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Age and Productivity Capacity: Descriptions, Causes and Policy Options

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Abstract

This article reviews how work performance differs over the life cycle by describing and discussing findings from various approaches. This includes managers' evaluations, the quantity and quality of goods and services produced by workers of different ages, the performance of age-mixed teams, to what extent the age distribution of employees depends on the type of work and how the age distribution changes due to technological change and business cycle shocks, analyses of employer-employee datasets, descriptions of age-earnings profiles in settings where they could reflect performance and the output of researchers and artists over the life cycle. The causes of productivity variation by age are also considered, with a particular focus on experience and cognitive abilities. The findings suggest that productivity tend to increase during the initial years in the labour market before it stabilizes and often declines towards the end of the working life. Productivity reductions at older ages are strongest in job tasks where problem solving, learning and speed are important, while for work tasks where experience and verbal abilities matter more, there is less or no reduction in productivity among elderly workers. Trends in the age-productivity relation are discussed in relation to changing work tasks and job requirements, combined with changes in the requirement of skills (decline in demand for physical strength, increase in the need to learn new skills). Policies that could be considered to raise productivity among senior workers include on-the-job training, education and promotion of health. However, a later retirement could also raise incentives to update one's own skills and work harder at older ages (which may be achieved through pension reforms and wage liberalisation). Moreover, a better age-mix in the workplace, allowing older and younger individuals to benefit from their comparative advantages, is likely to improve overall productivity in ageing nations.

Introduction

Extending the working life is a popular response to population ageing in order to maintain economic prosperity and sustainability. To achieve this, various policies are being considered, including changes in age-specific pension entitlements and age-discrimination laws (in particular, repealing laws for dismissing older workers without justification). However, attempts to extend the age at retirement will only be effective to the extent that productive employment can be extended. This is important in order to ensure that increased retirement age does not simply translate into periods of unemployment. In this context, taking age-specific productivity into account is necessary in order to understand which policies individuals and governments could undertake to increase the retirement age.

The Shape of the Age-Productivity Curve

Identifying exceptional achievement at early or late ages is not difficult. For example, Goethe published the second part of Faust only in 1832 when he was 82 years old, while James Watson discovered the DNA molecule in 1953 at the age of 25 with a few remarkable findings afterwards. Classic texts in the age-performance literature, such as Crichton-Browne (1905) and Osler (1906), are biased as they focus on exceptional performance by either senior or younger individuals to support their hypotheses of either an early or late productivity peak. Moreover, they only look at age performance among a small creative elite and use this to infer age variation in performance for the population as a whole.

Classic studies of elite achievement by researchers, innovators and artists by age tend to suggest that productivity peaks in the 30s and 40s, with substantially lower output at younger and older ages, also when quality (e.g., journal article citations) is controlled for (Lehman, 1953; Cole, 1979; Simonton, 1988; Miller, 1999; Kanazawa, 2003; Oster and Hamermesh, 1998). Further evidence suggesting that there is a negative association between scientific output and age from relatively early in adult life is given in studies of economists and scientists by Bayer and Dutton (1977) and Bratsberg *et al.* (2003). However, a relatively flat output profile for individuals aged 30–59 for 19^{th} century scientists is found by Dennis (1956), and for a limited sample of 20^{th} century researchers by McDowell (1982).

Nobel Prize Laureates do their most important contributions in their 30s, according to a study by Jones (2005). The onset of the most innovate age phase, however, increased by about 6 years over the 20^{th} century (which he suggests could be due to a longer training period as the knowledge base has expanded). The decline in innovative output, however, is found to be age specific and constant which implies that the plateau of peak performance has narrowed over time.

Entrepreneurial activity, start-up of new firms or expansions of existing ones, are more likely to be carried out by relatively young adults, according to findings from the 34 countries surveyed in the Global Entrepreneurship Monitor (GEMConsortium, 2004). Peak entrepreneurial activity is found among individuals aged 25–44. In support of a young entrepreneurial peak, Aubert *et al.* (2007) find, in a French study, that the more innovative a firm is, the higher the wages of younger employees are relative to wages of other age groups.

