Université de Fribourg - Faculté de Sciences Ecomiques et Sociales

Université Lumière Lyon 2
Ecole Doctorale Sciences Ecomiques et Gestion

Groupe d'Analyse et de Théorie Economique

Ageing, Productivity, and Earnings: Econometric and Behavioural Evidence

Thèse de Doctorat

Présentée et soutenue publiquement par

Małgorzata Wasmer
de Varsovie (Pologne)

le 15 septembre 2011

en vue de l'obtention du grade de

Docteur ès sciences économiques et sociales
délivré par l'Université de Fribourg (Suisse)

et

Docteur en sciences économiques
délivré par l'Université Lumière Lyon 2 (France)

Directeurs de Thèse :

Thierry Madiès	-	Professeur, Université de Fribourg (Suisse)
Marie Claire Villeval	-	Directrice de recherche CNRS, Université Lyon 2 (France)

Jury :

Volker Grossmann	-	Professeur, Université de Fribourg (Suisse)
Rafael Lalive	-	Professeur, Université de Lausanne (Suisse) - Rapporteur
Stéphane Robin	-	Chargé de recherche CNRS, Université Lyon 2 (France)
François-Charles Wolff	-	Professeur, Université de Nantes (France) - Rapporteur

Fribourg, 2011

Acknowledgments

First and foremost, I would like to express my deepest gratitude to my thesis supervisors: Thierry Madiès and Marie Claire Villeval. I am sincerely thankful for their continuous supports, advices and encouragements, despite their very busy schedule. Additionally, I am very much indebted for the tremendous amount of trust and the constant source of inspiration they have provided throughout this challenging experience making it a real adventure. In particular, I would like to thank Thierry Madiès to have encouraged me to participate in the Doctoral Course in Gerzensee, as well as take part in numerous national and international research seminars and conferences. I am also truly grateful to Marie Claire Villeval for guiding me while taking my first steps in the fascinating world of experimental economics.

I would like also to express my gratitude to the committee members, Rafael Lalive and François-Charles Wolff for having accepted to referee my work, Volker Grossmann and Stéphane Robin for their presence in the jury and taking time to read my work.

This thesis would never have been completed without the financial assistance of the Chair of the Regional and International Economics and the Department of Economics at the University of Fribourg that enabled me to participate in international conferences. The grant for the "thèse en cotutelle" awarded by The Rectors' Conference of the Swiss Universities (CRUS) has been also highly appreciated.

I would like also to thank Sylvain Ferriol for designing the software used in the experiment conducted for this dissertation; Angélique Brut from GATE as well as Ph.D. students from Fribourg Tjaša Bjedov, Simon Schnyder and Eva Spring for their assistance during the experiment. In addition, I would like to address a special warm thank you to the employees of Crédit Suisse in Lausanne: Daniel Python, Anne Ray, François Magnenat and the participants of our experiment.

During my Ph.D., I also benefited from a research stay at the National Institute for Statistics and Economic Studies in Paris. This stay would not be possible without the hospitality of Didier Blanchet. I would like to thank, especially, Muriel Roger for our fruitful collaboration on the empirical paper, for her availability and priceless support. I would also like to thank Sébastien Roux and Anthony Briant for their valuable remarks and to Virginie Régnier for her assistance in the dataset construction.

I address a special thanks to Professors and Ph.D. students in Fribourg for their comments at different stages of my work during internal seminars. At the same time, I want to thank all the members of Group of Analysis and Economics Theory (GATE) for their hospitality and fruitful remarks during my research stays and seminars in Lyon.

In addition, I would also like to extend a very warm and special thank you to all my friends and colleagues at the University of Fribourg, particularly to Eva Spring, Tatiana Walther, Audrey Saumon, Sandra Daguet and Tjaša Bjedov for dispensing some much needed words of support and advice in many occasions. A very warm thank you to my real friend and partner in crime, Simon Schnyder, for his invaluable friendship, providing a stimulating research and pleasant social environment, and the great sense of humour.

The last but not the least, I would like to extend my heartfelt appreciation to my loving family, without whom my accomplishments would have no purpose or meaning. I am especially grateful for the endless support and encouragement given by my loving husband Kilian, and for having faith in me during the difficult stages of the project. During these stages, he has made all the difference and I am eternally indebted for being there for me. Finally, I thank my little sunshine, my son Raphaël, for making me look at everything from a different perspective.

Contents

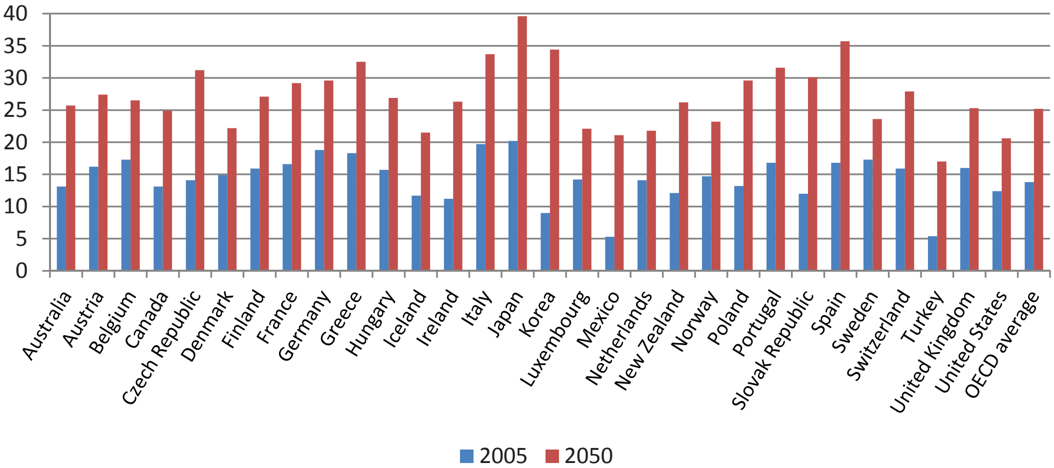
List of Figures

List of Tables

General introduction

The population of the developed countries is getting older. In 2050, one third of European population will be over 60 years old. There are two main factors responsible for this phenomenon. First, the rates of birth are well below the level necessary for the replacement of generations. In the OECD countries, fertility rates have gone down from 2.7 in 1970 to 1.6 in 2000, with a projected rough constancy for 2050. Second, the life expectancy continues to expand. Between 1950 and 2000, it has increased from 64 to 77 years and is projected to reach 83.5 in 2050. Moreover, the percentage of young (15-24) and prime-age persons (25-49) is progressively decreasing, while the share of older generations continues to rise. The share of population aged 65 and over is expected even to double by 2050 (see Figure 1) (OECD, 2006).

Figure 1: Ageing populations: Ages 65+ in OECD countries, 2005, 2050 (in %)



Source: OECD (2007)

In particular, the ageing population bears important consequences for labour markets, affecting the quantity and the composition of the labour force. Actually, the observed increasing life expectancy has not been accompanied by longer working lives. The changes in age-specific labour force participation rates generate, on the one hand, shrinking of the active population and, on the other hand, an increase in the average age of employees. Over the recent decades, due to prolonged education and, hence, later entry into the labour market, we have observed a decrease in labour force participation of young people. Within the European Union, the number of workers aged 20-29 is projected to decrease by 20 % while those aged between 50 and 64 will increase by 25 % over the next two decades (*The Economist, 16.02.2006*). The future economic output will need to be generated by relatively smaller and older labour force. Furthermore, once the baby-boom generation approaches retirement age, increasingly large cohort of workers will be retiring relative to the number of new labour market entrants available to replace them. Hence, one of the major concerns of public policy became a financial sustainability of the current social security systems regarding pension, health and elderly care.

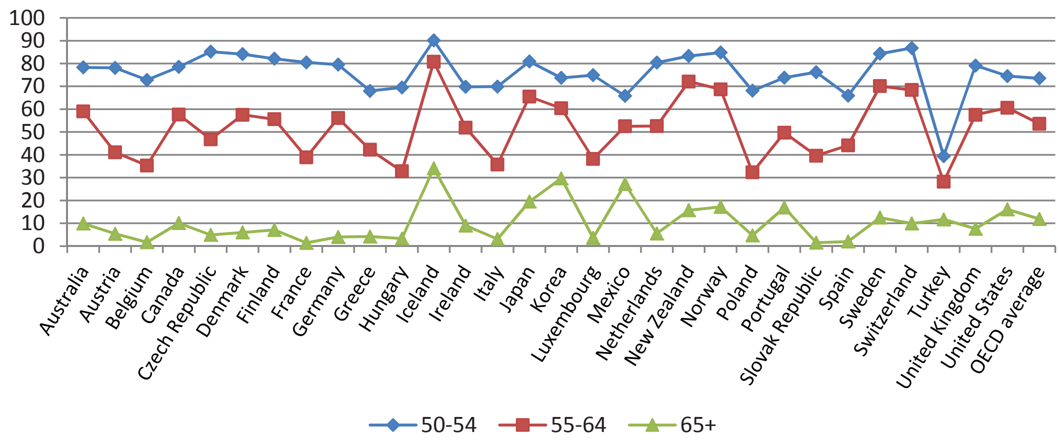
The problem seems to be further aggravated by the fact that an increasing number of older workers exit earlier from the labour market. Over the 80s and 90s, in many European countries, policy makers have argued that early retirement would improve job prospects for the young unemployed or create promotion possibilities for younger workers. This may have happened only if older and younger workers were substitutes. However, this hypothesis has not been confirmed by the empirical studies (Kalwij et al., 2009). In practice, the earlier exit of seniors from the labour force did not bring about the expected increase in the employment of the young. Entry and exit flows did not occur in the same sectors, companies or occupations. Early retirement schemes have been popular in the industrial sector and in industrial occupations in big firms, whereas entries have been much more concentrated in the services sector, services sector occupations and smaller firms (Auer and Fortuny, 2000). Moreover, generous early retirement provisions of the social security system not only encouraged 'voluntary' early retirement but also induced firms to push more employees into early retirement (Desmet et al., 2005; Smith, 2006). The share of 'involuntary' exits has been particularly high in the countries with low labour market participation rates of older persons. Over 50 % of the early retirees in Germany and Portugal, and over 40 % in France, state that their retirement was 'not by choice' (Dorn and Sousa-Poza, 2010).

Overall, the average effective age of retirement is well below the official age for receiving a full-age pension in many European countries. Men on average are still working at age 65 in Denmark, Iceland, Ireland, Portugal and Switzerland, but have retired by their 60th birthday in Austria, Belgium, France, Hungary, Luxembourg and the Slovak Republic. Women, in general, retire around one to two years earlier than men (OECD, 2009). In order to avoid an unsustainable increase in retirement dependency ratio, the policy makers try to discourage early retirement. A call for prolongation of a working life by raising the eligibility age to collect retirement pension is now on the political agenda of many countries. However, one of the consequences of required increase in labour force participation of elderly and a rise of the retirement age will be the acceleration of the ageing process of the labour force. In fact, the rapid increase in the older population combined with an increase in retirement age will result in a large increase in the number of older employees.

These very unusual in the perspective of recent decades demographical changes, accompanied by the undertaken political measures, will have serious repercussions at the micro level of the economy, namely on the enterprises who will be obliged to adjust to a serious shift in the composition of their workforce. It is still uncertain how easily an important increase in the supply of older workers will be accommodated by the firms. Large adjustment costs for the employers will concern also managing an increased number of workers willing to retire, and, at the same time, trying to recruit from a shrinking pool of labour. This process will certainly lead to labour shortages in certain domains. In this context, the prolongation of a working life may constitute a chance for the employers in a sense to enable them to keep longer the valuable workers. Over recent years, an increasing number of organisations and firms have realised that early retirement of older employees deprives companies of valuable expertise and creates a shortage of qualified employees (Worth, 1995; Munnell et al., 2006; Smeaton and Vegeris, 2009).

Nevertheless, the available evidence indicates that in many developed countries despite a political calling for an increase in employment level of the elderly, older workers continue to confront unfavourable labour market conditions compared to the other age groups. The seniors who experience age discrimination meet barriers to recruitment and hiring, diminished conditions of work and employment as well as limited career development (Macnicol, 2006; Ghosheh, 2008). Moreover, they tend to occupy a relatively low status in the labour market and are disproportionately represented among the long term non-employed (Walker, 2005; OECD, 2006). Consequently, the employment and hiring rates of older workers stay at a very low level. Figure 2 presents the employment rate of elderly people, aged 50 and more, in Europe and in the OECD countries.

Figure 2: Employment/population ratio of older workers in OECD countries (in %)



Source: OECD Statistics (2009)

The 2006 OECD report ("Live longer, work longer") has identified three main types of barriers that make employers reluctant to hire or retain older workers: 1) negative perceptions about the adaptability and productivity of older workers, 2) labour costs that rise steeply with seniority or age, and 3) strict employment protection rules. In fact, the negative image of older employees, which may lead to prejudices, is still quite common among the employers. An increase in the workforce's average age is frequently associated with higher labour costs as well as greater resistance to technological developments and only rarely with an expected increase in productivity (Brooke and Taylor, 2005; Remery et al., 2003; Johnson, 2007). Although employers appreciate older employees' experience, loyalty and low turnover, nevertheless younger workers are preferred when it comes to actual hiring decisions (Guest and Shacklock, 2005). Moreover, an ageing workforce is expected to lead to a strong increase in wage costs. Actually, in most countries, earnings tend to increase with worker's age and the last earned salary is generally the highest. So long as wages correspond to productivity at all ages, employers will find it profitable to employ older workers. However, if senior workers' wages exceed their productivity levels, older workers will represent losses for the companies (Skirbekk, 2003). Though, seniors constitute potentially very valuable resource for the employers. Thanks to the intergenerational transfer of know-how, the companies could make use of the complementary, age-specific skills of younger and older workers by setting up age-mixed teams and in this way maximise the human resource potential in a company (Joe and Yoong, 2004; Brooke and Taylor, 2005).

Consequently, the relationship between the age structure of workforce, earnings and productivity profiles is a key issue for the enterprises facing the phenomenon of ageing. The better understanding of this relationship is vital for the firms' optimal employment and remuneration policy, training offered and effort incentive system applied. Finally, the successful age mix of workers will determine the ultimate performance of the firm.

The present thesis addresses these issues in the following order. In the first chapter we will review different theoretical concepts that have been developed over time and we will depict recent empirical findings concerning the profile of earnings and productivity by age. Researchers puzzled with wages growing with worker's seniority wanted to understand the relationship between workers' age, wage rates and their productivity. Among the most prominent explanations that have been offered, we can distinguish human capital theory, job matching and deferred compensation models. In the second chapter we analyse the relationship between age, wage and productivity from the perspective of the firm. In particular, we focus on the empirical studies examining the age-related wage-productivity gap. Its existence might reduce the employment opportunities of workers whose wage exceed their productivity. It concerns especially older employees having high earnings but whose productivity level is often put in doubt. Therefore, in the following section, we present an original study providing an estimation of the labour productivity across different age groups. We use the French data on private firms that are particularly interesting as, among all OECD countries, France is characterised by one of the lowest employment rate of people over 55 (see Figure 2). Finally, the third chapter involves the behavioural analysis of the workforce touched by the ageing process. Thanks to the experimental approach, we can collect the unique data that allows analysing nuances of differences and interactions between junior and senior workers. In particular, we investigate the intergenerational differences in risk attitudes, workers' self-confidence and propensity to enter the competition, as well as the influence of the group age composition on the latter. All these elements are not negligible for the employers managing different generations of workers and facing the current shifts in the age composition of their employees.

Chapter one is composed of two sections. The first section presents the fundamental theories on the evolution of earnings and productivity with workers' age. One of the first explanations for widely observed upward sloping age-earnings profile was provided by the human capital theory suggesting that earnings rise with age as a consequence of the productivity increase due to investment in workers' human capital. Becker (1962) and Mincer (1962) have argued that workers, while gaining seniority or getting older, accumulate more and more firm-specific human capital that makes them more productive compared to others. As a result, this productivity increase brings a reward in a form of higher wages. Another theory has been proposed by Jovanovic (1979). He claimed that the growth of earnings does not depend on worker's tenure, but rather on the good quality of match between a worker and an employer. The observed wage increase simply accompanies the process of changing jobs by a worker while searching for the best match. Finally, the deferred compensation models (Lazear, 1979, 1981; Carmichael, 1983) justify increasing wage profiles with the need to create the proper incentives with a double effect: discourage shirking and increase workers' effort. After the presentation of each theory, brief empirical evidence is provided on various models. In general, empirical studies emphasize that different theories can provide complementary explanations and researchers often need to refer to many of them in order to explain their results on wage and productivity changes.

Obviously, the mentioned theories do not exhaust the analysis of the relation between age, wage and productivity. Therefore, the second section of chapter one invites to consider a number of empirical studies that give some further insights into this complex relation. Important and interesting findings on age-earnings and age-productivity profiles are presented separately in two sub-sections. In the part devoted to earnings, we focus in particular on two issues contradicting the common paradigms. First, the upward slope of age profile of earnings might correspond not only to employers' policy but also to preferences of their employees. Many people tend to behave in the opposition to the present-value maximisation theory preferring increasing over flat or decreasing profile of earnings even if the latter would maximize the net present value of their future profits (Loewenstein and Sicherman, 1991). Another noteworthy issue is whether wage indicates worker's productivity at any age. To answer this question, we present empirical evidence against the neoclassical assumption that workers are paid according to their marginal products. In fact, many firms apply a rigid remuneration scheme. As a result, within a firm, wages vary considerably less than individual productivity. We have a look at this issue from the theoretical and empirical point of view. In the second subsection, we focus on age-related labour productivity. Since negative perceptions about the adaptability and productivity of older workers has been identified as one of the main factor influencing their employment level, this part starts with a survey literature review on employers' beliefs about the advantages and disadvantages of employing younger and older workers. Afterwards, we analyse the actual reasons for a possible increase or decrease in productivity with age. Finally, we present different measures of individual job performance as well as some empirical studies investigating the impact of different workforce age compositions on firm's productivity performance. Despite suggested positive effects of age diversity on company's performance, many employers tend to consider older workers as relatively less productive.

Therefore, the relationship between productivity, earnings and workers' age is further investigated in chapter two. This part focuses in particular on aspects relevant for the employers. Although it has been well established that earnings continue to rise with age, the rise of workers' productivity is not evident and not easy to verify. If senior workers' productivity increases at a slower rate than earnings or even decreases, it may result in a discrepancy between current wages and productivity that make older workers less attractive for the employers. The first section of this chapter starts with a brief overview of empirical studies on age-related wage-productivity gap. Although first theories on wage and productivity have been developed already in the 60s, the first empirical papers testing this relationship at the firm level appeared only recently. Despite the growing interest in this subject, the quality and scope of analyses depends largely on the available data. This difficulty as well as other methodological challenges have been presented in the following part of the chapter. Overall, the existing research remains inconclusive about the existence of pay-productivity gap for senior workers.

