the study of cognitive aging?" *Psychology and Aging*, 12, pp 12-21.

Barrett, G. V. and R. L. Depinet (1991): "A reconsideration of testing for competence rather than for intelligence " *American Psychologist*, 46, (10), pp 1012-1024.

Bishop, J. (1991): "Achievement, test scores, and relative wages" in Kosters, Marvin H. (1996): Workers and their wages, Washingtion DC, AEI Press 1991.

Blanchet, D. (2001): Does Population Ageing Call for Large Adjustments in Training or Wage Policies?" Paper presented at the "Ageing, Skills and Labor Markets" INSEE/CEPII Conference, Sept. 7-8 2001.

Bloom, D. E. and J. G. Williamson. (1998): "Demographic Transitions and Economic Miracles in Emerging Asia" The World Bank Economic Review, 12, 3, pp 419-455.

Blum, J. E., L. F. Jarvik and E. T. Clark (1970): "Rate of change on selective tests of intelligence: A twenty-year longitudinal study of aging" *Journal of Gerontology*, 25, pp 171-176.

Blöndal, S. and S. Scarpetta (1999): "The Retirement Decision in OECD countries" Economics Dept. WP No. 202, OECD

Boissiere, M, J.B. Knight and R.H. Sabot (1985): "Earnings, schooling, ability and cognitive skills" *American Economic Review*, 75, pp 1016-1030.

Collins, B. and Tellier, A (1994): "Differences in conceptual flexibility with age as measured by a modified version of the Visual-Verbal Test" *Canadian Journal on Aging*, 13, pp 368-377.

Crépon, B., N. Deniau and S. Perez-Duarte (2002): "Wages, productivity and worker characteristics: a French perspective" INSEE, Mimeo.

Currie, Janet and Duncan Thomas (1999): "Early test scores, Socioeconomic Status and Future outcomes", *NBER Working Paper* 6943.

Dalton, G. W. and Thompson, P. H. (1971): "Accelerating obsolence of older engineers", *Harvard Business Review*, 49, 5, pp 57-67.

Deary, I. J., L. Whalley, H. Lemmon, J. Crawford and J. Starr (2000): "The stability of Individual Differences in Mental Ability from Childhood to Old Age: Follow-up of the 1932 Scottish Mental Survey", *Intelligence*, 28, 1, pp 49-55.

De la Mare, G. C. and R. D. Shepherd (1958): “Aging: Changes in Speed and Quality of Work among Leather Cutters” *Occupational Psychology,* 32, pp 204-209.

Disney, R. (1996): *Can we afford to grow older? A perspective on the economics of aging,* MIT Press.

Dolton, Peter J. and A. F. Vignoles (2000): „The pay- off to mathemaics A- Level“ in C. Tikly and A. Wolf (eds.) *The maths we need now,* pp 52-73.

Flynn, J. R. (1987): “Massive IQ gains in 14 nations: What IQ tests really measure” *Psychological Bulletin,* 101, pp 171-191.

Ghiselli, E. E. (1973): “The Validity of Aptitude Tests in Personnel Selection” *Personnel Psychology,* 26, pp 461-477.

Grogger, J. T. and E. Eide (1993): “Changes in college skills and the rise in the college wage premium” *Journal of Human Resources* 30, no. 2 (spring 1993), pp 280-310.

Hægeland, T. and T.J. Klette (1999): “Do higher wages reflect higher productivity? Education, gender and experience premiums in a matched plant-worker data set. “ In Haltiwanger, J. L., J. R. Spletzer, J. Theeuwes and K. Troske (1999): *The Creation and analysis of employer-employee matched data*, North Holland.

Harris, M. and B. Holmstrom (1982): “A theory of Wage Dynamics” *Review of Economic Studies* 49, pp 316-33.

Hellerstein, J. K. and D. Neumark (1995): “Are Earnings Profiles Steeper than Productivity Profiles? Evidence from Israeli Firm-Level Data” *Journal of Human Resources,* XXX (1), pp 89-112

Hellerstein, J. K., D. Neumark and K. R. Troske (1999): “Wages, productivity and worker characteristics: evidence from plant level production function and wage equations” *Journal of Labor Economics*, 17, pp 409-446.