In order to describe age variation in performance of the average worker rather than elite groups, one needs a different set of productivity measures. Supervisors' ratings are often used to identify the relation between the employee's age and his or her productivity. McEvoy and Cascio (1989) review 96 studies on the impact of the employee's age on supervisors' assessment and sales records and find no clear effect of age on productivity. Likewise, reviews by Warr (1994) and Waldman and Avolio (1986), based primarily on supervisor assessment, find no or a slightly negative impact of age on job performance. However, Remery *et al.* (2003) find that older individuals are seen as less productive in particular in firms with a higher proportion of senior workers, which is where knowledge about older individuals' work capacities is likely to be highest, in a survey 1007 Dutch personnel managers.

A general problem with most approaches used to measure age variation among workers is the sample selection problem. Good workers get promoted, while inefficient workers may lose their jobs. Hence, positive selection can increase by age, which could lead to bias in the estimates of the oldest age groups' working capacity. Self-assessed "work ability" is sometimes considered, and estimates from Finland suggest a clear decline by age of workers (van Ours *et al.* 2007). Solem (2006) presents evidence from Norwegian surveys on subjective general work ability that shows a decline from the 30s to the 60s. Nevertheless, respondents believe that they are equally capable of performing their work over the same age interval; although general work ability declines with age. This may be because relevant abilities are fully maintained and the worker is increasingly well matched to the type of work task he/she performs. A particular problem with managers' ratings and self-evaluations is that these evaluations can be biased as they are subjective. Evaluations of older workers could therefore be inflated due to loyalty concerns and as a reward for past achievement – or in the case of self-reports, as a means of self-justification, or even self-degradation. Discriminatory attitudes among managers towards older or younger individuals can also affect an age-productivity estimate, which reduces the validity of this approach (Levy, 2003; Salthouse and Maurer, 1996).

Measuring the impact of age on job performance is sometimes based on measures of the quantity and quality of a worker's output. Studies based on this approach tend to find that older employees have lower productivity levels. A study of a several industries from the U.S. Department of Labor (1957) finds that job performance increases until the age of 35 and steadily declines thereafter. At the end of the career, productivity declines by 14% in the men's footwear industry, and 17% in the household furniture industry. Czaja and Sharit (1993) investigate the extent to which age has an impact on computer-based work performance and find that increased age was associated with longer response times and a greater number of errors for all tasks considered. These task-quality/speed tests are potentially more objective as they do not rely on subjective assessment. However, they may be biased 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 what they would be able to do in a normal job situation (Salthouse and Maurer, 1996).

A recent estimation approach is based on analyses of employer-employee datasets (e.g., Gelderblom and de Koning, 2002; Hægeland and Klette, 1999). A key strength of these estimates are the large samples, which can encompass most workers in some of the main industries in a country; several samples include a few million individuals and thousands of firms. The most common finding from these studies is a hump-shaped relation between job performance and age. An overview over analyses of the effect of age on productivity using employer-employee datasets are given in the Annex. Of the 14 studies considered, 11 find a productivity decline in the 50s relative to the 30s and 40s, two have inconsistent results, while one finds that productivity peaks among the oldest workers. However, bias may come from the fact that many determinants of a firm's value-added, such as capital levels, are either omitted or poorly measured. The reverse causality problem could also be an issue – a company's success can increase the number of new employees and lead to a younger age structure, which could mean that a young age structure could be the consequence rather than the cause of a company's success.

Wages are often determined by other factors than individual contribution to the firms' value-added, including the role of unions, uncertainty about new workers productivity and delayed payment contracts where performance while being young results in higher earnings for those still employed while they are older (Agell and Lundborg, 1995; Freeman, 1982; Hutchens, 1989). Age-earnings profiles can, however, provide information on productivity differences in settings where wages are likely to reflect actual 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. Kotlikoff and Gokhale (1992) study age-variation in the wages offered when firms hire new employees. Their findings suggest managers have earliest productivity maximum, while office and sales-workers have somewhat older peaks, though they all reach their highest productivity in the 40s, with sharp declines thereafter.

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 analyzed here, men reached their peak earnings in their early 30s, and wages decreased substantially from around 40 years of age. In a similar study, Johnson (2003) looks at British manual workers earnings from the 1830s to the 1930s, and finds a stable age-earnings pattern where wages reach their peak in the mid-30s and remain stable or decline slightly thereafter.

Labour force attachment trends can also reveal information about age differences in productivity. If older workers cope less well with changes in the workplace, then rapid changes should affect them worse than younger age groups. Bartel and Sicherman (1993) put forward evidence that the risk of job loss is in fact greater among older workers when the rate of technological change is highest. This finding is also supported in studies based on inter-sectoral data (Ahituv and Zeira, 2000). Technological improvements may also disproportionally benefit the young, and in a study of German firms, Hujer and Radic (2005) find that older highly-skilled workers benefit less from technological improvements compared to the younger highly-skilled.