The original empirical study presented in the second section subscribes in the line of the current research. We employ a rich firm-level dataset on French enterprises. The study aims at estimating the actual profile of labour productivity across different age groups. Its original contribution consists in overcoming the limitation of the usual assumption of perfect substitution between different types of workers. In this purpose, we differentiate the workforce simultaneously by skills (low-skilled, high-skilled) and by age (young, middle-aged, old). Estimating a production function with a nested constant-elasticity-of-substitution (CES) specification in labour, allows the imperfect substitution between different age and skill categories of workers. Among the main findings, labour productivity has been found to highly depend on the skill category of workers and the sector of activity. Older workers appear to be the least productive in the low-skilled group, while among the high-skilled employees seniors tend to be the most productive age category. The discrepancy between productivity and earnings is likely to be a source of employment difficulties in particular for older low-skilled workers. Regarding the accordance with existing economic theories, the age-productivity and age-earnings profiles in manufacturing sector are compatible with a model of deferred compensation. The effort incentive problem might have been regulated by the firms by offering at the start of the career wages under the workers' marginal productivity and compensating this difference in the later periods. On the other hand, in services and in trade sectors, we observe the combined relevance of specific human capital and deferred compensation. The relative productivity over wage ratio in manufacturing is found to be the highest for young workers whereas in services and trade sectors it is the highest for the mid-age employees. Thus, it may incite the employers to maximize their profits in the economic downturn by laying off from both ends of the age distribution first. Consequently, it may create some tensions inside the company between workers belonging to different age groups.

In the perspective of ageing, the cooperation and competition between different generations of workers is a major challenge for the enterprises. In this context, the issue of managing the intergenerational teams in particularly important (Hamilton et al., 2003; 2004). Though, this phenomenon is still relatively little studied. Nowadays, many employers encourage competition between workers, for example by applying performance-related pay, in order to stimulate greater productivity and better quality of work (Booth and Frank, 1999; Lazear, 2000; Cuñat and Guadalupe, 2005). The employees, in order to gain employer's appreciation, try to perform better than others. Over recent decades, a pressure to prove their qualities has been especially high for senior workers. The technical and organisational changes due to the rapid development of information and communication technologies has required from workers to achieve quickly new skills and competences. Older workers have been especially concerned with skills obsolescence especially that employers started to attach less value to their previously accumulated work experience. Moreover, seniors started to be perceived as overly cautious, less competitive, less willing to learn and adapt to new conditions. Nevertheless, the recent studies show that seniors are no more risk averse than juniors and tend to be more cooperative. Both generations seem to respond strongly to competition (Charness and Villeval, 2009).

Therefore, the third chapter of this thesis involves the behavioural analysis of the workforce composed of juniors and seniors. In particular, we study risk attitudes, workers' self-confidence and propensity to enter the competition, as well as the influence of the group age composition on the latter. These factors, undoubtedly having an impact on the workers' individual productivity, cannot be measured using the traditional survey data. Hence, we decided to perform an artefactual field experiment within a company with employees. Due to its highly competitive environment as well as the presence of ageing problems, the experiment has been organised with the employees of a Swiss bank. The advantage of the experimental approach is that it allows the reconstruction and analysis of a chosen economic situation or phenomenon with an important control of the environment, allowing a manipulation of treatments (here the age composition of groups). The first section of this chapter presents the conceptual and methodological problems with the definition and the measurement of overconfidence, with a particular focus on age differences in confidence judgments. The second section describes the design and procedures of the experiment and presents the obtained results. Although no significant differences in attitudes towards risk and ambiguity have been found between both generations, seniors have higher propensity to enter the competition. Moreover, the information on age of others players clearly has an impact on this decision. Curiously, seniors are more willing to enter the competition when they are matched with many juniors. It seems that in such a situation of competition, seniors are determined to demonstrate that they are not more risk-averse or less prone to engage in competitive tasks than younger generation. However, the excessive entry of seniors turns out to be inefficient i.e. it brings them lower profits than they expected. Overall, the results of the experiment prove that the age composition of co-workers may have an impact on the decision efficiency of age-homogenous or age-heterogeneous groups. This result is particularly important in the perspective of ageing labour force and fast changing workforce age composition. When searching for the optimal age mix of workers, employers should not forget that well balanced age diversity is a potential source of improved performance.

Chapter 1: Existing theories and empirical evidence on evolution of productivity and earnings with age

This chapter is composed of two sections. The first section presents the major theories on the evolution of earnings and productivity with workers' age. Each theory is accompanied by brief empirical evidence. The second section completes the existing theoretical concepts by providing alternative explanations for the observed age-earnings and age-productivity profiles that have been revealed by a number of recent empirical studies.

1. Theoretical concepts on evolution of productivity and earnings with age

Over the 70s and 80s, the relationship between workers' age, wage rates and their productivity has attracted attention of many researchers. Observations of wage tending to grow with worker's seniority in the firm brought questions on the link between this phenomenon and the evolution of worker's productivity. Several possible explanations for these upward sloping age-earnings profiles exist. Among the most prominent, we can distinguish human capital theory, job matching and deferred compensation models.

The human capital theory (Becker 1962, Mincer 1962) suggests that wage profiles are either equivalent to or flatter than productivity growth over the life cycle. It motivates payment of higher wages to older or more senior workers by the fact that they have accumulated more firm-specific human capital and thus are expected to be more productive.

Older workers might be paid more than younger workers simply due to increase in their job tenure. Job-matching models (Jovanovic, 1979; Mincer and Jovanovic, 1981) allow the positive wage growth with workers' tenure in case of a good match between employer and employee. In the model of Postel-Vinay and Robin (2001), employer pays initially each worker his reservation wage which is usually lower than the value of their marginal product and afterwards wages rise as the employer matches some outside options.

Another possible explanation for upward-sloping wage structures can be generated by incentive considerations. Different versions of efficiency wage models (Lazear 1979; Carmichael, 1983; Akerlof and Katz, 1989) suggest that rising wage profile is an effective way to discourage workers shirking and to induce them to provide a higher level of effort. It might be of particular importance in firms where workers' characteristics are not totally observable and / or where monitoring of their performance is not perfect (Akerlof and Yellen, 1990).

However, the cost of such effort incentive might rise as workers get promoted and climb the hierarchy. First, "it may take more money to induce effort from the rich worker than from the one who is less well off. Second, raises upon promotion may increase because the optimal level of effort is higher at more elevated ranks, as decisions made at higher ranks have more wide-reaching effects; it is more important for the CEO to work hard than for a shop floor worker to do so. If the marginal return to effort is increasing in rank, convex wage profiles will arise" (Prendergast, 1999). Nevertheless, such convex wage schedules may provide incentives to all employees. Not only to those in senior positions but also to their younger co-workers who, if they hope to stay in the firm, are induced to perform at the optimal level.

1.1. Human capital theory

The age-earnings differentials are often justified by human capital theory. The explanation is based on the idea that wages increase over time due to investments in human capital, particularly investments in the job training (Mincer, 1974; Becker, 1975). Older workers are therefore paid more since they have accumulated more human capital and thus they are more productive.

After completion of schooling, formal or informal on-the-job training is the major productivity building investment. The tendency to invest in human capital concerns rather young persons. Postponing the decision about investment reduces their present value of net gains as the later investment produces returns over a shorter period (Becker, 1964). For the same reason, also firms are less willing to invest in training of older workers as the time of investment return is short and the cost is higher due to foregone earnings (opportunity costs) increase.

Decreasing marginal returns and increasing marginal costs lead to an optimal amount of human capital investment that negatively depends on age (Mincer, 1970). However, human capital investment may not monotonically decline with age if the accumulated human capital is rather specific than general. While the profitability of general skills depends on the length of working life, the profitability of specific skills only depends on the expected duration of the current job (Bartel and Borjas, 1977).

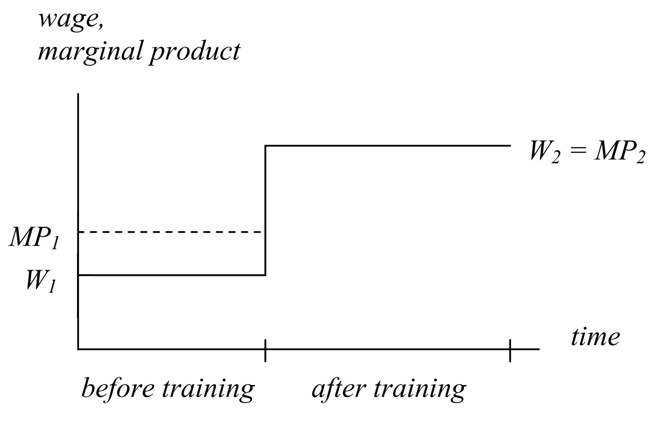
The theoretical models also suggest that the rate of earnings increase with age might be positively related to the level of skill (Becker, 1964). Empirical studies tend to confirm that age-earnings profiles are steeper, grow faster and peak later at given years of labour experience among more skilled and educated persons. Equally, the more educated employees retire at a somewhat older age, though they do not necessarily have a longer working life, since it begins after a longer schooling period (Mincer, 1970).

The theory makes a distinction between two types of human capital: general and specific.

1.1.1. General human capital theory

According to the general human capital theory, workers invest in general on-the-job training. Skills defined as general, increase worker's productivity in the current firm as well as in other firms. The firms providing general training could capture return from training offered in the first period only if in the second period their productivity rose by more than their wages. However, assuming competitive labour market, where wage rates paid at any firm are determined by marginal productivities in other firms, if one employer refuses to pay the market value for a person's skills, another employer may be able bid an undercompensated employee away. Consequently, the firms would be willing to provide general training only if they did not have to pay any of the costs. Hence, the only person ready to bear the cost of general training are the workers themselves as the training raises their future wages (Becker, 1962). Anticipating the future returns from general training, employees would accept to pay for training in the first period by receiving wages below their current productivity or what they could receive elsewhere (see Figure 3).

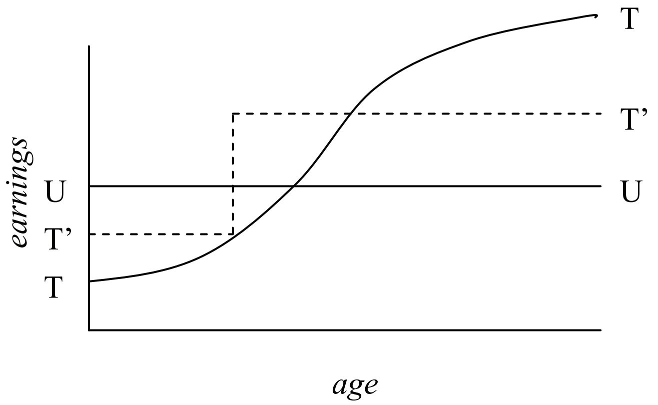
Figure 3: Worker invests in general on-the-job training



Source: Hutchens (1989)

The general training has an important impact on the relation between workers' earnings and age. Assuming that untrained worker receives the same wage rate regardless of age, his or her earnings profile would take a form of a horizontal line UU (see Figure 4). Now, if we suppose that a worker in a first period receives training, his or her earnings would be below the marginal productivity in the training period and equal to it afterwards, but exceeding the productivity of an untrained person (line T'T'). If, in addition, we assume that the increase of earnings is affected more at younger than at older ages, the earnings curve of a trained person would take a form of TT. Consequently, wages would rise over the life cycle at a decreasing rate until depreciation exceeds the level of skill acquisition, yielding a concave earnings profile.

Figure 4: Worker invests in general on-the-job training



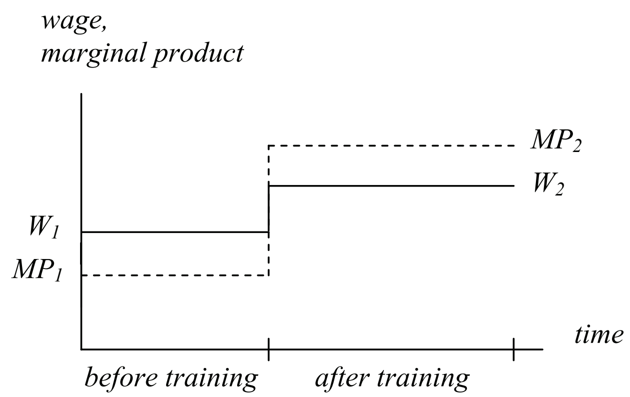
Source: Becker (1962)

1.1.2. Specific human capital theory

Apart of general training, a worker may also acquire specific on-the-job training. Its particularity is that it increases the worker's marginal productivity more in the firm providing such training than in other firms. Actually, it is often difficult to classify on-the-job training as purely general or purely specific. Nevertheless, the one that increases worker's productivity more in the firm providing it, is usually defined as specific training.

A specific training, same as general training, causes wages to grow with seniority because of increase in workers' productivity. Unlike general training, however, firms and workers are assumed to share the investment (costs and benefits) in workers' training. In the first period, while being trained, workers receive a wage that is lower than wages offered otherwise but still higher than their productivity. Thanks to training, workers become more productive and in the later period their marginal product jumps from MP1 to MP2 (see Figure 5). The second period wage, although higher than in the previous period, lies below the value of marginal productivity MP2. In fact, the employer and the employee set the second period wage so as to split the quasi-rents generated by specific training. On one hand, a wage being lower than productivity discourages the firm from laying off trained workers and thus encourages workers to participate in the training program. On the other hand, provided that the wage is higher than the one a trained worker could get elsewhere, it plays also a discouraging role towards workers quit (Becker, 1962). Actually, it is possible that in the second period the firm offers a worker more that he or she can receive elsewhere and still pays less than what the employee is worth at the current firm (Lazear, 1998).

Figure 5: Worker and firm invest in specific training



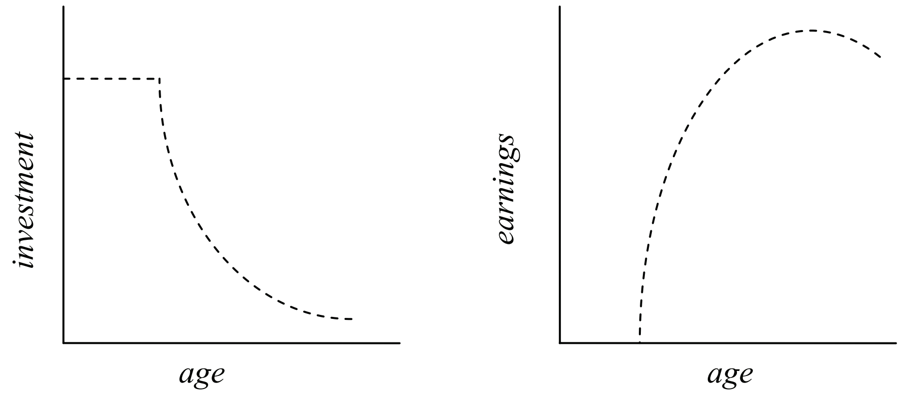
Source: Hutchens (1989)

In line with this theory, compared to an untrained employee, an investment in human capital steepens age-earnings profiles of workers who have been provided training. It lowers reported earnings during the initial investment period and raises them afterwards. Wages grow with seniority because of increase in workers' productivity induced by the provided training. In case of older workers, the spot wage will always be less than or equal to the spot value of their marginal product (Hutchens, 1989). Consequently, the workers' earning profile over age will be flatter than the productivity path (Hashimoto, 1981).

The theoretical model by Becker has been further pursued by Ben-Porath (1967) who developed an earnings maximizing model of human capital accumulation and a productivity-based explanation of earnings growing with age. In this model, the individual maximizes his expected value of the discounted earnings by appropriately allocating resources to human capital investment over his lifetime. The author assumes the following earnings function: $E_t = (1 - s_t)\, H_t - D_t$, where s_t is time spent investing in human capital, H_t is human capital itself, and D_t denotes direct costs of human capital investment. The human capital production function (its change over time) is defined as $\dot{H}_t = \beta_0 \left(s_t H_t\right)^{\beta_1} D_t^{\beta_2} - \sigma H_t$ where σ is the depreciation rate of human capital.

According to Ben-Porath (1967), there are three different phases of human capital accumulation: 1) an initial period of no earnings (i.e. full-time human capital production, interpreted as "formal schooling"), 2) a period of a part-time human capital production in which earnings rise at a declining rate (individuals both work and invest), and 3) a phase characterised by no training and earnings decline (see Figure 6). At any point in time, individuals with more schooling or greater ability invest more in on-the-job training.

Figure 6: Pattern of investment and a pattern of earnings in Ben-Porath model



Source: Taber (2008)

The model by Ben-Porath (1967) has been then generalised by Heckman (1976) who designed a life-cycle model of labour supply, earnings, consumption, and non-monetary utility of education that contains the Ben-Porath's model as a special case. However, even the basic model by Ben-Porath manages to replicate the most important qualitative characteristics of the empirical life-cycle patterns.

1.1.3. Validity of human capital investment and the life cycle of earnings

Most of studies verifying the human capital theory focused on econometric testing whether the observed age-earnings profile (upward slope, deceleration and eventual decline) is a result of human capital investment. Mincer(1958, 1974) was the first to derive an empirical formulation of earnings over the life cycle. His model focuses on the life-cycle dynamics of earnings and on the relationship between observed earnings, potential earnings, and human capital investment, both in terms of formal schooling s_i and work experience (on the job investment) x_i:

$$ln\ wage\,(s,x) = \alpha_{0i} + \rho_{si}s_i + \beta_{0i}x_i + \beta_{1i}x_i^2 + \varepsilon_i \qquad (1)$$

where ρ_s is the "rate of return to schooling" (assumed to be the same for all schooling levels) and ε is a mean zero residual with $E\,(\varepsilon \mid s,x) = 0$. Since the theory does not suggest a clear linear relationship between earnings and experience, the model includes a quadratic term of work experience.

This model served as a basis for numerous empirical studies that modified Mincer earnings function to integrate worker's tenure on the job (see e.g. Bartel and Borjas (1981), Mincer and Jovanovic (1981), Topel and Ward (1992)). Using data on individuals, the estimated regression took the following form:

$$ln\ wage\,(s,x,t) = \alpha_{0i} + \rho_{si}s_i + \beta_{0i}x_i + \beta_{1i}x_i^2 + \beta_{0i}t_i + \beta_{1i}t_i^2 + \varepsilon_i \qquad (2)$$

where t_i denotes years of tenure with the current employer. It has been argued that the inclusion of tenure in the earnings function is necessary if one wants to measure correctly returns to human capital accumulated on the job via experience coefficients. Otherwise, they would be biased upwards. According to Mincer and Jovanovic (1981) the inclusion of tenure terms (t_i) in the function permits to separate estimates of returns to general and specific human capital after correction for heterogeneity bias. They approximate that among factors responsible for life-time wage growth, about 25 % is due to interfirm mobility, another 20-25 % to firm specific experience, and over 50 % is due to general (transferable) experience. Such results accord nicely with human capital theory, which holds that wages rise with seniority due to greater investment in general human capital and labour market experience as well as investment in specific training, which explains why, even after controlling for experience, wages rise with tenure (Hutchens, 1989).

However, it has been observed that incidence and duration of training declines with age, producing concavity in the wage profile, in line with Ben-Porath's model. Mincer (1997) analysing Panel Study of Income Dynamics panel data found that annual wage growth of otherwise comparable workers in 1976 jobs was 4.4 % greater during the 1968-82 period for those who received training than for those without training in the same year. Due to greater frequency and intensity of training, its effect on wage growth was two to three times greater for young workers (less than 12 years of work) than for older ones.

Actually, the rising wage profile not only provides incentives to young persons to invest in training and education in anticipation of higher earnings in the future but training is also an attractive investment from the point of view of the employer. It is likely to be associated with significantly higher workers' productivity. Analysing

British panel data, Dearden et al. (2006) estimated the magnitude of the impact of training on wages being only half as large as the impact of training on productivity.