Herbertsson, T. T. and J. M. Orszag (2001): “The Costs of Early Retirement in the OECD” WP 01:02, May, Institute of Economic Studies.

Horn, J. L. Cattell, R. B. (1966): “Refinement and test of the theory of fluid and crystallized intelligence” *Journal of Educational Psychology,* 57, pp 253-270.

Horn, J. L. Cattell, R. B. (1967): “Age differences in fluid and crystallized intelligence” *Acta Psychologica 26,* pp 107-129.

Hoyer, W.J. (1998): "Aging and the development of learning", in M. A. Stadler (ed.) *Handbook of implicit learning*, Sage Publications, US, pp. 445-470.

Hunter, J. E. and Hunter, R. F. (1984): Validity and utility of alternative predictors of job performance” *Psychological Bulletin*, 96, pp 72-98.

Ilmakunnas, P., M. Maliranta and J. Vainiomäki (1999): “The role of Employer and Employee Characteristics for Plant Productivity” *WP-223, Helsinki School of Economics and Business Administration.*

Jackson, W. A. (1998): *Political Economy of Population Ageing,* E. Elgar Publishing Limited. United Kingdom.

Jenkins, Andrew (2001): “Companies’ Use of Psychometric Testing and the Changing Demand for Skills: A Review of the Literature”, Centre for the Economics of Education Working Paper”, LSE, United Kingdom.

Kate, R. D. and J. M. Perloff (1992): “Who works for Piece Rates and Why” University of California at Berkeley, Dept. of Agricultural and Resource Economics Working Paper: 627, p. 18, May.

Kotlikoff, L and J. Gokhale (1992): Estimating a Firm's age-productivity Profile using the present value of workers' earnings" *Quarterly Journal of Economics*, Nov, pp 1215-1242.

Kutscher, R. E. and J. F. Walker (1960): Comparative Job Performance of Office Workers by Age” *Monthly Labor Review,* 83 (1), pp 39-43.

Lazear, E. P. (1979): “Why is there Mandatory Retirement?” *Journal of Political Economy*, vol. 87, no. 6.

Mark, J. A. (1957): “Comparative Job Performance by Age” *Monthly Labor Review* 80, pp 1467-1471.

Martin, L. G. and N. Ogawa (1988): “The effect of cohort size on relative wages in Japan” in Lee, R. et al. (eds.) *Economics of Changing Age Distributions in Developed Countries.*

McEvoy, G. M. and W. F. Cascio (1989): “Cumulative Evidence of the Relationship Between Employee Age and Job Performance” *Journal of Applied Psychology*, Vol. 74, No. 1, pp. 11-17.

Medoff, J. L. and K. G. Abraham (1981): "Are those paid more really more productive? The case of experience" *Journal of Human Resources*, XVI (2).

Murnane, J. R., J. B. Willett and F. Levy (1995): “The Growing Importance of Cognitive Skills In Wage Determination” *Review of Economics and Statistics*, no. 77.

Murnane, J. R., J. B. Willett,, and Y. Duhaldeborde and J. H. Tyler (2000): “How important are the cognitive skills of teenagers in predicting subsequent earnings?” *Journal of Policy Analysis and Management* 19, no. 4, pp 547-568.

Nishimura, K. G., K. Minetaki, M. Shirai and F. Kurokawa (2002): "Effects of Information Technology and Aging Work Force on Labor Demand and Technological Progress in Japanese Industries: 1980-1998", Discussion Paper CIRJE-F-145, Faculty of Economics, University of Tokyo.

OECD (1998): “Work Force Ageing: Consequences and Policy Responses” *Maintaining Prosperity in an Ageing Society: the OECD study on the policy implications of ageing Working Paper*, AWP 4.1.

Park, D. C., R. E. Nisbett, and T. Hedden (1999): “Culture, cognition, and aging” *Journal of Gerontology,* 54B, pp 75-84.

Rothe, H. F. (1949): “The Relation of Merit Ratings to Length of Service” *Personnel Psychology* 2, Summer, pp 237-242.

Rybash, J. M., W. Hoyer and P. A. Roodin (1986): *Adult Cognition and Ageing,* New York: Pergamon Press.