Age diversity has been suggested to have a positive effect on productivity through better "age-matching" between salespersons and customers and through complementarity of different age groups, but the evidence seems inconclusive. Experimental research suggests cooperation is highest when juniors and seniors are mixed together (Charness and Villeval, 2006). However, Leonard and Levine (2003) considered 800 retail stores employing 70,000 individuals and found that age diversity was negatively related to sales. Hamilton *et al.* (2004) studied the productivity of workers in a garment plant that had shifted from individual piece rate payments to team piece rate payments, and again found that greater diversity in age was associated with lower productivity gains. A European study on age diversity suggests that while in a German car assembly plant, age diversity increases the probability of calling in sick, evidence from Finnish firms show a positive effect of age diversity (van Ours *et al.* 2007). Van Ours *et al.* suggest that this seeming contradiction is due to different levels of observation, where age diversity at the team level (German case) may be negative (as age diversity may imply impeded communication), while diversity at the plant level (Finnish case) may mean that in some parts of the plant (e.g., management) there are many older (wise, experienced) workers while in other parts (e.g., production), there are many younger (fit, flexible) workers. Hence, complementarity at the firm level may well be consistent with the lack of it at the team level.

Several macroeconomic investigations find a relation between national/regional age structure and economic growth. However, results diverge and while Brunow and Hirte (2006) find that 30–44 year olds boost per capita output growth across European regions, Feyrer (2005) finds that the 40–49 year old age group is the strongest associated with productivity growth using a large panel of developed and developing countries, while Lindh and Malmberg (1999) and Malmberg and Lindh (2002) find that the share of 50–64 year olds is associated with economic growth in the OECD from 1850–1990. Moreover, Tang and MacLeod (2006), using Canadian regional data, suggest that older workers have a modest negative impact on productivity growth, while Nishimura *et al.* (2002) find that the share of well-educated workers above 40 years raised technological progress in the 1980s, but decreased it in the 1990s when investigating technical progress and growth in Japan 1980–1998. It is not clear why certain relations between the age structure and economic growth levels exist. They could be due to other factors than age variation in work performance, such as high savings levels among certain age groups (i.e., higher capital levels could raise growth) or omitted factors in the regressions (which both affect economic growth as well as mortality, fertility or migration levels).

Causes of Age Variation in Work Performance Relation

Workers' productivity levels differ by age for many reasons, including the length of work experience, cognitive functioning, education, physical abilities, stamina, health, family and care obligations, motivation, energy, matching of the worker to the task, loyalty and personality.

Average muscle strength decreases by roughly 10% per decade for ages 20–60, by approximately 15% each decade for ages 60–80, and 30% each decade after age 80 (Mazzeo, 2000). De Zwart *et al.* (1995) show that aerobic capacity peaks somewhere in the 20s and declines by around 1% per year. Flexibility decreases with age, which makes it difficult to adopt certain working positions (Bosek *et al.,* 2005).

Moreover, cognitive skills have been shown to be increasingly important to work tasks over time, as both the work intensity and the industrial composition change over time, while physical strength is becoming decreasingly important (Broadberry, 1997; Spitz-Oener, 2006; Skirbekk, 2008). Cognitive ability test scores have been found to be more closely correlated with labour market performance than any other observable characteristics among job candidates (Schmidt and Hunter, 1998).

Some cognitive abilities decline with age, while others tend to be relatively robust over the life cycle. A division can be drawn between crystallised abilities, which remain at a high functional level until late in life, and fluid abilities, mental abilities that are strongly reduced over the life span (Horn and Cattell, 1966; Verhaegen and Salthouse, 1997). Crystallised abilities depend on accumulated knowledge, and includes semantic meaning and vocabulary size. The second group, fluid abilities such as perceptual speed and reasoning abilities, tend to relate to performance and speed of solving tasks related to new materials.