On the other hand, the real significance of including job tenure in earnings functions has been a subject of fierce debate. The cross-section data analysis has been suspected to suffer from a sample selection bias because of job-matching effects. Indeed, it is possible that workers with high unobserved match quality receive and accept high wage offers from their existing employers. Consequently, they tend to stay in their jobs which results in a positive correlation between wages and tenure confirmed by the data (Abraham and Farber, 1987; Altonji and Shakotko, 1987). However, other authors have argued that in fact the direction of the sample selection bias is not so certain. They pointed out the possible negative effect if workers who move to new jobs, and hence have relatively lower tenure, are those who receive high alternative wage offers (Topel, 1986; 1991 and Garen, 1988).

Later on, Stevens (2003) has shown that introducing in the model endogenous wage offers results in the unambiguously negative bias on the return to tenure. Workers with high levels of specific human capital tend to stay in their jobs even when match quality is low. Thus, specific capital is negatively correlated with match quality. At the same time, in the absence of specific human capital, matching does not introduce a positive relationship between wages and tenure.

1.2. Job matching models

Due to lack of consensus concerning different aspects of human capital model, it has been suggested that alternatives to this model should be considered[1]. Bartel and Borjas (1981) pointed out that an important factor, which must be taken into account while analysing the earnings distribution, is labour turnover. It tends to affect not only the growth of wages across jobs but also the rate at which wages grow within the job. Using the National Longitudinal Surveys of Young and Mature Men, they demonstrated that job mobility may prove successful provided it is undertaken early in the life cycle of an individual. Those who have gained already considerable experience and settled in one firm may expect larger lifetime wage growth than similar workers still changing jobs. The potential gains to quitting appear to be positive for young men, and zero or negative for older ones. However, the type of quits is not without importance. Bartel and Borjas distinguish between quits due

[1] Concerning literature confirming human capital model and for relation between training received from the current employer and increased wage growth see e.g. Duncan and Hoffman, 1979; Mincer, 1988; Barron et al., 1989; Brown, 1989; Altonji and Spletzer, 1991; Barron et al., 1993 and Barrel, 1995.

to 1) finding a better job, 2) being dissatisfied with the current job, and 3) personal reasons. In both age groups, those who quit for another job usually experience significant wage gains. Though, there exist certain age differences in the nature of quits. At older ages, they are mainly result of dissatisfaction with the current job and, in general, do not bring significant wage growth.

Furthermore, Topel and Ward (1992) have found that a career development among young workers is characterized by high turnover and rapid wage growth before transition to relatively stable employment. During the first ten years of labour force participation the typical young worker holds seven jobs, and over one third of average wage growth during this period is due to job changing. Based on this finding, the authors called for a re-evaluation of the standard human capital investment model of lifecycle earnings. The job-changing activities of young workers observed by Topel and Ward appeared strongly consistent with models of on-the-job search and job matching (Jovanovic, 1979; Mortensen and Pissarides, 1994). According to these models, the declining probability over life cycle that an individual will change job is, in part, evidence of successful initial mobility by young workers, which is confirmed by corresponding life-cycle wages increase.

Finally, let us compare both theories. It can be noticed that the human capital model states that the positive correlation between wages and tenure reflects an increase in productivity that results from investments in firm-specific human capital. On the other hand, the job matching model argues that this positive relationship comes from the market good worker-employer matches. In this model, future wages do not depend on the worker's length of tenure. It is rather the quality of match, not the wage, which dictates the rate of turnover, thus observed tenure (Hotchkiss, 1998).

1.2.1. Jovanovic's matching model

The job matching model proposed by Jovanovic (1979) predicts that workers remain on jobs in which their productivity is revealed to be relatively high and that they select themselves out of jobs in which their productivity is revealed to be low. Wages are assumed to always equal expected marginal products for all workers, conditional upon all the available information at that time. Wage growth is positive only if the average production exceeds the employer's expectation at time zero. In particular, the good match generates wage growth as tenure increases.

The model assumes that worker's contribution to the total output $X(t)$ depends on the tenure, that is the period spent in the firm, t:

$$X(t) = \mu t + \sigma z(t) \tag{3}$$

μ is a measure of the quality of the match whereas σ is the same for each firm-worker match. μ and σ are constants and $\sigma > 0$; $z(t)$ is a standard normal variable with mean zero and variance t. When the match is formed, μ is unknown but as the match continues, further information is generated. In particular, a "good match" is characterized by large μ.

It is assumed that workers differ in their productivities across different jobs and in a given task that the employer needs to have performed. The main problem concerns optimal assignment of workers to particular jobs. Due to imperfect information on both sides of the market (employers and employees), turnover is generated as the phenomenon of optimal reassignment which tends to decline with time as better information about the quality of match becomes available. A worker's productivity in a particular job is not known *ex ante* and becomes known more precisely as production takes place and the worker's job tenure increases. With accumulation of tenure and experience, the workers' mobility declines. This phenomenon is mainly attributable to locating a successful match after the initial job search period when a worker aims at gaining experience, wages, and skills by moving across firms in order to find eventually a suitable job in which one can settle and grow for a long time (Mincer and Jovanovic, 1981). Good matches tend to survive and poor matches are likely to end. A key difference is that survivors learn that they are well matched, so that their own probability of moving decline with tenure after some critical amount of know-how has been accumulated.

1.2.2. Empirical evidence on job matching model

Over time considerable efforts have been undertaken to test the job matching model against human capital theory and to determine its empirical importance. In his review of the empirical studies of job matching, Garen (1988) concluded, "The evidence surveyed in this paper does not reveal any consensus about the importance of the job matching model. The results from the studies of wage determination are mixed. Some of the findings imply that matching accounts for nearly all of the wage-tenure correlation, while others suggest only a part is explained by this model". Garen attributes the inconclusiveness of the empirical works to the absence of the data sets that would measure the quality of the worker-firm match (and thus determine wages and turnover), for example the worker's performance on the job.

Following the suggestion by Garen, Bishop (1990) conducted a robust test of job-matching theory. He analyzed a data set containing measures of the match quality between job and worker defined as the productivity of the individual worker relative to co-workers reported in a supervisor's productivity ratings. The major findings are that both involuntary and voluntary turnover is negatively related to employer productivity ratings, which is consistent with job matching theory. This phenomenon appeared, however, to concern only small- and medium-sized non-union establishments. Moreover, while job matching turn out to be an important phenomenon at most establishments of this type, it did not account for a significant share of the rise in average productivity that occurs in the first year of tenure on the job.

Among other empirical works, the positive and strong relationship between worker tenure and wage has been also confirmed by Topel (1991). Farber (1994)has shown that tenure is initially positively and soon after negatively correlated to the hazard rate of separation, while Pissarides and Wadsworth (1994) has found a negative link between tenure or wage and the worker propensity to search on the job.

1.3. Deferred compensation models

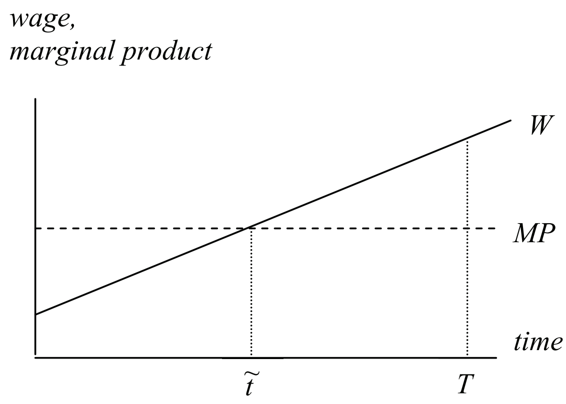
The third explanation for an observed upward sloping age-earnings profile has been provided by deferred compensation models which underline the possibility of incentive based compensation schemes. In order to discourage workers' shirking, the firm pays young workers below their marginal productivity and later in their career remunerates them over their marginal product. Senior workers receive high salaries, not due to relatively higher productivity but because it creates the appropriate wage incentives for them and for their younger co-workers (Lazear, 1981). Consequently, a steeper wage profile increases workers' effort. In particular, the young workers who hope to stay in the firm are induced to perform at the optimal level. Among the technologies that give rise to delayed payment contracts are those which pose monitoring difficulties (Lazear, 1979; 1981) or which involve specific training (Carmichael, 1983).

1.3.1. Lazear's model of delayed payment contracts

It has been observed that even in the absence of on-the job training or investment in human capital, the earnings growing with workers' age are widespread. The agency models by Becker and Stigler (1974) and Lazear (1979, 1981) demonstrated that the use of seniority wages can be motivated by an incentive for increased effort. Moreover, delayed payment contracts tend to discourage shirking and malfeasant behaviour, in particular when it is difficult for the employer to monitor worker's effort.

According to Lazear's model, initially workers are paid less than their marginal productivity, and as they work effectively over time within the firm, earnings increase until they exceed marginal productivity (see Figure 7). A steep earnings path not only reduces the worker's incentive to shirk, but also it affects the amount of output per hour consequently increasing worker's productivity. Thus, workers produce more and are paid more if their wage paths are steeper than their productivity. A worker who shirks, risks being caught and get fired before obtaining the wage premium foreseen at the end of the contract.

Figure 7: Delayed payment contract in Lazear's model

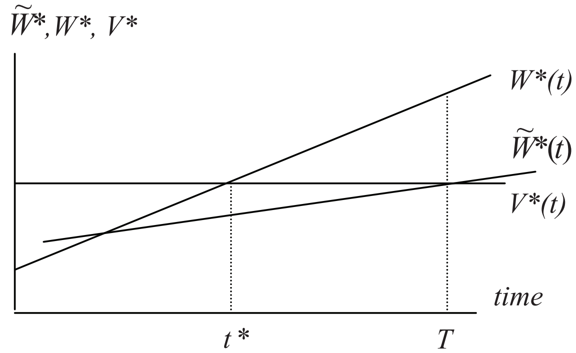


Source: Lazear (1981)

While steeper profiles increase workers' effort, flatter profiles (in which smaller amount of earnings are suspended until late in workers' life) might make firms more honest. Indeed, in a situation when older workers are paid above their marginal product and there is no transfer of know-how from older to younger employees, it would be optimal for a firm to make redundant all workers at time $\tilde{t}$ and, instead, hire new cheaper workers. However, the reputation concerns could prevent the firm from engaging in moral hazard behaviour. Thus, the delayed payment contracts tend to be long-term contracts and are likely to be associated with large established firms as those who are less likely to fail and who are more concerned with reputation (Lazear, 1979; Hutchens, 1986).

By the same token, the deferred compensation can reduce workers' voluntary turnover rate. Since wages are higher than productivity towards the end of the career, wages send the wrong signal to workers who might not want to retire at the efficient age. Hence, mandatory retirement clause might be needed as a part of an efficient labour contract in order to induce workers to leave the firm at the optimal date (Lazear 1979). Figure 8, below, illustrates this situation. Let us consider a worker who has a value of marginal product over his lifetime, $V^*(t)$, and a wage rate $W^*(t)$. He is receiving an amount less than his VMP for $t < t^*$and an amount greater than his marginal product for $t > t^*$. At point T, the value of $V^*(T)$ is equal to the individual's reservation wage at t, $W(T)$.

Figure 8: Optimal date of retirement in Lazear's model



Source: Lazear (1979)

If a worker was paid at each point in time according to his spot value of marginal product $V^*(t)$, then at time T the value of the worker's marginal product would be just equal to his reservation wage and the worker would have no more incentive to work. Thus, it would determine the optimal date of retirement for the worker. But when workers are paid less than their marginal products when they are young and more when old, their wage rate at T will exceed their marginal product and, therefore, also the reservation wage. Since in this situation the worker will not retire voluntarily, the mandatory retirement at the point T is necessary. However, as noticed by Lazear (1979), although the mandatory retirement usually means firm-worker separation, it is also possible that worker stays with the firm after re-negotiating his contract. The new contract might imply changes in wage rates as well as in working conditions (working hours, flexibility, effort, etc.) so that they match better the interests of both, the employer and the worker, over the time period between T and retirement.

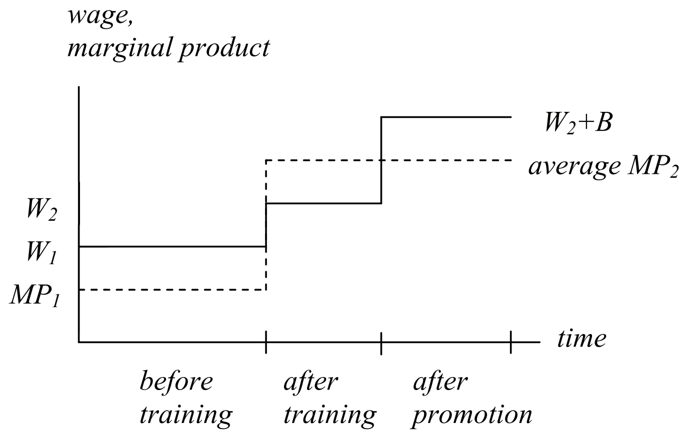
1.3.2. Carmichael's model of seniority based promotions

Although Lazear's theory explains why wages grow with tenure in the firm, it does not provide an insight into why wages grow with labour market experience. Carmichael (1983) extended a human capital theory in an empirically relevant direction and demonstrated that when a job involves specific training, it can be efficient for the firm, to pay older workers a wage that exceeds the value of their marginal product.

In the Carmichael's model, a worker enters on the market with general human capital worth W_a (equal to alternative wage). When he finds an employment, he joins a firm contracting two-period wages: W_1 and W_2. His first period productivity MP_1 is equal to alternative wage (W_a) minus the cost of firm-specific training. This training raises worker's productivity in the second period to MP_2.

At the end of the training period, a worker receives a raise in wage to a level just below his alternative wage rate. Suppose there are two types of second period jobs, denoted as type 1 (lower ranked) and type 2 jobs (higher ranked). Sometime in the middle of their second period (after training), a worker receives a promotion based on his seniority which ensures that his entire second period earnings are sufficient to compensate him for the training costs paid in the first period and the low initial wage in the second period ($W_2 < MP_2$). A worker is promoted when he is the senior member of type 1 job and a vacancy appears (due to a retirement) in the type 2 jobs. Promotion involves a wage increase (to a level of $W_2 + B$) as well as a change in duties. Figure 9 illustrates this pattern. It is assumed that worker's marginal product is constant over the second period, even if he switches jobs. Since, by assumption, workers in the type 2 jobs are no more productive than those in type 1 jobs, it can be shown that at least some of these more senior workers are paid a wage greater than marginal product (that is, $W_2 + B > VMP_2 > W_2$).

Figure 9: Carmichael's model of seniority based promotion



Source: Hutchens (1989)

1.3.3. Consequences of delayed payment contracts for firm's propensity to hire older workers

Large number of empirical studies suggests that firms do indeed follow deferred compensation model (Kotlikoff and Gokhale, 1992; Barth, 1997; Abowd et al. 1999; Prendergast, 1999; Lazear, 2000; Fukao et al., 2006). Actually, firms systematically "overpay" their older employees and "underpay" their younger counterparts. The fact that wages do not reflect the actual productivity but increase with seniority may result in raised employment difficulties for older workers. Indeed, we observe that for certain jobs many firms employ, but tend not to hire older workers.

Hutchens (1986) argues that when the firm shifts compensation to the end of the contract, it incurs a form of a fixed cost (associated with e.g. a risk of shirking by workers or dismissal of non-shirkers by the firm) which is invariant to contract length, into the employment relationship. Since the firm pays this cost each time it hires a new worker, it tries to minimize hiring by entering into long-term relationship with young workers.

In order to test the hypothesis that delayed payment contracts are associated with establishments that employ but do not hire older workers, Hutchens (1986) compares the inter-jobs values of the following index:

$$I\left(i,j\right)=\frac{\%\,of\ recently\ hired\ workers\ in\ industry\ i\ and\ occupation\ j\ that\ are\ over\ age\ k}{\%\,of\ all\ workers\ in\ industry\ i\ and\ occupation\ j\ that\ are\ over\ age\ k} \tag{4}$$

where age k was set at 55 and recently hired workers concern those who have been employed by the enterprise within last 5 years. In order to estimate the logit model, the index has been regressed on the census data. The dataset contains information on almost one million employees recorded in the National Longitudinal Survey of Men aged 45-59. The control variables include years of education, age at the time of entry into first job, health status, region of residence, part-time workers and wages set through collective bargaining. Small values of the index indicate a specific occupation in a given industry where older workers are employed but not hired. Analysis of the data reveals that, indeed, employer behaviour often looks like age discrimination. Jobs for which older workers are employed but not hired (for example lawyers) do have the characteristics of delayed payment contracts, i.e. pensions, long job tenures, comparatively high wages and mandatory retirement. This hypothesis has been also confirmed by Heywood, Ho, and Wei (1999) using data from establishments in Hong Kong.

However, while explaining this phenomenon, there exists another aspect that should not be neglected. According to Hutchens (2006), one of the reasons why older people are not hired for posts currently held by older workers is that these jobs are more likely to be filled from the inside, in particular when they involve costs associated with specific training. Actually, the employer might prefer to fill vacancies after older workers with insiders due to better information on insiders than outsiders[2]. An insider, either young or old, seems naturally the best worker for a job with a delayed payment contract.

[2] For a review on job assignment and promotion assuming this type of asymmetric information see Valsecchi (2000).

1.4. Conclusions

The first part of this chapter presents the development over the 70s and 80s of the major theoretical concepts on evolution of earnings and productivity with age. The empirical studies, that appeared considerably later, revealed that the observed wage and productivity profiles of individual workers cannot be fully explained by either human capital theory or job matching or deferred compensation models. In fact, human capital and incentive theories can provide complementary explanations. For example, the accumulation of specific human capital is most important at early stages of careers and in jobs which require specific skills. The deferred compensation models appear optimal in jobs where worker effort and/or output are difficult to verify and where a wage-productivity gap is socially desirable for increased effort incentive reasons.

Moreover, both theories partially explain why firms employ senior workers but are reluctant to hire them. According to human capital theory, older workers tend to have accumulated important amount of firm-specific human capital whose particularity is that it increases worker's productivity more in the firm that has provided the appropriate training than in other firms. Consequently, seniors can be efficient employees in their current firm but since they cannot easily transfer their competences to another company, they have reduced chance to find a new potential employer. On the other hand, deferred compensation model, involving payment to young employees under their productivity and older workers above their productivity, tend to be based on a long-term relationship. Thus, it is difficult for an older person to join an enterprise applying deferred compensation scheme.

Furthermore, multiple empirical studies underline that in order to explain wage and productivity changes, even within the same firm, one needs to refer to different theories (Baker et al., 1994). Many authors observe the significant wage effect of labour market experience and interpret it as an indication of relevance of general human capital, whereas the returns to tenure (time spent in the firm) are meant to indicate returns to specific human capital (Altonji and Shakotko, 1987; Topel, 1991; Yamaguchi, 2007). However, a significant tenure effect can be also consistent with Lazear's agency theory (Abowd et al., 1999). Seltzer and Merrett (2000), using a long panel data for employees of Australian bank, find that both incentive theory and theory of specific human capital explain tenure effects in individual wages. The combined relevance of both theories within the same firm has been found by Grund and Westergård-Nielsen (2005) who find the productivity profile steeper than the wage profile at the beginning of a worker's career, followed by wage profile steeper than productivity at its end. We will come back to this issues in chapter 2, when interpreting the results of the empirical studies on age-related pay-productivity gap.