Salop S. and J. Salop (1976): “Self-selection and turnover in the labor market” *Quarterly Journal of Economics* 90, November, pp 619-628.

Salthouse, T. (1984): “Effects of age and skills in typing” *Journal of Experimental Psychology*, General, 113, pp 345-371.

Salthouse, T. (1992): "Shifting Levels of Analysis in the Investigation of Cognitive Aging" *Human Development* 35, pp. 321-342.

Salthouse, T. (1996): "The Processing-Speed Theory of Adult Age Differences in Cognition", *Psychological Review*, Vol. 103 (3), pp 402-428.

Salthouse, T. and T. J. Maurer (1996): “Aging, Job Performance and Career Development” in J. E Birren & K. W. Schaie (eds.), *Handbook of the Psychology of Aging*, 4th ed., Academic Press Inc.

Schaie, K. W. and S. L. Willis (1986a): “Training the Elderly on the Ability Factors of Spatial Orientation and Inductive Reasoning” *Psychology and Aging*, Vole 1, No. 3.

Schaie, K. W. and S. L. Willis (1986b): “Can Decline in Intellectual Functioning be Reversed?” *Developmental Psychology*, Vole 22, No. 2.

Schaie, K. W. (1958): “Differences in some personal characteristics of "rigid" and "flexible" individuals” *Journal of Clinical Psychology*, *14*, pp 11-14.

Schaie, K. W. (1994): “The Course of Adult Intellectual Development” *American Psychologist*, 49, pp 304-313.

Schwartzman, A. E., D. Gold, D. Andres, T. Y. Arbuckle and J. Chaikelson (1987): “Stability of Intelligence. A 40 year follow-up.” *Canadian Journal of Psychology*, 41, pp 244-256.

Sharit, J., and S. J. Czaja (1994): “Ageing, Computer-Based Task Performance, and Stress: Issues and Challenges” *Ergonomics*, 37 (4), pp 559-577.

Shearer, B. (1996): “Piece-rates, Principal-Agent Models, and Productivity Profiles: Parametric and Semi-parametric Evidence from Payroll Records” *Journal of Human Resources* 31 (1996), pp 275-303.

Shimer, R. (2001): “The Impact of Young Workers on the Aggregate Labor Market” *Quarterly Journal of Economics*, 116, pp. 969-1007.

Stockford, L. and H. W. Bissell (1949): “Factors Involved in Establishing a Merit-Rating Scale” *Personnell*, Summer, pp 94-116.

Thurnstone, L. L. and T.G. Thurstone (1963): *SRA Primary Abilities*, Chicago: Science Research Associates.

Tyler, J. H., R. J. Murnane, J. B. Willett (2000): “Do the Cognitive Skills of School Dropouts Matter in the Labor Market?” *Journal of Human Resources* 35(4), pp 748-754.

Verhaegen, P. and T. Salthouse (1997): “Meta-Analyzes of Age-Cognition Relations in Adulthood: Estimates of Linear and Nonlinear Age Effects and Structural Models” *Psychological Bulletin*, Vol. 122, No. 3, pp 231-249.

Waldman, D. and B. J. Avolio (1986): "A meta-analysis of age differences in job performance" *Journals of Applied Psychology,* 71, pp 33-38.

Warr, P. (1994): "Age and Employment" in H. Triandis, M. Dunnette and L. Hough (eds.): *Handbook of Industrial and Organizational Psychology,* 2nd Ed, pp 485-550, CA: Consulting Psychologist Press.

Welford, A. T. (1958): *Ageing and human skill*. London: Oxford University Press.

Willis, R. J. (1986): "Wage Determinants: A survey and Reinterpretation of Human Capital Earnings Functions" ch. 10 in O. Ashefelter and R. Layard (eds.) *Handbook of Labor Economics*, Vol. 1.

Willis, S. L. and P. B. Baltes (1980): "Intelligence in adulthood and aging: Contemporary issues" in L. W. Poon (ed.) *Aging in the 1980s,* Washington D.C. American Psychological Association, pp 260-272.

Willis, S. L., & Schaie, K. W. (1998): Intellectual functioning in midlife. In S. L. Willis & J. Reid (Eds.), *Life in the middle,* San Diego, CA: Academic Press, pp. 233-247.