Schwartzman *et al.* (1987) find that verbal skills (crystallised abilities) remain virtually unchanged at older ages, while reasoning and speed (fluid abilities) decrease from early adulthood, 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. A decline over the working life span in some mental abilities has been found to be similar for both men and women, and the same patterns are found across different countries and cultures (Maitland *et al.,* 2000; Park *et al.,* 1999). Furthermore, individuals with high ability levels are subject to the similar changes in cognitive functioning as those with low ability levels (Baltes and Mayer, 1999; Deary *et al.,* 2000). Age-related reductions in *memory* and *learning capabilities* have been documented among many non-human species, ranging from fruit flies to primates (Bunk, 2000; Minois and Le Bourg, 1997).

In some occupations, the cognitive abilities that remain stable are the ones most closely correlated to job success. Senior employees can remain highly productive within a field that they know well and where relatively long experience is beneficial. *Tacit knowledge*, procedural knowledge used to solve everyday problems, tends not to decrease at older ages. The age-robustness of this ability could explain why many older managers perform as good as younger ones (Colonia-Willner, 1998). However, when performing unfamiliar work, workers have to rely on the ability to learn and to adjust exactly those skills that decline most with age. Senior individuals are less able than young individuals to reorient themselves to new task requirements and to solve novel problems (Smith, 1996) and age-induced productivity reductions may increase with the complexity of new work tasks (Myerson *et al.,* 1990). Hence, staying within one field of expertise relates to high productivity, while changing between fields can lower productivity much more (e.g., Cole, 1979; Rybash *et al.,* 1986).

Experience is often quoted by employers as one of the most important determinants of job performance (Bellmann, 2007; Golini, 2004). Salthouse (1984) uses typists as an example of a profession where experience alleviates the impact of cognitive reductions. He finds that older typists compensate for their reduced speed through the use of more efficient work strategies compared to their younger counterparts. Ericsson and Lehmann (1996) argue that it takes roughly 10 years to achieve expert competence in games and situations where strategic and analytic competence is important, such as chess. The 10-year estimate is also 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).

A Norwegian survey (Econ, 1998) shows that only 0.6% of the employers preferred workers with a length of experience above 10 years. As the average age of entering the labour force in the OECD is in the early 20s (depending on educational levels, OECD, 1999), this would suggest that 99.4% of the employers find workers sufficiently experienced in the 30s, which would exclude experience as a major advantage between workers in the 50s and 60s compared to workers in the 30s and 40s, although all have an advantage compared to workers in their 20s. The increased prevalence and opportunity of part-time work increases the opportunities for active labour force participation among the elderly. These types of flexible work settings contrast the situation for assembly line workers in the past, where constant and continuous attention was needed.

Improving Productivity and Employment at Older Ages

Romans sometimes described old age as *mala aetas,* the bad age, and young age as *bona aetas*, the good age (Parkin, 2003). However, age-related changes to physique and mind have changed since Roman times, and cognitive and health deterioration takes place at increasingly later ages in contemporary societies. And surroundings have changed, where the introduction of technologies compensating declines in sensory and muscular capabilities, electric wheelchairs, more user-friendly computer systems, effective medicines against pain and hypertension and working at home opportunities allow one to continue to function professionally in older ages in a large number of work places.

There is evidence that mental abilities have improved over the course of the last century (Tuddenham, 1948; Flynn, 1987; Neisser, 1997). Improvement in cognitive skills have been found to also take place for individuals aged 50–79 during the last decades (Romeu Gordo, 2005) which is likely to be related to rapid growth in education and on-the-job training (Lutz *et al.*, 2007; Riphahn and Trübswetter, 2006). Individuals from younger cohorts are likely to be more trained and motivated when taking ability tests, as such tests are increasingly being used in job candidate selection processes (Jenkins, 2001).

Paralleling the sustained decline in mortality (which has taken place for at least two centuries in Northern Europe), disability-free life expectancies have increased (Crimmins *et al.,* 1997; Manton *et al.,* 1997; Lee, 2003; Romeu Gordo, 2005; Schoeni *et al.,* 2001). The morbidity decrease is partly related to less physically demanding work tasks. Costa *et al.* (1986) argues that 29% of the observed decline in chronic disease rates and 75% of the decline in back problems in the 20th century was caused by a shift to non-manual labour and a reduction in the physical load. Not only has work become less strenuous, but estimates put forward by Ausubel and Grubler (1995) suggest that in France, Germany, the UK, USA and Japan, the number of hours worked per year declined by at least a third from 1850 to 1987, which is likely to imply a substantial reduction in the health requirements to work.