2. Important empirical findings concerning age-earnings and age-productivity profiles

The theories presented in the first part of this chapter propose several distinct explanations for upward-sloping wage structures as workers get older. They are justified by the increased workers' productivity thanks to longer tenure and acquired experience. Or, they are applied as productivity-enhancing method by encouraging a higher level of effort. However, there exist additional explanations that theories do not take into account but which have been proved by a number of empirical studies.

First, some interesting facts on age-profile of earnings will be presented. We will see that its increasing slope might be not purely employer's decision but also a result of workers' preferences. Then, we focus on the observed phenomenon of wage compression within the firms i.e. when wages vary less than individual productivity. Finally, we signal possible errors concerning the interpretation of age-earnings profile depending on the characteristics of the available dataset. Second, we present some empirical evidence concerning the productivity variation by age. This subsection starts with the presentation of the actual employers' beliefs about advantages and disadvantages of employing junior and senior workers. Then, we depict determinants and existing measurement methods of individual job performance, followed by the empirical studies evaluating the effect of age composition on the firm's productivity.

2.1. Age-profile of earnings

The observed firms' remuneration policies indicate that earnings tend to rise with workers' seniority. Indeed, a newly-hired employee receives initially a certain wage which, due to a sequence of promotions and pay increases, reaches with time a higher level. Most employers offer to senior workers not only higher wages but also larger non-wage compensation such as pension rights, vacation time and other benefits (Hutchens, 1986). These observations confirm the principal theoretical intuition (presented in the previous part) for increasing age-earnings profile. However, the upward-sloping age-earnings profile might not only be desired by the employers but also correspond to preferences expressed by workers (Loewenstein and Sicherman, 1991).

Another interesting issue in the context of age-earnings differentials is whether wage indicates worker's productivity at any age. There exist several theories as well as empirical evidence (Frank, 1984; Campbell and Kamlani, 1997) contradicting the paradigm of equality of wage and marginal productivity. These different studies do not focus directly on the "age effect". Nevertheless, they bring valuable insights into the age-earnings relationship. Actually, although the empirical research is often built around the neoclassical assumption that workers are paid their marginal products, empirical studies point out that wage rates vary substantially less than individual productivity values. Even if a wide discrepancy in productivity among individual workers exists, many firms continue to follow strict remuneration scheme based on education, experience and tenure length. As a result of this rigid remuneration scheme, in response to a negative productivity shock, employers instead of adjusting wages, adjust their employment structure. Consequently, the least productive workers or those, whose wages exceed their productivity levels, are the first to become redundant. If this is the case of older workers, they will constitute the most vulnerable age group on the labour market.

While analysing age-profile of earnings one should not neglect the confusion existing in the literature concerning their interpretation (Thornton et al., 1997). The most frequent mistake is about confounding differences between wages of individuals at different points in their lives (cross-section) and wage differences within persons over time (longitudinal data). Thus, on the basis of cross-section data, it is impossible to make conclusions concerning earnings changes of individuals over time.

2.1.1. Workers' preferences for increasing age-earnings profiles

Interestingly, the upward-sloping age-earnings profile might not only be desired by the employers but also correspond to preferences expressed by workers. It has been shown that many people prefer increasing over flatter or decreasing profile of earnings even if the latter would maximize the net present value of future profits. Thus, such behaviour violates the principle of present-value maximization. Loewenstein and Sicherman (1991) provide empirical evidence on this subject. They asked 80 persons to answer a questionnaire and rank alternative payment options 1) for a job and 2) for rental income from a small apartment building. Most of respondents expressed a preference for increasing payment scheme, in particular with regard to wage payments. Only the minority demonstrated preferences for decreasing payment option compatible with present-value maximization. Even after having provided the respondents with arguments favouring the decreasing payments, most of them have not changed their preferences and opted for an increasing payments profile.

Regarding the respondents' motivation, the authors expected that some of them might associate level of wage with level of productivity so that a payment increase could create a sort of "feeling of mastery". A preference for increasing earnings could also come from a taste for increasing levels of consumption accompanied by self-control problems to save adequately in earlier periods. People could also derive current utility from expecting higher consumption in the future.

Among reasons for choosing the increasing profile of earnings, the respondents most frequently indicated "a taste for increasing payments" followed by "savouring" (pleasure of expecting higher income in the future), "inflation consideration" and "aversion to earnings decrease". Such explanations accounted for 71 %.

According to Loewenstein and Sicherman (1991), the observed individual preferences for increasing payments could explain why actual earnings profiles offered by firms might be steeper than those predicted by the theories. However, likewise, the authors underline that in order both employers and employees could benefit from upward-sloping remunerations, it is necessary that job contracts guarantee long-term employment.

The preference for increasing wage payments has been further confirmed in the experimental study by Duffy and Smith (2010) who found that the taste for increasing income is increasing in the size of the payments and is strongest for intermediate wages.

2.1.2. Intra-firm wage rigidity

Some of the existing theories predict earnings profile to be flatter than profile of workers' marginal productivity (specific human capital theory) and some other predict them to be steeper (deferred compensation model). Nevertheless, the empirical research is often built around the standard neoclassical model assumption of competitive labour market. It implies that workers are paid their marginal products by cost-minimizing firms and thus at any point in time, a person's wage indicates the person's productivity[3]. Consequently, data on wages are often used as sufficient statistics for workers' productivity in order to estimate empirical models concerning so various economic aspects as growth models based on estimation of production function (Duffy and Papageorgiou, 2000), skills' substitutability (Ciccone and Peri, 2003) or capital-skill complementarity (Duffy et al., 2004).

In recent years, this assumption has become more and more controversial. The perfect competition on the labour market is highly doubtful. In fact, depending on the actual level of competition, employers might apply different wage policies. In the absence of competition for employees from other firms, employers tend to offer

[3]However, Becker (1962) argues that even if a discrepancy between marginal labour product and wage tends to be interpreted as a proof of competitive market imperfections (monopsony power), it would occur even in a perfectly competitive environment provided it involves investment in specific training.

a rather flat wage-tenure schedule. If competition from other employers is likely to take place, the employer will probably try to choose his optimal wage structure in a way to hit two conflicting targets: "a steep wage-tenure profile to deter quits of his employees but a flat one so that workers with a high quit propensity are still attracted to the firm" (Manning, 2003).

Until now, rich argumentation has been provided why wages and productivities may actually diverge. Over the past twenty years, several theories have been developed to explain why firms, even if a wide discrepancy in productivity among individual workers exists, continue to follow strict remuneration scheme based on education, experience and tenure length (Table 1). Thus, wages are determined by other factors than individual contribution to firm's value-added.

Table 1: Theories of wage rigidity

Theory	Source of wage rigidity
Contract theory	Long-term contracts between firms and workers set wages in advance and are negotiated on a staggered basis [Fischer 1977; Taylor 1979].
Implicit contract theory	Workers are risk averse, preferring a real wage that is stable over the business cycle to one that rises in expansions and falls in recessions. A firm offering its workers a steady wage could therefore pay an average wage below what it would otherwise have to pay because it would be giving workers a compensating differential in return for the lower average wage. This risk aversion gives firms and workers an incentive to reach an implicit understanding that the wage will be kept stable over the business cycle [Baily 1974; Gordon 1974; Azariadis 1975; Stiglitz 1986].
Efficiency wage theory	Workers' productivity depends positively on the wage [Solow 1979; Yellen 1984; Stiglitz 1986].
a. Shirking model	The cost of losing one's job depends positively on the wage, so that a higher wage will induce fewer workers to shirk and risk dismissal [Shapiro and Stiglitz 1984].
b. Gift-exchange model	Workers view a higher wage as a gift from the firm, inducing them to work harder as a gift to the firm [Akerlof 1982, 1984].
c. Adverse selection model	A higher wage raises the average quality of a firm's applicant pool. In addition, adverse selection may also apply to quits, since a firm's most productive workers are the most likely to quit if it cuts wages [Weiss 1980, 1990].
d. Turnover model	Workers' quit rates depend negatively on the firm's wage. Thus, a firm paying higher wages will have lower costs of hiring and training new workers. In addition, its workers on average will have acquired more firm-specific human capital, making them more productive than similar individuals with no experience at the firm [Stiglitz 1974; Schlicht 1978; Salop 1979; Hashimoto and Yu 1980].
Fair wage-effort hypothesis	If workers' wages are below their perceived fair wage, then their effort depends on the ratio of their wage to their perceived fair wage [Akerlof and Yellen 1990].
Insider-outsider theory	Firms do not dismiss their current workers (i.e., insiders) and hire the unemployed (i.e., outsiders) at a lower wage because of the cost of hiring and training new workers and because of the ability of insiders to harass or not cooperate with new entrants hired to replace dismissed insiders. The costs of replacing insiders with outsiders gives insiders a great deal of power in setting their own wage [Lindbeck and Snower 1988].

Source: Campbell and Kamlani (1997)

Five of the most prominent theories concerning wage rigidity are contract theory, implicit contract theory, efficiency wage theory, fair wage theory, and insider-outsider theory. According to implicit contract theories, compensation is redistributed over the period of the contract, independently of the current level of productivity. Thus a person's spot wage might have little to do with spot productivity. While facing uncertainty about new workers productivity, employers may offer remuneration scheme taking a form of e.g. complex insurance if employees are relatively more risk averse than firms (Stiglitz, 1975; Malcomson, 1999) or a deferred compensation system.

The marginal productivity theory of wages has been examined by Frank (1984) who noticed that many firms follow strict pay schedules that are much more egalitarian than actual productivity differences between workers. Obviously, measuring individual productivity could be very costly for the firm and that would explain wage compression. However, the rigid pay schemes have been observed even in occupations where there is relatively easy to observe individual productive contribution. Frank (1984) constructed direct estimates of the marginal productivity of employees in a variety of enterprises that could reasonably be assumed to purchase labour under competitive conditions (estate salespeople, car salespeople, research scientists) and then compared these estimates with the amounts these workers are actually paid. The main findings contrast sharply with the characterization of labour market equilibrium as it is described in traditional neoclassical models. Wage rates tend to vary substantially less than individual productivity values. The most productive workers appear to be paid substantially less than their marginal products while the least productive members - substantially more.

Moreover, Frank (1984) pointed out that workers might attach great importance to their relative standing in the income hierarchies of the groups to which they belong. He demonstrates that in this case and if status can be treated like most other goods, people will expect compensating wage differentials: the premium for occupying a low-ranked position and implicit price to pay for occupying a high-ranked position in an earnings hierarchy, which tends to rise over time as incomes grow.

The analysis of reasons for wage rigidity has been carried out also by Campbell and Kamlani (1997). In order to test which existing theory gains the strongest empirical support, the author conducted a survey of 184 firms, mostly compensation executives in Business Week 1000 corporations, and some smaller ones. Respondents were given a series of statements based on various theories of wage rigidity and were asked to indicate the importance of each of them in explaining why their firm normally does not cut wages during recessions to the lowest level at which it can find the necessary number of qualified workers (provided their firm normally does not cut wages as low as possible in recessions). First, the results revealed that firms do not pay wages that are equal to workers' productivity. On average, respondents indicated that the pay differential would equal only about half the differential in productivity. The fact of keeping wage differentials between employees smaller than productivity differentials was justified by a concern that large pay differentials would be harmful to workers' morale.

Furthermore, investigating the reasons for wage rigidity, the authors found the strongest support for explanations based on adverse selection in quits and on the effect of wages on effort. Firms fear that, in particular for white-collar workers, cut in wages could increase the number of quits and decrease their effort, result in lower output or poorer service. Though, highly-skilled workers were found more likely to quit than to reduce their effort in response to a pay cut (Agell and Lundborg, 1995). White-collar workers often acquired more firm-specific human capital, they perform jobs that are more challenging and less standardized between firms. It makes their hiring and training costs higher compared to other employees. Thus, employers wish to reduce their turnover and retain them in the firm. On the other hand, the implicit contract theory and impact of wage cut on level of effort is supposed to well explain wage rigidity for blue-collar and less-skilled workers. Also, hiring and training costs appear to be a relatively important factor but significantly less than for white-collar workers.

Moreover, the effect of wages on effort concerns employers' fear that wage cuts would generate negative feelings among workers and thereby lead to less effort. Cohn et al. (2011) conducted a field experiment to test whether workers respond to wage cuts and whether their response depends on co-workers' wages. They showed that, in a group of two, cutting both workers' wages reduced their work performance significantly. However, cutting only one worker's wage resulted in a decrease in his or her performance that was twice as large. In contrast, the spared worker's performance remained unaffected. These findings confirm the fair wage-effort hypothesis, which can explain intra-firm wage compression. Consequently, firms may find it optimal to refrain from cutting wages in recessions, even though wage reductions would decrease labour costs. Since wages are not equal to productivity, firms would rather lay off their least productive workers than lose their most productive workers through quits. Also, the interview of three hundred business executives by Bewley (1999) revealed that during the economic downturns, the executives might be reluctant to cutting wages of their current employees or new hires since they believe that it would hurt workers' morale. Consequently, it could harm the cooperation between the employees and make it impossible to convince them to internalize the managers' objectives for the company.

The similar argument is often used in the context of pay cut for older workers. In a competitive labour market, if older workers were less productive than younger workers, the employers would be forced to pay older workers a lower wage rate than they pay younger workers without a necessity to lay them off. In real world, it is argued that lowering the wages of older workers would adversely affect their morale and consequently their effort level or productivity. However, as pointed out by Lazear (1979), it is not evident that terminating older workers rather than lowering their wages would improve the morale of the remaining employees: "a 60-year-old worker who is faced with approaching termination is not necessarily going to have a better attitude than one who knows his wage rate will be lowered 5 years from now". It is true that it might be difficult to judge the actual decrease in productivity of an older worker in order to adjust his wage accordingly. However, the author remarks that "laying off a worker adjusts his wage rate to zero. This is a poorer approximation of his true productivity decline than any smooth wage adjustment."

Wage rigidity has been also the object of a study by Caju et al. (2007). They estimated nominal and real wage rigidity over the period 1991-2002 for different categories of workers in Belgium. Earnings of white-collar workers have been found substantially more rigid than those of blue-collar workers. Similar as Campbell and Kamlani (1997), the authors put attention to the fact that firms want to avoid decline in effort or quitting the firm by the white-collar workers. Therefore, employers may be reluctant to cut wages of these workers whose effort is less easily monitored and having high replacement costs.

Consistent with the prediction of the shirking model and the adverse selection model applied to quits, Du Caju et al. (2007) have found both real and nominal rigidity to decline with age. Since the job loss is more costly for older workers, they are less likely to quit or shirk, even if their earnings increases are below their expected bargaining reference point. The low rigidity could be also related to the fact that automatic pay increases due to age or tenure flatten out with age. Moreover, as the extra-wage components of earnings become more important for people with more experience and responsibilities, real decreases in total earnings could be more probable. Real rigidity has been evaluated as 35% lower for workers over 45 years old. Real and nominal wage rigidity has been found highest for the youngest workers. In general, their wages tend to be lower and thereby closer to the minimum wage. Likewise, there are more workers with very low education and poorly paid jobs in the lowest age category. The last phenomenon might be the result of the union bargaining within firms. If unions care more about senior workers and their preferences, incumbent workers controlling the union might exploit newcomers. Furthermore, employment protection legislation in particular the last-in first-out rule may protect older workers more than younger workers. Due to this rule firms cannot simply replace high wage older workers for low wage young workers (de Hek and van Vuuren, 2010).

2.1.3. Controversies about interpretation of age-earnings profile - longitudinal versus cross-section data

After having analysed, in the previous part, theoretical concepts on evolution of productivity and earnings with age, people's actual preferences for increasing age-earnings profiles and the phenomenon of intra-firm wage rigidity which results in wages that do not necessarily indicate persons' productivity, this part is devoted to a very important issue of correct interpretation of the age-earnings profiles.

Depending on the type of available data, it is possible to investigate how earnings change with workers' age, how they vary across different age groups and to forecast the evolution of future earnings. The longitudinal data permit to analyse the changes of individual's pay over his life cycle as well as the cohort analysis over time. The cross-sectional earnings data allow depicting the contemporaneous differences between individuals of different ages, belonging to different cohorts.

However, in the literature, certain confusion concerning the interpretation of age-earnings profiles has been observed. Many economists misinterpret the real meaning of these profiles confounding differences between individuals at different points in their lives and differences within persons over time (Luong and Hébert, 2009). They claim that cross-sectional, point-in-time data can also describe how earnings change over the working life of the average worker, i.e. rising rapidly at younger ages, reaching a peak, and then declining before retirement. In fact, cross-sectional profiles generally understate the actual course of earnings over the average individual's life cycle. Moreover, the characteristic inverted U shape (earnings peak and decline) of cross-sectional profiles is not always observed in time series earnings data - almost never for a cohort's nominal earnings path, and only sometimes for a cohort's real earnings path (Thornton et al., 1997).

While analysing cross-sectional data that compare individuals in different cohorts at different ages, it is impossible to make conclusions concerning earnings changes over time. For example, one cannot expect that a 20-year-old today will in 30 years have the same remuneration as a 50-year-old person today. Moreover, as different age cohorts vary in size, the baby boom generation will be expected to have relatively lower wages than a cohort of baby bust. Also, the cross-sectional age-earnings profile might not explicitly account for the change over time in returns to education due to changes in technology and the industrial structure (Gohmann et al., 1998).

The problem with the interpretation of the cross-sectional data, which in contrast to the longitudinal data, do not track the earnings of specific individuals through their lifetimes but rather show the earnings of different ages at some particular point in time, has also been noticed by McConnell and Brue (1994). The authors state explicitly that: "the fact that the age-earnings profiles ultimately decline must be interpreted with some care. While it is tempting to attribute the declining incomes of older workers to diminished physical vigour and mental alertness, the obsolescence of education and skills, or the decision to work shorter hours, the decline may be largely due to the character of the data. (...) Longitudinal data which do trace the earnings of specific persons over time indicate that earnings continue to increase until retirement."

The explanation for the shape of cross-sectional earnings profile grounded in human capital theory has been surprising already for Mincer (1970). He pointed out that original model does not directly apply to cross-sections and the theory deals with lifetime behaviour of individuals, not with differences among individuals of different ages. The distinction between longitudinal (cohort) analysis and contemporaneous (cross-section) analysis would not matter only in some exceptional cases such as stationary economy or an economy in which changes are "neutral" with respect to categories entering the human capital model.

Furthermore, concerning the characteristic inverted U shape of cross-sectional age-earnings profile, one should notice that in fact it will take place only if earnings of a younger cohort grow at a sufficiently faster rate to eventually overtake the earnings of an older cohort. It is also possible that the decline in earnings for older age group observed in a cross-section might represent simply a selection bias. If availability of pensions (or other types of non-labour income) encourages some workers to retire earlier and at the same time individuals with higher pensions are those with higher earnings, there will be a higher rate of withdrawal from the labour force for these workers compared to lower-paid individuals. Then, from a cross-sectional profile perspective, the average earnings of older workers may appear to decline sharply. But evidently, such a phenomenon would not represent the actual course of earnings for the remaining workforce (Thornton et al., 1997).