To extend the productive working life at older ages, a government could follow many different policies. Taxes, earnings and pension systems need to be restructured in order to increase incentives for older individuals to continue to work rather than to retire. However, the question is not only about creating financial incentives for a long and productive working life, but also about the need to alter norms, beliefs and behaviour that affect labour force participation and work effort among seniors.

Many elderly would like to continue working when they reach retirement age, while employers are often hesitant to employ them, making it difficult to increase retirement ages. High costs are often seen as the main disadvantage of older workers (Golini, 2004; Munnell *et al.,* 2006). Pension payments and health insurance often increase by age, and as wages may not be adjusted for this, it implies that older individuals are costlier for firms (Scott *et al.* 1995). In firms with steep wage profiles and pension benefits, employment opportunities have been found to be worse for elderly in the US (Hirsch *et al.,* 2000), Hong Kong (Heywood *et al.,* 1999) and the UK (Daniel and Heywood, 2007).

For example, in Japan, it is customary for those who retire from a normal working career to enter a lower-wage but relatively prestigious second career in their 60s (Clark *et al.,* 2006). Ichino *et al.* (2006) find that when displaced older workers' minimum wages they are willing to accept fall faster than those of prime-age workers, they catch up in terms of employment. A comparison of earnings levels and employment rates across the OECD suggest that wage flexibility and willingness to accept lower wages relates to longer working lives (OECD, 2006).

However employers/governments also need to make fundamental changes to how they view older workers. Flexible retirement and part-time positions, improved career planning and more internal mobility, preventive measures and occupational health programmes could increase work productivity of the elderly (see Lindley *et al.,* 2006 for "good practice" examples). Age discrimination must end, job training opportunities should be given without age constraints, and age-specific dismissal legislation should be phased out. One could, if possible, reorganize to allow the elderly to perform work tasks where they have their comparative advantages, which is where experience, management and communication skills are important rather than tasks which require high processing speed and rapid reorientation.

More pensioners means that taxes need to be increased to support more pensioners, and higher taxes slow the creation of jobs. However, a change of norms is necessary, where a higher pension age should become the custom, and seen as necessary and fair. Further, beliefs that justify early retirement, e.g., that retiring early increases job opportunities for the young, should be abandoned. In countries such as the Netherlands, France, Germany, Spain, Italy and the UK, between 40% and 70% of the individuals agree that "older people should be forced to retire when jobs are scarce" (van Ours *et al.,* 2007).

If one expects a later retirement, one's training investment decisions are likely to change. A longer remaining working life implies that it will be optimal for individuals to invest more in updating skills and to increase work efforts at older ages. When the elderly expect to work longer, they will have incentives to invest more in training and to work harder. They will also continue to update, maintain and extend their professional networks, which will be easier if a larger proportion of the age group remains active. Socialising has been shown to be good for mental health and for many, particularly men, the work place is the key place to meet others (Cohen, 2004; Melchior *et al.,* 2003).

As the current population is likely to be urban, have sedentary occupations, and use motorized transport, exercise should be encouraged through increased availability of green space and sports facilities. More exercise can increase work capacity at older ages. James and Coyle (1998) find that regular exercise improves the working memory function among older men, while obesity has been found to have negative effects on cognitive performance net of education, occupation, cigarette smoking, alcohol consumption, total cholesterol, and a diagnosis of diabetes (Elias *et al.,* 2003; Geroldi *et al.,* 2003; Gustafson *et al.,* 2003).

Encouraging new nutritional habits and increased exercise could lower the negative impacts on productivity, such as absenteeism, disability, workplace injuries and health costs (Schmier *et al.,* 2006; Colditz, 1999). Cereals and fish, red wine or even aspirin could possibly strengthen cognitive functioning (Nilsson *et al.,* 2003; Solfrizzi *et al.,* 2003). Governments could also impose stronger non-smoking legislation, as smoking has been found to negatively affect cognitive functioning, also when adjusting for the negative selection of smokers (Deary *et al.,* 2003). Moreover, better system design can reduce computer problems for older workers (Czaja and Lee, 2007).

In spite of the seemingly unavoidable age-related reductions in cognitive abilities, targeted training programmes and engagement in complex work tasks may provide a way of halting the decline. Schooler *et al.* (1999) find that the degree of job complexity is associated with the level of mental functioning at older ages, which could be due to continued learning in the workplace. Schaie and Willis (1986) conclude that training 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. Katzman (1993) argues that participating in educational courses increases synaptic density in the neocortical association cortex, and could therefore delay the onset of dementia by up to 4–5 years. Using a British industry dataset from 1983–1996, Dearden *et al.* (2006) find that training is associated with productivity increases, and more so than what wage increases would suggest. Likewise, in separate studies of German firm panel-datasets, Zwick (2002) and Kuckulenz and Maier (2006) identify large productivity increases in response to the training of workers of different ages.