2.2. Age-related labour productivity

The fact that earnings tend to increase with seniority is often used as an argument against older employees who are considered costing too much compared to their productivity. However, although the level of earnings can be relatively easily verified, the right estimation of workers' productivity is already much less evident. In particular, there is no well-defined method of estimating how productivity varies by age. Consequently, the age structure of a given workforce is largely based on the employer's anticipations and beliefs about productivity of junior and senior workers. In order to evaluate managers' willingness to employ workers belonging to different generations, this part starts with a brief review of the survey literature concerning employers' beliefs about advantages and disadvantages of employing younger and older employees.

Though, the real question is the actual evolution of productivity with age and whether labour productivity is age-specific. Hence, the following part describes, first, various factors having impact on increase and decrease in productivity with age and, second, different approaches used to measure individual job performance.

Finally, the last part of this section will be devoted to empirical studies evaluating the effect of age composition on the firm's productivity. Although a given workforce is composed of many individuals, the different mixture of junior and senior workers might create working environment more or less favourable for the productivity increase.

2.2.1. Advantages and disadvantages of employing younger and older workers – opinions held by the employers

Searching for the optimal age structure of workforce, many employers base their hiring decisions on the beliefs they hold about productivity of different age groups. In particular, the negative views about the adaptability and productivity of senior employees, translates into lower hiring and retention rates, especially once workers reach their early to mid-50s (OECD, 2006). In the large-scale postal survey of personnel managers, Warr and Pennington (1993) found that, indeed, age is an important factor in recruitment decisions in many organisations.

There is some evidence that employers have rather stereotypical views about the strengths and weaknesses of younger and older workers. Senior employees tend to be considered as difficult and not willing to train, lacking creativity, too cautious, incapable of heavy physical work and disliking taking orders from younger workers (Walker, 2005). According to 2001 employers' survey carried out in Sweden, 50 % of all employers considered older workers to have less relevant skills than younger workers and to be more rigid and inflexible with respect to changes in the workplace (OECD, 2003). In addition, 70 % of them reported that they never or only very rarely hired older workers. Similarly, in the United States, a 1998 survey of employers revealed that while older workers were often seen as being more loyal and committed than younger workers, they were also seen as being less flexible, less willing to participate in training and less likely to have up-to-date skills (OECD, 2005). One notable exception is Denmark, where in one survey, human-resource managers generally reported that competences did not differ systematically by age and that age had no importance in their hiring decisions (OECD, 2006).

Obviously, both age groups have their advantages and disadvantages as employees. The review of the survey literature shows that managers' opinions are fairly divided in this aspect.

Advantages of employing older workers

Many researchers report positive perceptions of senior workers by their employers or they report that common stereotypes (lower performance, flexibility or adaptability, less potential, and less ability to learn new skills) are not justified (Bennington and Tharenou, 1998; Fenstermacher and Kleiner, 1999; Kaplan, 2001; London, 1996; Mallier and Shafto, 1992; Moberg, 2002; Paul and Townsend, 1993; St-Amour, 2001; Yearta and Warr, 1995). Based on an extensive review of the literature by Guest and Shacklock (2005), the most frequent references to the advantages of employing older workers concern: experience and developed skills, reliability/dependability, loyalty, low turnover, attendance/low absenteeism, knowledge and doing a better quality job (see Table 3). Moreover, older workers tend to be seen as likely to retain plenty of 'mileage', being productive, flexible, less accident prone and not lacking in creativity.

Many managers believe that older workers benefit the firm thanks to their knowledge, reliability and dedication (Buck Consultants, 2007) . Most of private-sector employers interviewed by the Center for Retirement Research at Boston College, declared that older workers' "knowledge of procedures and other aspects of the job" and their "ability to interact with customers substantially enhanced their productivity" (Munnell et al., 2006). Workers over 50 are appreciated by human resources executives for their loyalty and dedication to the company, commitment to doing quality work, solid performance record and are considered as someone you can count on in a crisis. Some employers prefer older workers to their younger counterparts because they value their maturity, and strong work ethic (Johnson, 2007).

Advantages of employing younger workers

Some other research has argued that younger workers are valued more than older workers by employers (Min and Kleiner, 2001; Australian Government Productivity Commission, 2005). Among the advantages of employing younger workers, the most frequent references were made to their flexibility, training, adaptability or willingness to change and more relevant skills (for a complete list see Table 2).

In terms of the perceived advantages of younger workers, O'Neill (1998) identified that younger workers had more or better vision, hearing, strength and endurance, cognitive processing and intellectual capital (except for general knowledge and verbal ability). Employers rated younger workers as being more creative and easier to train (Steinberg et al., 1998), ambitious, mentally alert, hardworking and creative. Furthermore, employers perceived junior employees as being less cautious, higher in physical capacity, more interested in learning technological skills, less accident prone, in better health and less resistant to change (Taylor and Walker, 1994).

Table 2: Perceived advantages of younger and older workers (in alphabetic order)

Perceived advantages of	
younger workers	older workers
• ability to learn new skills/creativity • adaptability/willingness to change • aggressive spirit • education quality/relevance • flexibility • less illness and injury • less expensive to hire • mental alertness • new technology knowledge/skills • physical abilities (some) • training-faster response • less expensive • take less time to learn	• fewer accidents • accuracy • attendance/absenteeism • better quality job • commitment/able to be counted on in crisis situations • creativity/flexibility • experience and developed skills • ethical decision making/honesty • job turnover • knowledge/expertise • loyalty • maturity • people management/influence on • younger workers/mentoring roles • productivity • reliability/dependability • trainability • work ethic

Source: Guest and Shacklock (2005)

However, perceptions of advantages of older or younger workers need careful application. Not all individuals will perform at the same level or standard, nor will they ‘age’ at the same rate. It is possible that young people work faster, but they make more mistakes. Older people can take longer to train, but they will do things more thoroughly and produce a higher standard of work (James, 2001). Naturally, older workers will have more experience, but the importance is the relevance and currency of such experience.

Productivity versus cost: employers’ concern about an ageing workforce

Despite all the perceived advantages associated to employment of senior workers and political calling for extending working life, a Dutch large-scale survey has revealed that most of the 1000 polled companies and organisations (73 %) declared to associate an increase in the average age of their workforce with higher labour costs (see Table 3). More than half of the respondents claimed that ageing will increase absenteeism; reinforce resistance to change and new technology. Moreover, it will certainly require reorganisation of work and might adversely affect a company’s image. Older workers are commonly thought of as costing more because they earn higher salaries, retire early, are considered difficult to retrain and prone to higher rates of absenteeism and work injuries than younger workers (Brooke, 2003).

On the other hand, 55 % of survey's participants expected that an increase in the average age of their workforce would result in an increase in know-how and experience. Merely 15 % supposed that it would lead to fewer conflicts and only 7 % hoped it would bring about an increase in productivity (Remery et al., 2003).

Table 3: Employers' opinions about expected consequences of an ageing workforce (in %)

Consequences	Percentage of employers answering			
	(Highly) unlikely	Neutral	(Highly) likely	Total
• Increase in labor costs	7	20	73	100
• Greater resistance to change	12	31	57	100
• Increase in absenteeism	9	35	56	100
• Increase in know-how and experience	14	30	55	100
• Review of the way in which work is organized	17	31	52	100
• Need to improve working conditions	14	36	50	100
• Less enthusiasm for new technology	16	34	50	100
• Fewer conflicts within the organization	30	55	15	100
• Negative effect on organization's image	40	45	15	100
• Increase in productivity	52	41	7	100

Source: Remery et al. (2003)

Actually, many firms express concern about the cost of employing older people. Senior employees may be seen as particularly expensive due to higher salaries, fringe benefits or higher health care costs. Medical benefits damage employment prospects for older workers especially in the United States, where it is the employer who covers most medical expenses (Johnson, 2007).

Employers also may be more reluctant to hire senior job applicants than retain older workers due to occurring training costs. Seniors, expected to retire relatively soon (especially due to possible early retirement), might be less eager to undertake training in order to maintain their productivity. For the same reason, employers do not have incentive to invest in older workers if it might be difficult to recuperate the training costs. Hence, senior workers are offered fewer opportunities to participate in training programmes. However, as shown in the recent (2010) report by the Australian Computer Society, due to high labour turnover of juniors (younger workers are five times more likely to change jobs than older workers), older workers tend to stay longer with an employer after training than younger workers.

Furthermore, in the recent decades, the demand for older workers has suffered also due to the rapid development of information and communication technologies. It was not evident for senior workers to keep up with innovative work practices and the continuous training has not always been offered. Consequently, technological and organisational changes induced earlier retirement (Bartel and Sicherman, 1993; Haegeland et al., 2007) and negatively affected the wage bill share of older workers (see Aubert et al., 2006; Beckmann, 2007; Rønningen, 2007). In this context, training appears to have a positive impact on the employability of older workers, by reducing their turnover or by increasing hiring rates more than for other age groups (Behaghel et al., 2011).

2.2.2. Age and individual job performance

As shown in the previous part, employers tend to hold rather stereotypical views about the strengths and weaknesses of younger and older workers. Thus, there is a great need to investigate on the actual variation of productivity with age and to see whether labour productivity is age-specific. If labour productivity is age dependent, and older workers are less productive, then ageing workforce would bring about a decline in aggregate productivity, even if age-specific productivity were to remain constant (Börsch-Supan, 2008). This process could be observed at the firm level as well as in the whole economy.

The main challenge for the research concerning workers' age and productivity is the difficulty to measure the marginal productivity of individuals. Although the earnings can be measured with reasonable precision, there does not exist any definite way of estimating how productivity varies by age. Existing empirical studies on this subject often involve a large degree of uncertainty. They rely on strong assumptions that are likely to bias the estimates or they consider a narrow set of occupations which limits validity of conclusions to particular jobs.

Furthermore, it happens that certain confusion regarding the interpretation of age-productivity profiles takes place. Namely, the cross-sectional analysis is sometimes incorrectly followed by conclusions on evolution of productivity with worker's age, whereas, in fact, it describes the difference in productivity within the current population. It has been found that studies based on cross-sectional data typically find a younger ability peak than time-series analysis where the same individuals are followed over time. For example, Schaie (1996) found in his study on word fluency that, in the longitudinal dataset, this ability did not decline before the age of 53. In cross-sectional settings, it has been found to deteriorate already at age of 25. Hence, studies based on time-series are generally supposed to be biased upwards. On the other hand, cross-sectional approach might suffer from downward bias of productivity estimates since younger cohorts have on average higher education and ability levels (Dickens and Flynn, 2001).

Factors determining individual job performance

It is very important to make a distinction between a set of common factors that influence the productivity of the total workforce (firm's type, used technology, organisation of work, etc.) and the elements having an impact on the individual productivity potential. The current productivity of each individual is a result of evolution over time of different factors, such as: physical and mental abilities, education and job experience. Combined with the company's characteristics, job requirements and task description, these elements determine individual job performance in the current workplace.

Physical capacities as well as cognitive abilities are both expected to change or evolve with worker's age. Although today's seniors are more physically fit and the shift from goods-producing to services-producing jobs has reduced the physical demands of work (Munnell et al., 2006; Spitz-Oener, 2006), it has been proved that physical productivity tends to decrease as workers get old (for the review see de Zwart et al., 1995).

At the same time, it is not so evident to establish a clear correlation between the evolution of productivity over the life cycle and changes in *cognitive abilities*. According to Horn and Cattell (1966), we can differentiate between crystallised abilities and fluid abilities. Crystallised abilities (e.g. verbal skills) depend on acquired knowledge and can stay virtually unchanged until late in life. On the other hand, fluid abilities (e.g. reasoning and speed) might start declining already from early adulthood. Therefore, it has been observed that productivity reductions at older ages are the strongest in job tasks where problem solving, learning and speed are important. For work tasks where experience and verbal abilities matter more, there is less or no reduction in productivity among elderly workers (Skirbekk, 2008). For example, no evidence of a mental productivity decline has been found by Van Ours (2010) who compares publication scores in economics journals by members of the Department of Economics of the Tilburg School of Economics and shows that productivity in publishing increases with age up to age 50 and stays constant after that.

Even if some cognitive abilities are likely to decline with worker's age, thanks to longer *experience* and higher levels of job knowledge, senior workers can maintain their productivity level. It is well illustrated in a study by Salthouse (1984) on the effect of age and skills in typing. Compared to their younger colleagues, older typists were found to compensate for their lower typing speed by using more efficient work strategies. A vast experimental literature indicates that despite age-related declines in perceptual and motor capacities and basic cognitive processes, older persons may perform equally well as their younger counterparts thanks to accumulation of specialised knowledge (Bosman, 1993; Charness, 981a, 981b; Charness and Bosman, 1990; Rybash et al., 1986; Salthouse, 1987, 1989, 1990). These studies, investigating age differences in skill acquisition indicate that older adults are capable of acquiring new skills, and that practice brings about important increase in performance. Older employees, both white-collar and rank-and-file workers, are often appreciated for their tacit knowledge and familiarity with procedures to solve everyday problems (Munnell et al., 2006).

In general, senior workers can stay highly productive in the domains that they know well and where having a long experience is important. On the other hand, as people grow older while staying within the same field of expertise, they take a risk that the skills they developed will be less and less transferable. It is particularly important in the perspective of the currently observed accelerating technological progress. It increases demand on such skills as *being able to learn* and to adjust to new ways of working, while a long work experience becomes less important (Baltes and Lindenberger, 1997; Hoyer and Lincourt, 1998). In addition, a decline in self-confidence for career-relevant learning experiences may contribute to older workers' greater reluctance to pursue learning and development activities (Maurer, 2001). Finally, although senior workers today have much higher *education* levels than their predecessors, their education and skills may be obsolete compared to the younger generation (Guest and Shacklock, 2005).

Approaches used to measure the influence of age on individual productivity

The relation between age and job performance has been studied by several different disciplines such as social psychology, medical science and labour economics and each of them uses different methods. Among the most common approaches we can distinguish: supervisors' ratings, measuring quantity and quality of a worker's output and employer-employee matched datasets analysis.

Studies based on *supervisors' ratings* have not found any clear or systematic relation between worker's age and productivity (McEvoy and Cascio, 1989; Warr, 1994). However, the main disadvantage of these studies consists in high subjectivity bias. Evaluating workers' performance, managers might wish to reward certain age categories of workers for their past achievements or loyalty.

More objective methods are the *work-sample tests*, measuring quantity and quality of a worker's output. They usually take a form of a task-quality or speed tests such as test of computer-based performance. These studies tend to find that senior workers have lower productivity due to longer response time or a greater number of errors. The potential bias might come from the time-limit (performance during a short test might not correspond to one's everyday productivity) or participants selection (only certain age groups or narrow occupations).

In economics, the estimation of workers' productivity has been most often based on analysis of *the matched employer-employee datasets*. In this case the individual productivity is measured as the workers' marginal impact on the firm's output or value-added. The most common result is a hump-shaped relation between job performance and age (Andersson et al., 2002; Crépon et al., 2002; Ilmakunnas et al., 2000; Haltiwanger et al., 1999). Employees in their 30s and 40s are found to be the most productive group. Senior workers, above the age of 50 seem to have lower productivity despite their higher wages. Contrasting results have been presented by Hellerstein and Neumark (1995) in their study of Israeli manufacturing firms where they suggest that productivity increase over the life span. However, the authors underline themselves that due to the high inflow of young immigrants as well as the poor data quality, no definite conclusions about age and productivity could be drawn. Also, in a study of American firms, Hellerstein et al. (1999) suggest that those above 55 contribute the most to the firm's output. However, when using the value-added instead of output as an indicator of productivity, they find that the peak productivity shifts to 35-54-year-olds workers. Thus, the conclusions of empirical studies stay quite ambiguous.

2.2.3. How the age composition of workforce relates to firm's productivity performance?

As we have seen in the previous parts, the individual job performance is a complex phenomenon. There are many different factors having impact on worker's productivity. Some are very individual such as physical or cognitive abilities. Some others depend on working environment (technology, working methods) that can favour or hinder worker's performance. Nevertheless, there is one more dimension that should not be neglected when speaking about age and productivity. It is the age composition of a given workforce. Different mixtures of young and old are likely to produce more or less productive work environment (Guest and Shacklock, 2005). On the one hand, heterogeneous workforce is expected to be beneficial. Young workers can introduce new techniques to older employees, whereas seniors can share the knowledge that they have obtained through years of experience in the particular industry or in a particular firm. On the other hand, age diversity might be crippled by communication and coordination problems (Hansen et al., 2006).

The concept of an optimum workforce age mix that maximises firm's profits is still investigated. The right combination of age and skills is not always possible or easy to implement. Obviously, labour turnover is constrained by market rigidities and law regulations. But a real problem is also a limited supply of labour with required characteristics, especially nowadays or in the near future because of smaller age cohorts. It is then particularly important to combine older and younger workers' skills so that they complement each other. Then, the increased initial costs of the younger workforce may be balanced by their currency of skills and knowledge, which in turn can be balanced by the experience and stability of older workers (Brooke, 2003).

The existing studies tend to underline the positive effects of age diversity on global productivity (Barrington and Troske, 2001; Hansen et al., 2006; Garibaldi et al., 2010). Börsch-Supan and Weiss (2011), estimating the relation between the age structure of work teams and their productivity for a car manufacturing plant, find that older workers are slightly more likely to make errors in the production process. However, since they hardly make any severe errors, they prove to be especially able to keep control in difficult situations. On the other hand, Hamilton et al. (2004) using a novel panel data from a garment plant, conclude that holding the distribution of team ability constant, teams with greater diversity in age are less productive.

In the context of inter-generational teams, it is worthy to mention a theoretical paper by Breton et al. (2006) based on an overlapping-generations model with adverse selection, where wages are reputation-based. They show that even if an employer is indifferent between inter- and intra-generational teams, workers may care about the age composition of the team. This occurs because age differences between co-workers usually reflect differences in work histories, as well as actual and attributed productivities (i.e. reputations). As a result, young and high-productivity agent will always prefer to work in inter- than intra-generational teams. The authors explain this result as follows. First of all, two young, inexperienced workers are unlikely to be able to provide training to each other. Thus, a young worker who believes that such training might allow him to increase his productivity, and so his wage, will prefer to be teamed up with an experienced senior worker. Moreover, if it is possible to assess individual contributions to a team output by using individual reputations, an older co-worker with a clear (either good or bad) reputation implies less uncertainty when it comes to determine who did what in the team. This might be preferable to a high-productivity worker who wants to be easily identified, and will favour team arrangements that minimize the uncertainty on team members' contributions.

The influence of age composition of the workforce on firm performance has been also a research subject of a number of empirical studies. However, there is no consensus in their final results. The issue whether firms with young rather than older workers are more successful and whether firms with homogenous or heterogeneous workforce are doing better, has been investigated by Grund and Westergård-Nielsen (2008). They used linked employer-employee panel dataset for Danish companies over 1980-1998 in order to estimate the following multivariate linear model:

$$logY = \beta_0 + \beta_1 mean\,age + \beta_2\,(mean\,age)^2 + \beta_3 sdv\,of\,age + \beta_4\,(sdv\,of\,age)^2 + X\delta + \varepsilon \quad (5)$$

Firm performance Y has been measured as value added par employee. The age structure of workforce has been captured by the mean age and the standard deviation of worker's age. The authors control for tenure, schooling, share of females and blue collars (vector X). ε is en error term. Among the main results, the authors find that both mean age and dispersion of age in firms are inversely U-shaped related to firm performance. Thus, companies with either very homogenous or very heterogeneous workforces with respect to age of employees have much lower productivity (lower value-added per worker). Estimating the fixed effects model, the authors found that the most productive firms were those with an average age of employee of 37 years and with a standard deviation of about 10 years.

Another study that tries to answer the empirical question of how labour productivity at the plant level is related to the age composition of the labour force is the one by Malmberg et al. (2008). Using the panel data concerning the Swedish mining and manufacturing industries over the period 1985-1996, the authors estimate a model with a log value added per worker as dependent variable and log of the age variables as explanatory variables:

$$logY = \beta_0+\beta_1 log\,(share \leq 29)+\beta_2 log\,(share\,30-49)+\beta_3 log\,(share \geq 50)+\beta_4\,(ed.\,mean)+\varepsilon \tag{6}$$

The workforce has been divided into three age groups: less than 30, between 30 and 50 and above 50 years. The only explicit control variable is the mean length of education. In order to avoid problems related to omitted variables bias, the authors control for plant-level fixed effects. OLS as well as IV regressions results suggest that high shares of older employees are associated with higher productivity than high shares of young workers.

The contrary results have been presented by Lallemand and Rycx (2009). The authors find that a higher share of young workers within a firm is favourable to firms' productivity while a higher share of older workers is harmful. They investigate the effects of the workforce age structure on the productivity of large Belgian firms in two subsequent cross-sections for 1995 and 2003. More precisely, they examine different scenarios of changes in the proportion of young, middle-aged and old workers and their expected effects on firm productivity. The age classes have been defined in the same way as in the study by Malmberg et al. (2008). The model, estimated by OLS with White heteroscedasticity-consistent standard errors, takes the form:

$$lnY_j = \beta_0+\beta_1 ln\,(share\,16-29)_j+\beta_2 ln\,(share\,30-49)_j+\beta_3 ln\,(share \geq 50)_j+\gamma X_j+\delta Y_j+\varepsilon \tag{7}$$

where Y is the value added par employee, X is a reach set of aggregate worker characteristics per firm: the mean and standard deviation of education (number of years of schooling), the mean and standard deviation of gross hourly wages in order to control for efficiency wage effects (Akerlof and Yellen, 1986; Weiss, 1991), the share of blue-collar workers, the share of women, and the percentage of part-time workers. Y_j is a set of firm characteristics: the size (exact number of employees), the industrial sector (at the NACE one digit level), the level of collective wage agreement, the regional affiliation and the type of economic and financial control.

Overall, the presented empirical studies on the effect of age composition on firm-level labour productivity find contradicting results. However, it must be noticed that it is very difficult to draw some direct comparisons. These studies are characterised by many peculiarities such as specification of independent variables, but also in terms of data: various time dimensions, firms from different economic sectors and from different countries with other institutional environment. Moreover, they do not control for the capital stock and do not account for potential endogeneity of the age composition of a firms' workplace. These limitations have been addressed by other studies, using somewhat more structural approach, based on the estimation of a production function. They will be further discussed in details in the following chapter 2.

2.3. Conclusions

In order to understand the complexity of the relationship between age-earnings and age-productivity profiles, the theoretical concepts, presented at the beginning, have been then completed, in the second part of this chapter, with important empirical findings.

We have seen that the increasing age-earnings pattern characterised by lower wages for young workers and higher wages for older workers has been widely observed in reality. However, it turns out that the wage profile does not necessarily correspond to worker's productivity at any age. Despite a large heterogeneity in productivity level of individual workers, many firms apply a rigid remuneration scheme based on education, experience and tenure, resulting in high wage compression within a firm.

One of the reasons is an evident difficulty to measure the productivity of an individual worker or a particular age group. The intergenerational differences in job performance have been investigated using so different methods as supervisors' ratings, measuring quantity and quality of a worker's output or through analysis of employer-employee matched datasets. Although, the obtained results tend to stay quite ambiguous, most of them suggest that productivity follows an inverted U-shaped profile, where significant decrease comes after the age of 50. Nevertheless, one should remember that in spite of hump-shaped cross-sectional age-productivity profiles, individuals could experience productivity increase throughout their life cycle. Indeed, thanks to better technologies, higher education level and more capital, both younger and older workers might become increasingly productive over time.

Moreover, the productivity of both generations within a firm could be reinforced through the efficient age-mix of workers with complementary or synergistic age-dependent skills. The physical strength, high education level and skills currency of young workers could complement experience, maturity of judgement, reliability, and managing skills of older employees. Many studies suggest the positive effects of age diversity in a company. Nonetheless, up to now, many employers tend to consider older workers as relatively less productive. This fact combined with widely spread seniority-based remuneration system raises an important question about existence of a wage-productivity gap for older workers. This very important from the employers' point of view issue will be further investigated in the coming chapter 2.

Chapter 2: Firm-level relationship between age, wage and productivity

This chapter analyse the relationship between age, wage and productivity from the perspective of the firm. It starts with the review of the empirical studies examining the age-related wage-productivity gap. It is followed by the original study which, using the French data on private firms, provides an estimation of labour productivity across different age groups.

1. Research on age-related pay-productivity gap

While deciding on its production level, a firm has to choose the optimal level of labour needed to generate the given output. From an economic point of view, there is an incentive to find the age mix of the workforce that can produce a given output at the least cost. This will be the age mix that yields the highest labour productivity and is described as the optimal age mix of the firm's workforce (Guest and Shacklock, 2005). Although the distribution of earnings is usually easy to verify, due to measurement problems there exist large uncertainties regarding the levels of productivity for different age categories of workers.

As noticed by Johnson (2007), ageing per se may affect worker's productivity, either positively or negatively. Thus, the assumption that all the workers are equally productive after controlling for variables such as education, experience, and job tenure is not very convincing. A better approach would be to relate individual productivity measures to earnings and examine how this relationship varies by age, but individual productivity is difficult to measure. Therefore, existing empirical studies try to evaluate the productivity of different generations by aggregating employees in different age groups. Nevertheless, the common problem is the underlying assumption that workers belonging to the same age category have a similar productivity level. Although, if individuals are aggregated at the firm level, the relationship between productivity and age should still hold (van Ours and Stoeldraijer, 2010).

According to Johnson (1993), most employers and probably most employees seem to believe in a rule of thumb that average labour productivity declines after some age between 40 and 50. If this is true, and earnings continue to rise with age, older workers may have a wage that is higher than their productivity and as a result, the gap between wages and productivity can arise. In a perfectly competitive labour market there is no reason for an age-related pay-productivity gap to occur because firms pay workers according to their marginal productivity. However, with the existence of labour market institutions, imperfect information and/or costly monitoring of productivity the direct relationship between age and productivity disappears and an age-related pay-productivity gap may occur (Van Ours, 2010). It is important since workers whose wages exceed their productivity levels might have reduced employment opportunities. It is observed that as a result of a rigid remuneration system, in response to a negative productivity shock, employers instead of adjusting wages, tend to adjust their employment structure. The least productive workers or those who cost too much are the first to become redundant.

Since productivity is a firm-level phenomenon, establishing the relationship between age and productivity requires matched data at the level of the firm. The next part includes a short review of existing studies followed by the methodological problems often encountered in this type of research.

1.1. An overview of empirical studies based on production function approach

In the empirical literature, there is relatively little research aiming at productivity and wage data comparison and their correlation with workers' age. Moreover, it remains inconclusive about whether there is or not a pay-productivity gap for older workers. One of the reason is that each study has its own peculiarities and limitations. Studies differ in terms of data (country, time period, cross-section or panel), specification of dependent and independent variables as well as chosen estimation methods. Different specifications of estimated production function are briefly presented in the box at the end of this section.

One of the first studies based on the matched worker-firm data was the contribution of Hellerstein et al. (1999). In order to analyse the relationship between productivity and wage differentials among US manufacturing workers, the authors use a 1990 cross-section plant-level matched employer-employee dataset. The employees are distinguished by different demographic characteristics such as gender, race, marital status, age, education and occupation. In this purpose, a translog production function is jointly estimated with an earnings equation. A plant-level production function takes a form:

$$lnY = lnA + \alpha lnK + \beta lnM + \gamma lnQL + g\left(K, M, QL\right) + \mu \qquad (8)$$

Plants produce output Y that is a function of capital K, materials M and a quality of labour aggregate QL. $g\left(K, M, QL\right)$ denotes the second-order terms in the production function (Jorgenson et al., 1973), and μ is an error term. The labour aggregate QL is a function of labour inputs:

$$QL = (L + (\phi_i - 1) L_i) \tag{9}$$

where L is the total number of workers, L_i is the number of workers belonging to category i and ϕ_i is the marginal productivity of i workers relative to the reference group. As underlined by the authors, the corrections for number of working hours does not change the conclusions. Different categories of workers are assumed to be perfectly substitutable but have potentially different marginal products. The relative marginal productivities of different types of workers are restricted to be equal across demographic groups. Furthermore, the proportion of workers defined by one demographic group is restricted to be constant across all the groups.

In order to quantify and compare productivity and wages for various groups of workers, the plant-level production function has been estimated simultaneously with the average wage equation of the form:

$$ln(w) = a' + ln (L + (\lambda_i - 1) L_i) \tag{10}$$

where a' is the log wage of the reference group (for example, male, nonblack, never married) and the λ_i represents the relative wage differentials associated with each category. The relative wages of workers are restricted to be constant across all the demographic groups. Moreover, all workers within the same set of demographic groupings are assumed to be paid equally. Hellerstein et al. (1999) have used information on the plant-level rather than individual level earnings in order to compare easily wage and productivity differentials. As long as both are estimated at the plant-level, any unobservables should affect the estimates similarly. In order to estimate relative wage differentials for different types of workers, total wages have been regressed on the composition of workforce. The parameters are estimated using nonlinear least squares.

The authors allow possible inequality between relative marginal productivity and relative wage for different groups of workers, which could be then interpreted as an indicator of long-term incentive contracts or discrimination. Among the main findings, prime-age workers are found as productive as younger ones. Moreover, productivity and earnings of prime age and older workers rise at the same rate over the life cycle. Thus, the authors claim that wage differentials reflect actual differences in marginal products for most types of workers, particularly for the age category. The finding that wage profiles are equivalent to productivity is coherent with the general human capital model by Mincer (1974).

The method used by Hellerstein et al. (1999) has been expanded by Crépon et al. (2003). They use the available French matched employer-employee panel dataset for the period 1994-1997. In order to remove some of the biases associated to OLS estimation of production function, the authors run the estimations using OLS with fixed effects and GMM procedure. Since the use of the translogarithmic function does not change the results, for simplicity, they consider the following Cobb-Douglas production function:

$$logQ_i = \beta logK_i + \alpha logL_i^* + \varepsilon_i \tag{11}$$

where Q_i is firm's value-added, L_i^* denotes labour inputs, K is the capital stock and ε_i is an error term. The total amount of work L_i^* is a sum of hours worked by employees of type k in plant i, multiplied by their hourly productivity:

$$L_i^* = \sum_0^K \lambda_{ik} L_{ik} \tag{12}$$

The authors make use of disaggregated data on wages that were not available to Hellerstein et al. and decompose the labour input in the following way:

$$L_i^* = \sum_0^K \frac{\lambda_{ik}}{w_{ik}} w_{ik} L_{ik} \tag{13}$$

where w_{ik} is an hourly wage of workers k in plant i. Thanks to this operation, the production function can be modified in a way to contain directly a ratio of hourly productivity to wage $\delta_{ik} = \frac{\lambda_{ik}}{w_{ik}}$ for different workers categories:

$$logL_i^* = logL_i + log\bar{w}_i + log\delta_{i0} + log\left(1 + \sum_1^K \left(\frac{\delta_{ik}}{\delta_0} - 1\right) P_{ik}^w\right) \tag{14}$$

so that, instead of parallel estimation of production function and earnings equation, here only one equation is estimated.

$P_{ik}^w = \frac{w_{ik} L_{ik}}{\bar{w}_i L_i}$ indicates the share of total wages received by workers of type k in firm i.

The ratio of productivity to wages for different types of workers δ_{ik} is assumed to be equal across firms. Similarly as Hellerstein et al. (1999), different types of workers are assumed to be perfectly substitutable.

The results obtained by Crépon et al. (2003) contrast with those by Hellerstein et al. (1999). The authors state the existence of a wage productivity gap which tends to expand with age. The wages continue to increase with workers' age whereas the productivity stops rising at one point or even declines. It is though unclear whether the old workers are overpaid or the young ones underpaid, or if both events take place. However, the authors pointed out that increase in wages for workers over 35 cannot be interpreted as reflecting human capital accumulation.

Expanding on the previous methodologies, (Aubert and Crépon, 2003; 2007) made use of the larger French panel data, covering period 1994-2000, and decomposing the labour force into thinner age groups. Through the estimation of the Cobb-Douglas production function, they found that productivity tends to grow with age up to age of 40 and stabilises afterwards. In all sectors, workers aged 35-39 appear to be slightly less productive than those over 40 and around 15 to 20 % more productive than young workers under 30 years old. At the same time, the authors found no evidence of a significant difference between wage and productivity that could explain the lower employability of older workers. Although for workers older than 55 a slight decrease in productivity is observed, this result is not statistically significant. Hence, the result is consistent with the original paper by Hellerstein et al. (1999).

The following three studies, using the same estimation method, based on production function and wage equations, find however some evidence on the wage-productivity gap increasing by age. Ilmakunnas and Maliranta (2005) observe the positive correlation between age and the wage-productivity gap that they attribute to strong seniority effects in wage setting. Dostie (2006) using Canadian matched worker-firm data, concludes that both wage and productivity profiles are concave, but productivity is diminishing faster than wages for workers older than 55. Finally, a cross-section study by Hellerstein and Neumark (2007) who refer to their previous article (Hellerstein et al., 1999) strongly rejects the hypothesis of productivity and wage differentials equality. The authors use the same specifications and sample selection criteria like in the previous paper but use this time larger and more representative dataset. The estimated age profiles suggest that the most productive group are prime-age workers (35-54), followed by the younger ones and the seniors (over 55) as the least productive. Furthermore, the wage profile steeper than productivity profile is consistent with the deferred compensation model à la Lazear.

However, according to Van Ours (2010), a productivity-wage gap at high ages should not be overestimated. The author analyses the relationship between age, wage and productivity using a matched worker-firm panel dataset from Dutch manufacturing covering the period 2000-2005. Using a variety of estimation methods, he finds little evidence of an age related pay-productivity gap. The results of GMM estimation, with the use of instrumental variables in order to control the endogenous character of the age structure, reveal that both productivity and wage costs increase with age, but in a similar way.

Cobb-Douglas production function (Douglas and Cobb, 1928) is the most widely used functional form in economics to represent the relationship of an output to inputs. It takes the following form:

$$Y = AK^{\alpha}L^{\beta}$$

where *Y* is total production, *L* denotes labour input, *K* denotes capital input and *A* is total factor productivity. α and β are the output elasticities of labour and capital, respectively. These values are constants determined by available technology. The Cobb-Douglas form imposes strong assumptions on the underlying functional relationship; in particular, the elasticity of substitution of capital for labour is fixed to unity.
A generalization of the Cobb-Douglas production function is the ***Constant Elasticity of Substitution (CES) production function***. It has been developed by Arrow, Chenery, Minhas, and Solow (1961). The formal specification with two inputs is:

$$Y = A(\delta_1 K^{-\rho} + \delta_2 L^{-\rho})^{\frac{-v}{\rho}}$$

The parameter $A \in (0,\infty)$ determines the productivity, $\delta \in (0,1)$ determines the optimal distribution of inputs, $\rho \in [-1,0) \cup (0,\infty)$ determines the constant elasticity of substitution which is $\sigma = 1/(1+\rho)$ and $v \in [0,\infty)$is equal to the elasticity of scale.

CES form encompasses the Cobb-Douglas (if σ approaches 1 for $\rho \to 0$), the Leontief (if σ approaches 0 for $\rho \to \infty$) and the Linear production functions (if σ approaches ∞ for $\rho \to -1$ and v is equal to 1) as its special cases. Although this function is more flexible than Cobb-Douglas, the main restriction is the constancy of the elasticity of substitution between inputs along and across the isoquants irrespective of the size of output or inputs (capital and labour) used in the production process (Henningsen and Henningsen, 2011).

An alternative function that permits variable elasticities of substitution and transformation patterns is the ***Translog production function*** that has been introduced by Griliches and Ringstad (1971), Berndt and Christensen (1973) and Christensen, Jorgenson and Lau (1973). It is the second order approximation to any unknown aggregate production function, using Taylor series. For two inputs, the translog production function is specified as:

$$lnY = lnA + \alpha_K lnK + \alpha_L lnL + \beta_K (lnK)^2 + \beta_L (lnL)^2 + \beta_{KL} lnKlnL$$

Unfortunately, this function is not invariant to the units of measurement of inputs and output. Further, on account of inclusion of *lnK*, *lnL*, their product and their squared values, estimation of parameters of this function often suffers from multicollinearity problem (Mishra, 2007).

1.2. Methodological issues

In the studies that have been presented above, the relationship between age and productivity has been analysed within a framework of production function. As noticed by Hellerstein et al. (1999), the estimation of a production function is a complicated task, especially when distinguishing among many types of workers. One of the difficulties consists in available data limitations. Although the number and quality of data is increasing, we still tend to observe lack of information on quality dimensions of labour and capital inputs, technologies used and organisational structure of enterprises.

Besides data availability, the major difficulty concerns the potential endogeneity of explanatory variables. According to the early critics by Marschak and Andrews (1944), the usual inputs exogeneity assumptions that are required for the consistency of OLS are unlikely to hold in production function estimation. In fact, inputs are not under the control of econometrician but are chosen in an optimal way by the producers themselves. Through the increasing availability of panel data, the problem of misspecifications that could be assumed fixed over time has been limited. Over years, different new solutions to the endogeneity problems have been proposed, such as instrumental variables or "between" and "within" estimations. The latest approaches are attributed to Arellano and Bond (1991) and Olley and Pakes (1996). In recent years both methods have experienced further developments. Many researchers in order to avoid the simultaneity problem often encountered at the aggregate level, have shifted to the use of thinner and thinner slices of micro-data. This approach however has exacerbated other problems and misspecifications such as high heterogeneity (Griliches and Mairesse, 1995).

Finally, an important issue are the restrictions imposed on the production process due to specific model chosen for the analysis. In the context of productivity according to workers' age, the specification of labour input is particularly important. Usually made assumptions on perfect substitution among different types of workers not only remain doubtful but also do not stay without an influence on the estimated workers' productivity.

1.2.1. Data availability

Most of studies estimating age-productivity profiles within the framework of production function require the use of plant-level data on inputs and outputs matched with individual-level data on workers with different demographic characteristics. The construction of such dataset is not always easy due to available data limitations. Some information that have an impact on company's outcome and therefore should enter the production function, are not always accessible. Ideally, one would like to know establishment characteristics such as age of the enterprise, economic sector, capital stock and its technical state as well as the right output measure - value added or gross output. For example, Griliches and Ringstad (1971) discuss potential virtues of a value-added output specification. It enhances comparability of data across industries and across establishments within industries, when they differ in their degree of vertical integration. Regarding the relevant workforce characteristics, they include the composition of the labour force with respect to age, qualifications, education and tenure as well as the number of hours worked and hourly wages. The missing data are likely to complicate the analysis of age-productivity profiles. For instance, the lack of information on educational attainment of workers does not let take into account intergenerational differences in productivity due to different levels of education and as we know, older cohorts have less formal education than younger cohorts (Van Ours, 2010).