Conclusion

The evidence put forward in this article suggests that job performance often does decrease at older ages, but not for all work tasks and less so in occupations where abilities that do not decline by age are important. Moreover, the elderly's productive potential is likely to have increase over time as modern jobs decreasingly rely on strength, cognitive abilities and health of the elderly improve, and part-time flexible work arrangements have become commonplace. More training, better work organisation, and more flexible earnings systems could allow the elderly to benefit from their comparative advantages and effectively extend the working life. Changes in incentive systems, regulations and habits that lead to less smoking, better nutrition and more exercise could further decrease disability levels and raise cognitive functioning is likely to help increase work performance levels and labour force participation at older ages.

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Annex: Overview of employer-employee data sets

Authors	Region/ country	Sample size	Control variables	Productivity measurement	Age-productivity profile	Remarks
Aubert and Crépon (2004)	France	70,680 companies, >3,000,000 employees	Industry type	Firm's value added	Productivity peaks ages 40–44, stable or uncertain thereafter	Assumption: Senior workers employed in older less productive firms – otherwise they would be more productive
Barrington and Troske (2001)	US	11773 Manufacturing and 6736 Service firms	Education, gender, etnicity, occupational structure	Firms' Value added	Share of workers above 50 negatively related to productivity	Manufacturing and Services
Crépon *et al*. (2002)	France	77,868 companies, >3,000,000 employees	Gender, occupation, no. of hours worked Firm'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
Gelderblom and de Koning (2002)	Netherlands	431 firms	Full time workers	Firm's value added	Productivity peaks between ages 40–50 and declines afterwards .	Manufacturing and non-manufacturing
Grund and Westergård-Nielsen (2005)	Denmark	29863 firms	Gender, education, tenure, occupation, Firm size and age, type of industry	Firm's value added	Productivity peaks at age 37	
Hægeland and Klette (1999)	Norway	7,122 companies, 270,636 employees	Education, experience, no. of hours worked Companies' age, industry type, region, public ownership, foreign ownership	Firm's value added	Productivity peaks in the early 30s, declines in the late 30s	Manufacturing
Haltiwanger *et al*. (1999)	Maryland/U.S.	? (all companies in Maryland 1984–1997)	Gender, education, immigrant status Firm's age and size, industry type, period	Sales per employee	Workers aged 55+ have lowest productivity	All industries
Hellerstein and Neumark (1995)	Israel	933 companies	Occupation Industry type no. of employees, companies' capital and input factors R&D spending	Firm's output	Productivity peaks at 55+	Poor quality of data, large inflow of younger immigrants
Hellerstein and Neumark (2004)	U.S.	>3,101 companies, >265 412 individuals	Occupation, race, education, marital status. Capital, materials, region, no. of employees	Firm's output	Productivity highest for 35–54	Manufacturing
Hellerstein *et al*. (1999)	U.S.	3,102 companies, 128,460 employees	Gender, race, occupation, marital status, education No. of employees, region, type of establishment, industry type	Firm's output or value added	Productivity peaks at 55+ if output is used as estimate. Productivity lowest for 55+ if value added is used	Manufacturing
Ilmakunnas *et al*. (2004)	Finland	>3,882 companies, >279,181 employees	Education, experience, no. of hours worked Firm's age, capital	Firm's value added	Productivity peaks around age 40.	Manufacturing
Prskawetz *et al*. (2005)	Sweden	95,443 firms	Education, employment Firm's age and size, time	Firm's value added	Productivity peaks 30–49. Regional estimate peaks 50–59.	Mining and manufacturing
Prskawetz *et al*. 2007	Austria	34,375 companies 1,563,873 employees	Education, part-time work, gender, occupation. Firm size and age	Firm's value added	Productivity peaks 30–49	Mining and manufacturing
Schneider (2006)	Germany	1104 Manufacturing and 758 Service firms	Education, seniority, non-native, gender. Capital, size, technology, age, location	Firm's value added	Productivity peaks 35–44 for manufacturing, no consistent finding for service sector	Manufacturing and services