Moreover, it is important to measure properly the company's labour input. Number of hours worked is a better measure than the number of workers, since the latter does not make a difference between part-time and full-time employees. If workers in different age groups work different number of hours, then, using the information on number of workers, one would mismeasure the proportion of labour supplied by workers in different groups. For example, if older employees on average work fewer hours per week than the young ones, then the seniors' labour input would be overstated.

Particularly important in the context of age-productivity estimation is the availability of longitudinal data. This is especially true if the age and quality of the capital stock or the age of the establishment correlate with the age structure of the workforce. Some studies underline that in certain sectors older workers tend to work with older, less productive capital endowment (Malmberg et al., 2008). In a cross section (or between establishments) analysis this would lead to an underestimation of the productivity of older workers (Göbel and Zwick, 2009). Longitudinal data enable within-establishment comparison and thus correct for the bias induced by unobservable factors, such as the quality of capital or establishment age, that are correlated with certain age groups and establishment productivity (Crépon et al., 2003; Aubert and Crépon, 2007).

1.2.2. Endogeneity and selection bias

The rich dataset, however, will not help yield consistent parameter estimates in the production function if the production function itself is misspecified. The greatest econometric challenge consists in correction for the simultaneity or endogeneity bias (Griliches and Mairesse, 1995). It is likely that there are some omitted plant-specific state variables that affect simultaneously input choices and output. Then, the input demand might be correlated with the productivity shocks unobservable by the econometrician but observed or predicted by the firm (Marschak and Andrews, 1944). A profit maximizing (or cost-minimizing) firm facing positive productivity shocks will expand its production and thus increase the inputs level. On the other hand, a consequence of the negative shocks will be a production decrease and lower input usage. As a result, simple OLS estimation of the production function can lead to biased estimates of the parameters of interest.

In particular, the endogeneity might concern the changes in the age composition of the workforce. If a firm anticipates a negative productivity shock, it might adjust inputs at the same time so that it becomes impossible to identify whether a decrease in production is due to a lower level of inputs or due to a decrease in demand. A firm facing a low demand might stop hiring new workers or fire some of the younger employees. Then, we will observe a decrease in productivity accompanied by higher share of older workers. One could wrongly conclude that the aging workforce was responsible for the drop in productivity while in fact there was just a correlation between the drop in productivity and an increase in the share of older workers (Van Ours, 2010). Similarly, a positive productivity shock could encourage a firm to hire some young workers. Then, we will observe an increase in productivity generated by relatively younger workforce. Therefore, one could wrongly conclude that increase in productivity was due to young employees. The causality problem that appear is whether firms employing relatively older workforce are less productive or if firms employ relatively older workforce because they are less productive (Aubert and Crépon, 2003).

Another related problem is endogenous selection. The workforce observed in the firm is not a random draw from the population. The estimated productivity concerns only employees, thus the people still actively present on the labour market. It could be that only the best senior workers remain active while the least productive leave the firms and possibly even the labour force. Moreover, workers who expect to earn low wages at old age might be willing to retire earlier than workers with a high earnings potential (de Hek and van Vuuren, 2010). At the same time, firms wish to keep workers with high productivity, and stimulate low productive workers to retire. Consequently, this could introduce an upward bias for the productivity of older employees. Finally, the selection bias is possible also when some highly productive workers, initially low-skilled, might access with time the high-skilled positions along their career. As a result, we will observe more high-skilled and high-productive persons among older workers.

In order to overcome the problem of endogeneity several approaches have been developed. The two traditional solutions comprise instrumental variables and fixed effects. Among more modern approaches, the most known are the two following: a procedure developed by Arellano and Bond (1991) and the one initiated by Olley and Pakes (1996). Both have been further expanded by other researchers.

Instrumental variables

Instrumental variables approach relies on finding appropriate instruments, i.e. variables that are correlated with the endogeneous explanatory variables but not with the production function residuals. The natural instruments would be input prices which have a serious impact on the choice of inputs but do not directly enter the production function. Moreover, under the assumption of perfectly competitive input markets, the firm has no influence on market prices so that they should not be correlated with the production function residuals. However, using input prices as instruments has not been very successful in practice. First of all, they are often not reported by firms that make them difficult to use. Furthermore, in order to be helpful as instruments, they should vary significantly across firms due to differences in exogeneous input market conditions and not in unobserved input quality (Ackerberg et al., 2006). The challenge is to find "external" instrumental variables with strong resolving power.

Fixed effects

The basic assumption behind fixed effects estimation is that unobserved productivity is constant over time. Then, production function parameters can be estimated consistently using mean differencing, first differencing or the least squares dummy variables. However, since within a firm the changes of production and age structure between years are likely to be determined in the same period, fixed effect estimates are likely to be not particularly useful for the estimation of age productivity profiles (Göbel and Zwick, 2009).

Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond (2000) Approach

An alternative approach to control for the endogeneity bias has been developed by Arellano and Bond (1991) in a dynamic panel data model. It consists in estimating an equation in first-differences with appropriately lagged levels as instruments. Though, since lagged variables in levels are often weak instruments for contemporaneous differences, in case of highly persistent data, the method appeared to suffer from finite sample bias and poor precision of the estimates. This problem has been further addressed by Blundell and Bond (1998) who proposed the use of extra moment conditions that rely on certain stationarity conditions of the initial observation. When these conditions are satisfied, the resulting system GMM estimator has been shown to have much better finite sample properties in terms of bias and root mean squared error than that of the first differenced GMM estimator (Blundell and Bond, 1998; Blundell, Bond and Windmeijer, 2000). Within this framework lagged levels are used as instruments for contemporaneous differences and lagged differences as instruments for contemporaneous levels.

The use of lagged observations in order to instrument current values of the inputs has been applied in a number of studies dealing with age and productivity (e.g. Crépon et al., 2003; Aubert and Crépon, 2006; Daveri and Maliranta, 2007; Lallemand and Rycx, 2009). The underlying assumption is that contemporary shocks that may affect productivity and the age structure of the workers are orthogonal to the past level of capital and the firm's age structure.

Nevertheless, instrumenting the age structure by its lagged values has some limits. In particular, concerns about the quality of lagged values as instruments, and the large standard errors usually found, make it difficult to draw solid conclusions. These limits have been acknowledged, among others, by Aubert and Crépon (2004), Dostie (2006) and Roodman (2006). It has been confirmed that Arellano and Bond's technique is a very useful method for dealing with any autoregressive characteristics in the data. However, too many instruments might bias the estimator to the within estimate. Borowczyk-Martins and Vandenberghe (2010) underline that also system GMM procedure proposed by Blundell and Bond (2000) suffers from two types of problems: 1) the estimated results are typically extremely sensitive to a great number of methodological choices (e.g., the number of lags for each variable), and 2) instruments are often weakly identified, casting doubts on the quality of the estimations. The potential weak instrument problem for the system GMM estimator has been also established by Bun and Windmeijer (2007).

Olley and Pakes (1996), Levinsohn and Petrin (2003), Ackerberg, Caves and Frazer (2006) Approach

A more structural approach for the estimation of production functions has been proposed by Olley and Pakes (1996) and further developed by Levinsohn and Petrin (2003). They start from assumptions about the underlying economic process and timing of input decisions by firms. The main idea is that firms primarily respond to productivity shocks by adapting the volume of their investments (Olley and Pakes) or intermediate inputs (Levinsohn and Petrin). Whenever such data are available, they can be used to proxy productivity shocks. An advantage with respect to the system GMM is that these methods do not require relying on instruments that lack a clear-cut economic meaning and which tend to be only weakly correlated with the included endogenous variables (Borowczyk-Martins and Vandenberghe, 2010). At present, there exist only few studies that apply this approach to estimate age-productivity profiles (Hellerstein and Neumark, 2004; Dostie, 2006; Roger and Wasmer, 2009).

The approach by Olley and Pakes (1996) and Levinsohn and Petrin (2003) has been questioned by Bond and Söderbom (2005) and Ackerberg et al. (2006). Their main concern has been identification problem because of collinearity in the first step estimations of the labour coefficient and investment (for Olley and Pakes) or material input (for Levinsohn and Petrin) coefficient. Ackerberg et al. (2006) propose an estimation procedure to solve these issues that assumes a strict time schedule for the decisions on material inputs/investments, labour, and capital. In particular, they allow labour input to have dynamic implications.

These assumptions about the unobserved timing of information on productivity shocks and the timing of input decisions for the different inputs have been found controversial also by Göbel and Zwick (2009). They notice that, in the context of estimation of age-productivity profiles, the existing employment protection law, skill shortages or industrial relations could lead to much more complex timings with respect to employment decisions for different age groups than those assumed in the above models. For example, in many countries, older employees are stronger protected by labour law or by agreements against dismissals.

1.2.3. Production function specification and elasticity of substitution

Finally, in the framework of estimation of the production function, one should not forget about the limitations coming directly from the model specification. When trying to evaluate age-productivity profiles, the right definition of the labour input is of particular importance. Most of the empirical studies that have been evoked above (see point 1) draw on the additive specification of the labour input, i.e. productivity of the firm's labour is equal to a sum of productivities of all the individual workers (Hellerstein et al., 1999; Crépon et al., 2003; Aubert and Crépon, 2003; Dostie, 2006; Van Ours, 2010). Consequently, workers with different demographic characteristics are assumed to be perfect substitutes in production.

In reality, whether young and older workers are substitutes remains doubtful. Workers of different age might be imperfect substitutes, or even complementary to some degree. In this case, hours worked by younger and older persons cannot simply be added to obtain an aggregate measure of labour input (O'Mahony et al., 2005). Ideally, they should be weighted by their respective relative productivities. In the same way, other characteristics should be controlled for such as education or skills.

It has been well documented that differences in the production function of firms might be related to the differences in their substitution possibilities (Dupuy, 2004). The degree of substitutability is usually measured by a parameter known as the elasticity of substitution. In the context of age-heterogeneous labour, it describes the degree to which older workers can be substituted for younger workers, and vice versa, while producing a given output at the least cost (Guest and Shacklock, 2005).

Nevertheless, in the economic literature based on production function estimation, we tend to observe a certain trade-off between two assumptions concerning labour force: 1) perfect substitution and 2) equality of relative wages and relative marginal products. As mentioned above, in microeconomic studies estimating labour productivity, it is usually assumed that all the types of workers are perfectly substitutable. On the other hand, studies on returns to higher education, schooling externalities or macroeconomic modelling of demographic change often make use of the CES (constant elasticity of substitution) production function, thus allowing imperfect substitution of different types of workers. Card and Lemieux (2001) model returns to higher education allowing imperfect substitution between similarly educated workers in different age groups. Ciccone and Peri (2003) estimate the long-run aggregate elasticity of substitution between skilled and unskilled workers. Iranzo and Peri (2006) investigate production externalities of college education, accounting for imperfectly substitutable skill groups and skill-specific technologies. Finally, Prskawetz et al. (2005) and Prskawetz and Fent (2007) analyse the sensitivity of the projected labor productivity with respect to alternative assumptions about future labor supply and the substitutability, and productivity of the labour force at different ages. However, at the same time, all these studies assume the equalities between marginal productivity and wages of workers belonging to different age or skill category.

1.3. Conclusions

Overall, it is evident from the review of existing studies on the relationship between age and productivity that no clear conclusion can be drawn from earlier research. Some authors argue that wage differentials reflect differences in workers' productivity, whereas others suggest an existence of a wage-productivity gap that tends to increase with employees' age. These results are not always easy to compare since they use datasets for different countries with their own specific economic characteristics and labour market regulations. Moreover, the mentioned studies do not cover the same time period. Some use cross-sectional information whereas others dispose of panel dataset. At the methodological level, we observe also certain differences in the choice of the method dealing with endogeneity of the age composition of a firms' workforce.

Though, the existing studies have one common limitation. It is the assumption of perfect substitution between different types of workers. In fact, within the given enterprise, workers of different ages might be less than perfectly substitutable. Hence, the optimum age composition of a given workforce might depend on two elements: relative marginal productivity and the degree of substitutability between workers of different ages (Lam, 1989). The original empirical study presented next adds to the existing research on age-productivity profiles by allowing imperfect substitution between workers with different skills and of different ages, and at the same time not imposing the condition of equality for workers' wages and their marginal products.

2. Empirical evidence on labour productivity differentiated by age and skills – an original test on French data[4]

This section aims at evaluating the actual profile of marginal productivity across the age classes within the workforce. The comparison with earnings profiles allows us to analyse the relative productivity and test whether differences in wage shares across groups of workers are justified by proportional productivity contribution.

Age-productivity profiles may differ between occupations. Older workers can remain highly productive in the domain they know well and where relatively long experience is important. For example, thanks to tacit knowledge, older managers may perform as well as younger ones (Colonia-Willner, 1998). Thus, the workforce has been differentiated not only by age (young, middle-aged, old), but also by skills (low-skilled, high-skilled). The simultaneous differentiation by age and by skills is of high interest in the perspective of possible dissimilarities among different categories of workers with respect to the sensitivity to work effort incentives, training offered, etc.

Although there is a growing research interest in the relation between age and productivity, the empirical analyses so far have often been focused on the estimation of Cobb-Douglas production functions specification in capital and labour. The firm-level labour productivity itself has been treated as a simple summation of productivities of individual workers (Hellerstein et al., 1999; Crépon et al., 2003; Aubert and Crépon, 2003). Thus, the existing studies are characterised by an assumption of perfect substitutability between different categories of workers. In this study, we refer to the production function estimation as well. However, in contrast to the previous studies, the use of the less restrictive, constant-elasticity-of-substitution (CES) functional form is proposed at the level of labour input. This more general form, thanks to smaller number of constraints imposed on the production technology, allows the imperfect substitution between different categories of workers.

The dataset used in this study (DADS-BRN) covers the French manufacturing, services and trade sectors. French data are particularly interesting in the perspective of our study. Actually, among all OECD countries, France is characterised by the highest employment rate of people aged 25-54 (81.8 % in 2010) and at the same time one of the lowest employment rate of people over 55 (39.7 % in 2010). Due to early retirement plans, the actual average effective age of retirement is 60 years. Moreover, workers over 50 are often touched by long-term unemployment. In particular, the low-skilled workers face problems to stay employed and once unemployed, they hardly find a new job.

[4] This section is the result of a collaboration with Muriel Roger.

Differentiating the workforce simultaneously by age and skills allows us to observe the differences in the age-productivity and age-earnings profiles separately within each skill group. We find that this differentiation is, in fact, very important. The productivity profile observed across different age groups seems actually to depend on the skill level. Among the main findings of this study, in the low-skilled category, labour productivity is found to be the lowest for the seniors. Regarding the high-skilled labour, in manufacturing, the mean productivity stays quite stable across the age groups, being the highest for the workers over 50. Also in trade sector, the high-skilled oldest employees are clearly the most productive group. Moreover, we observe a very similar age-earnings pattern across the sectors. The wage profile for the high-skilled workers is steeper than for the low-skilled employees. Furthermore, in both skill groups and in all three sectors we find an evidence for wage compression, i.e. wage rates vary considerably less than productivity.

The results for the manufacturing sector show that the age-productivity and age-earnings profiles are compatible with a deferred compensation system. It might indicate that the effort incentive problem has been regulated in practice by many firms by offering at the start of the career wages under the workers' marginal productivity and compensating this difference in the later periods. On the other hand, in services and in trade, we observe the combined relevance of specific human capital and deferred compensation.

Though, the most interesting aspect is the workers' productivity in relation to their cost. It is particularly important as for the employers it may present an incentive to exclude some age groups from the labour market and to give preference to the others. In our study, the relative productivity over cost in manufacturing sector has been found to represent a similar pattern in both skill groups, being the highest for the young, followed by middle-aged and old workers. In both skill groups in services sector and for low-skilled trade employees the productivity/earnings ratio is the highest for the middle-aged, followed by young and senior workers. This discrepancy between productivity and wage can be a source of employment difficulties particularly for the older low-skilled workers.

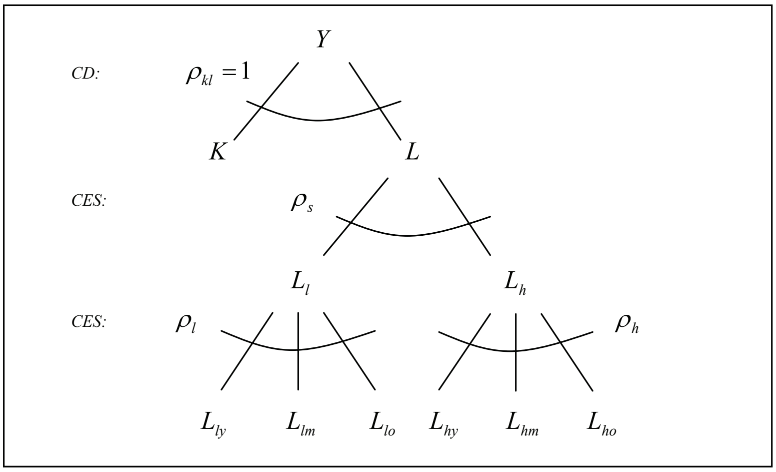
The remaining of this section is organised as follows. The next subsection describes the model. Then, the chosen estimation method is presented. After the dataset description and the analysis of the estimation results follow the conclusions.

2.1. The model: production function with labour as nested CES

The assumption of perfect substitutability between workers with different characteristics implies that employing one worker while dismissing another one will not lead to any change in the marginal products of either of them as one is perfectly substitutable for another. However, it has been noticed that actually there might arise an interaction of workers within a firm (Lengermann, 2002). The productivity of a certain employee might be affected by co-worker's characteristics. It might matter whether the employee works together with a colleague with the same level of skills, similar age, etc. In particular, there exists empirical evidence that the human capitals of young and older workers are imperfect substitutes (Kremer and Thomson, 1998). Hence, labour is not necessarily as easily substitutable as it seems at first glance. This study tries to overcome this problem by choosing such a form of the production function that would take into account the potential imperfect substitutability inside of the workforce - between high-skilled and low-skilled workers and between different age categories within each skill group. In this purpose, we estimate the Cobb-Douglas production function specification in capital (K) and labour (L) whereas the labour input itself takes a form of the nested constant-elasticity-of-substitution (CES) function.

Since Arrow et al. (1961) have formulated the function of type CES, numerous studies have been pursued in order to estimate its parameters. However, none of them has been used so far in the context of the labour productivity analysis.

Figure 10: Scheme of the production structure



Our benchmark (see Figure 10) takes into account two skill groups (low-skilled (L_l) and high-skilled (L_h)) and within each skill category - three age groups of workers (young (L_y), middle-aged (L_m), old (L_o)). The labour input is allowed to be heterogeneous across but homogeneous within closely defined groups of workers. Thus, it is assumed that the employees belonging to the same skill-age group (e.g. young low-skilled) are perfectly substitutable.

At the "highest level", our production function takes the Cobb-Douglas form given by:

$$Y = f(K, L) = AK^{\alpha}L^{\beta} \tag{15}$$

where K denotes capital, L stands for labour and A is a Hicks neutral technological progress.

At the "second level" the labour aggregate is defined as a CES function of high-skilled and low-skilled workers:

$$L = \left(\sum_i \delta_i L_i^{\rho_i}\right)^{\frac{1}{\rho_i}} \tag{16}$$

where i indicates the skill category. Finally, each skill group of workers is a CES function by itself:

$$L_i = \left[\sum_j \delta_{ij} L_{ij}^{\rho_{ij}}\right]^{\frac{1}{\rho_{ij}}} \tag{17}$$

where the age category is denoted by j .

Based on this choice of production function, we aim at estimating the distribution parameters: δ_i, δ_{ij} as well as the substitution parameters: ρ_i and ρ_{ij}. The elasticity of substitution is defined as $\sigma = \frac{d\ln(x_1/x_2)}{d\ln\left(\frac{\partial Y}{\partial x_1}/\frac{\partial Y}{\partial x_2}\right)}$ and is a measure of the percentage change in factors demand due to a percentage change in the marginal rate of technical substitution so that the output remains constant. For the case of constant returns to scale it takes the form: $\sigma = \frac{1}{1-\rho}$. The inverse of sigma $\left(\frac{1}{\sigma}\right)$ denotes a change in the marginal rate of technical substitution due to a change in factor proportions so that the output remains constant.

Productivity contribution

Given the estimates of the production function parameters, we compute the labour marginal product for different categories of labour. In this setting, the constant returns to scale are assumed at the level of labour inputs. According to the Euler's theorem, under homogeneity of degree 1, the labour function might be represented as a sum of its inputs multiplied by their marginal products:

$$f(L_1, L_2, ..., L_n) = L_1 \frac{\partial f}{\partial L_1} + L_2 \frac{\partial f}{\partial L_2} + ... + L_n \frac{\partial f}{\partial L_n} \tag{18}$$

Therefore, we can define the marginal product of labour as labour input contribution to the firm-level production.

Skill differentiation

For the given skill group, it takes the following form:

$$MP_i = \frac{\partial Y}{\partial L} \frac{\partial L}{\partial L_i} \tag{19}$$

$$MP_i = AK^{\alpha} \beta \left(\sum_i \delta_i L_i^{\rho_i} \right)^{\frac{\beta}{\rho_i} - 1} \delta_i L_i^{\rho_i - 1} \tag{20}$$

The marginal rate of technical substitution depends not only on the factor intensity and the distribution parameter but also on the level of substitution between different labour categories. It shows the rate at which one input may be substituted for another, while maintaining the same level of production. The relative marginal product of labour for workers differentiated by skills is given by:

$$\frac{MP_1}{MP_2} = \frac{\partial L / \partial L_1}{\partial L / \partial L_2} = \lambda = \frac{\delta_1}{\delta_2} \left(\frac{L_1}{L_2} \right)^{\rho_i - 1} \tag{21}$$

In order to compare productivity contribution over different skill categories, we compute for each enterprise a ratio of marginal product of workers belonging to certain skill group in relation to the average marginal product of labour. For two categories of skills, the ratios take the following form:

$$\frac{MP_1}{MP_{av}} = \frac{L}{L_1 + \lambda^{-1} L_2} \; and \; \frac{MP_2}{MP_{av}} = \frac{L}{\lambda L_1 + L_2} \tag{22}$$

where MP_{av} is the average marginal product of total labour.

Age differentiation

The marginal product of labour for a given age group in a specified skill category is defined as:

$$MP_{ij} = \frac{\partial Y}{\partial L} \frac{\partial L}{\partial L_i} \frac{\partial L_i}{\partial L_{ij}} \tag{23}$$

$$MP_{ij} = AK^{\alpha} \beta \left(\sum_i \delta_i L_i^{\rho_i} \right)^{\frac{\beta}{\rho_i} - 1} \delta_i L_i^{\frac{\rho_i}{\rho_j} - 1} \delta_{ij} L_{ij}^{\rho_{ij} - 1} \tag{24}$$

The relative marginal product of any two age groups of workers in a given skill group is:

$$\frac{MP_{i1}}{MP_{i2}} = \frac{\delta_{i1}}{\delta_{i2}} \left(\frac{L_{i1}}{L_{i2}} \right)^{\rho_{ij} - 1} \tag{25}$$

In our setting, we define relative marginal products as: $\frac{MP_{iY}}{MP_{iM}} = \varphi$, $\frac{MP_{iY}}{MP_{iO}} = \gamma$ and $\frac{MP_{iM}}{MP_{iO}} = \eta$ (where Y - young, M - middle-aged, O - old). The productivity contribution of each age group is given by the ratio of marginal product of respective age group over the average labour marginal productivity of a specific skill group:

$$\frac{MP_{iY}}{MP_{i}av} = \frac{L_i}{L_{iY} + \varphi^{-1}L_{iM} + \gamma^{-1}L_{iO}} \tag{26}$$

$$\frac{MP_{iM}}{MP_{i}av} = \frac{L_i}{\varphi L_{iY} + L_{iM} + \eta^{-1}L_{iO}} \tag{27}$$

$$\frac{MP_{iO}}{MP_{i}av} = \frac{L_i}{\gamma L_{iY} + \eta L_{iM} + L_{iO}} \tag{28}$$

Wage share

Our dataset contains rich information on earnings. Hence, according to the procedure above, we compute the share of a distinct age group in the wage bill of the given skill category. Given the productivity contributions and the analogously constructed wage shares, we can compare an earnings-productivity pattern for different categories of workers.

2.2. The method

In order to obtain consistent estimates of the production function parameters, we use the method developed by Levinsohn and Petrin (2003). The procedure consists in including in the estimation equation a proxy for the productivity shocks potentially observed by firms while making input decisions.

According to the chosen production function specification (see Figure 10), we consider the following value added form:

$$y_{it} = \beta_0 + \alpha k_{it} + \beta ln\left(\left(\sum_i \delta_i \left(\sum_j \delta_{ij} L_{ij\,it}^{\rho_{ij}}\right)^{\frac{\rho_i}{\rho_{ij}}}\right)^{\frac{1}{\rho_i}}\right) + \omega_{it} + \eta_{it} \tag{29}$$

The error term is composed of 2 elements: ω_{it} denoting productivity shocks likely observed by the firm and η_{it} having no impact on the firm's inputs decisions. y_{it} is a natural logarithm of value added and k_{it} denotes a natural logarithm of capital.

Following Levinsohn and Petrin (2003), we assume that firms decide on the level of capital at $t-1$, thus capital is a dynamic input. The labour and the intermediate input (materials) m_{it} are chosen at time t . The productivity shock ω_{it} is assumed to follow a first order Markov process:

$$p(\omega_{it}|I_{it-1}) = p(\omega_{it}|\omega_{it-1}) \tag{30}$$

where I is firm's i's information set at t.

The approach adopted in the current work consists in using intermediate input as a proxy for the unobservable productivity shocks. Hence, materials control for the part of the error term correlated with inputs. Given the above timing assumptions, the firm's demand for the intermediate input m_{it} is assumed to depend on the state variables k_{it} and ω_{it}.

$$m_{it} = f_t(k_{it}, \omega_{it}) \tag{31}$$

The assumption that intermediate input is strictly monotonic in the productivity shock allows inversion of materials demand function for ω_{it}

$$\omega_{it} = f_t^{-1}(k_{it}, m_{it}) \tag{32}$$

and substituting it into the production function so that the following first stage equation is obtained:

$$y_{it} = \beta ln \left(\left(\sum_i \delta_i \left(\sum_j \delta_{ij} L_{ij\,it}^{\rho_{ij}} \right)^{\frac{\rho_i}{\rho_{ij}}} \right)^{\frac{1}{\rho_i}} \right) + \phi_{it}(k_{it}, m_{it}) + \eta_{it} \tag{33}$$

where $\phi_{it}(k_{it}, m_{it}) = \beta_0 + \alpha k_{it} + \omega_{it}(k_{it}, m_{it})$.

By substituting the third-order polynomial in k_{it} and m_{it}, in place of $\phi_{it}(k_{it}, m_{it})$:

$$y_{it} = \delta_0 + \beta ln \left(\left(\sum_i \delta_i \left(\sum_j \delta_{ij} L_{ij\,it}^{\rho_{ij}} \right)^{\frac{\rho_i}{\rho_{ij}}} \right)^{\frac{1}{\rho_i}} \right) + \sum_{j=0}^{3} \sum_{n=0}^{3-j} \delta_{jn} k_{it}^{j} m_{it}^{n} + \eta_{it} \tag{34}$$

we can consistently estimate parameters for labour using the non-linear least squares method.

Identification of the input coefficients according to the method by Levinsohn and Petrin has been questioned recently. Bond and Soderbom (2005) argue that production function parameters are not identified from cross section variation when inputs are perfectly flexible and chosen optimally, and input prices are common to all firms. However, their result holds on the propriety that Cobb Douglas optimal capital and labour inputs demand can be expressed as log linear functions of real input prices.

This is not the case in our model where labour input takes a form of a CES production function. Moreover, we do not impose the condition of an optimal input choice implying wage and marginal productivity equality.

On the other hand, Ackerberg, Caves and Frazer (2006) pointed out the potential problem with the identification of the labour input coefficients in the first stage of the Levinsohn and Petrin method. The authors raise the question of collinearity issues. They claim that the simultaneous choice of labour input and material induces collinearity between the variables in the first step regression. Considering their statement, the identification of the labour parameters in our model is relaying on the non-linearities of the production function[5].

The second stage of the procedure helps us to identify the coefficient for capital. It starts with computing the estimated value of $\hat{\phi}_{it}$:

$$\hat{\phi_{it}} = \hat{y_{it}} - \hat{\beta} ln \left(\left(\sum_i \hat{\delta}_i \left(\sum_j \hat{\delta}_{ij} L_{ij\,it}^{\hat{\rho}_{ij}} \right)^{\frac{\hat{\rho}_i}{\hat{\rho}_{ij}}} \right)^{\frac{1}{\hat{\rho}_i}} \right) = \hat{\delta}_0 + \sum_{j=0}^{3} \sum_{n=0}^{3-j} \hat{\delta}_{jn} k_{it}^{j} m_{it}^{n} \tag{35}$$

For any candidate value α^*, we can compute the prediction for ω_{it} for all periods t:

$$\hat{\omega}_{it} = \hat{\phi}_{it} - \alpha^* k_{it} \tag{36}$$

Given these values, we regress non-parametrically ω_{it} on its lagged term ω_{it-1}:

$$\hat{\omega}_{it} = \gamma_0 + \gamma_1 \omega_{it-1} + \gamma_2 \omega_{it-1}^2 + \gamma_3 \omega_{it-1}^3 + \epsilon_{it} \tag{37}$$

in order to get the residual ξ_{it} and the conditional expectation $E\left[\omega_{it} \mid \omega_{it-1}\right] = \omega_{it} - \xi_{it}$.

Given labour coefficients, a guess value $\alpha^*$and $E\left[\omega_{it} \mid \omega_{it-1}\right]$, we can find a consistent estimate of a parameter for capital which is a solution to minimizing a squared sum of a sample residual of our production function:

$$\min_{\alpha^*} \sum_t (\eta_{it} + \xi_{it})^2 = \min_{\alpha^*} \sum_t \left(y_{it} - \hat{\beta} ln \left(\left(\sum_i \hat{\delta}_i \left(\sum_j \hat{\delta}_{ij} L_{ij\,it}^{\hat{\rho}_{ij}} \right)^{\frac{\hat{\rho}_i}{\hat{\rho}_{ij}}} \right)^{\frac{1}{\hat{\rho}_i}} \right) - \alpha^* k_{it} - E[\omega_{it} | \omega_{it-1}] \right)^2 \tag{38}$$

The asymptotic standard errors for estimated parameters are constructed using a bootstrap approach.

[5] Ackerberg, Caves and Frazer (2006) propose an alternative procedure to estimate production functions. In their approach, all the input coefficients are estimated in the second stage. Their procedure draws on Levinsohn and Petrin method. Intermediate input demand is indeed used as a proxy to net out an error term of the production function. The main difference is that the firm's demand for the intermediate input is assumed to be a strictly monotonic function of the productivity shock and all the input variables, i.e. capital and all types of labour. In the more complex model that we propose, the firm's demand for the intermediate input is thus a function of 8 arguments. When substituting the productivity shock with a third order polynomial depending on materials and other inputs, identification became really fragile with our data. We thus privileged the Levinsohn and Petrin method in our context.

2.3. Data and summary statistics

The dataset used in this study covers a short panel of data for years 2003 and 2004 for manufacturing, services and trade sectors in France. It comes from merging two different data sources: *Bénéfices Réels Normaux* (BRN) and *Déclarations Administratives de Données Sociales* (DADS). They both constitute mandatory employers' reports to the Fiscal Office. The BRN consists of firms' balance sheets and provides important information on the employers' output, capital stock and economic sector. The DADS contains rich data on the characteristics of the workforce. The number of hours worked is decomposed by workers' age and occupation. The valuable information on earnings allows to measure the share of a distinct labour category in total wage bill. However, the dataset is not without imperfection. Unfortunately, the DADS does not contain any information on workers' education level and tenure.

In order to distinguish among workers according to the level of skills, we make use of the available decomposition by occupation. The DADS employment data are arranged by occupation according to the French socio-professional classification. This classification is used in collective agreements for wage determination. A higher level of education places a worker directly on the "higher starting point" and experience then allows further wage increases. As emphasised by Thesmar and Thoenig (2000), this classification, based on the mix of education and experience, contains no information about the task-assignment. Therefore, the senior personnel ("Cadres") may include high-ranked directors as well as e.g. consultants without any supervision duty that have been classified as "cadres" so that the firm could justify their high wages. Using this occupation classification, we distinguish two skills categories of workers: high-skilled and low-skilled. The high-skilled correspond to employers, the senior and intermediate personnel. The office and sales employees as well as blue collar workers are included in the low-skilled category. For details, see Table 4.

Table 4: Skill classification

High-skilled labour	Low-skilled labour
Employers	*Non-manual workers*
Craftsmen	Office employees
Traders	Sales workers
Employers (of 50 or more employees)	*Manual workers*
*Liberal professions, senior and executive personnel**	Skilled industrial manual workers
Liberal professions	Skilled craftsman
Professors and scientific professions	Drivers
Artistic professions	Skilled handling, storage and transport workers
Senior administrative personnel*	Unskilled industrial workers
Engineers and senior technicians*	Unskilled artisans
Intermediate personnel	
Medical and social services	
Intermediate administrative personnel	
Technicians	
Foreman, supervisors	

* the senior personnel corresponds to the higher position and not the worker's age

Regarding the labour force composition, three age classes are considered within each skill group. We define young workers as those who are under 30 years old, the middle-aged workers between 30 and 50, and the senior employees as those over 50. The reason why we choose these age classes is twofold. First, since we keep only firms where all age categories are present, the condition of sufficient number of observations within each age group must have been met. Second, the data analysis revealed that the employment level is much more heterogenous among the young (up to 30) and among seniors (over 50) compared to the middle-aged (30-50) group. In particular, the lowest employment characterise the young under 25 and older persons over 55. Nowadays, many young people decide to prolong their education and, thus, enter relatively late into labour market. On the other hand, an earlier exit from the labour market is still quite common among the seniors. In 2010, 22.5 % of juniors (aged 15-24) and 6.7 % of seniors (aged 55-64) have been unemployed (OECD, 2010).

For the purpose of our analysis, the volume of production is represented by value added and the employment level is measured by number of hours worked. It permits to distinguish between part-time and full-time employees. The aberrant values have been eliminated. Value added, capital, labour cost and employment are required to take positive values. Only firms employing at least fifty workers have been considered. As a result of these operations, the final dataset contains 15'992 observations.

As far as a sector division is concerned, manufacturing, trade and services are distinguished according to NES16 (Nomenclature économique de synthèse en 16 postes). The agriculture, forestry and fishing as well as construction sector (due to high ratio of seasonal workers) have been excluded from manufacturing. Administration and financial services have not been takes into account in services sector.

The summary statistics of the main variables as well as the labour force composition by age and skills are represented in Table 5. We can observe substantial differences with respect to age-employment and age-earnings patterns of workers belonging to different skill groups.

Employment pattern

First of all, we can see that in all three sectors, i.e. manufacturing, trade and services, the workers between 30 and 50 years old account for around 60 % of the total hours worked. The employment of the young and the seniors is considerably lower. If we look separately at each skill group, we can notice that among the high-skilled, the number of hours worked by older workers exceeds those of the young. In particular, the discrepancies are the biggest in manufacturing. The opposite pattern characterises the low-skilled employees (with exception of manufacturing sector), where the young are more numerous than the seniors.

Earnings pattern

We observe that hourly earnings are increasing with age, for both skill groups and in all the sectors. The remuneration of the young workers is the lowest and the oldest employees are paid the most. According to economic intuition, high-skilled workers are better paid than the low-skilled. Taking into account the desaggregation by skills, the profile of mean hourly earnings of the low-skilled is considerably flatter - the earnings rise between consecutive age groups on average by 15 % and 4 %. Interestingly, the respective mean differentials (increase) in salaries between the high-skilled age groups are of 40 % and 30 %. Consequently, the range of salaries in this skill category is wider.

Table 5: Sample statistics, DADS-BRN, 2004

Variables*	Manufacturing			Services			Trade		
	share	mean	sdv	share	mean	sdv	share	mean	sdv
ln value added		-2.67	1.15		-3.01	1.26		-3.04	1.04
ln capital		-2.57	1.54		-3.32	1.85		-3.28	1.38
ln capital (t-1)		-2.61	1.57		-3.38	1.88		-3.34	1.39
ln materials		-2.81	1.63		-5.54	2.06		-6.81	2.15
ln materials (t-1)		-2.86	1.63		-5.59	2.03		-6.82	2.17
Hours worked by age:									
total	1.00	4.85	22.47	1.00	5.28	44.68	1.00	3.83	22.14
(*Ly*) young (<30)	0.18	0.79	4.04	0.21	1.09	4.99	0.28	1.08	6.74
(*Lm*) middle-aged (30-50)	0.60	2.85	11.68	0.58	3.07	24.65	0.57	2.19	12.90
(*Lo*) old (>50)	0.22	1.21	7.09	0.21	1.11	15.93	0.15	0.56	2.76
Hours worked by skills and age:									
(*Ll*) low-skilled	0.59	2.85	13.07	0.58	3.05	18.63	0.65	2.50	17.41
(*Lly*) young	0.18	0.52	2.61	0.25	0.74	3.57	0.34	0.86	5.88
(*Llm*) middle-aged	0.58	1.65	6.65	0.56	1.72	9.64	0.53	1.32	9.70
(*Llo*) old	0.24	0.68	4.05	0.19	0.59	6.24	0.13	0.32	1.99
(*Lh*) high-skilled	0.41	2.00	10.24	0.42	2.23	26.92	0.35	1.33	5.40
(*Lhy*) young	0.14	0.27	1.52	0.16	0.35	1.71	0.17	0.22	1.04
(*Lhm*) middle-aged	0.59	1.19	5.65	0.61	1.36	15.59	0.65	0.87	3.65
(*Lho*) old	0.27	0.53	3.27	0.23	0.51	9.94	0.18	0.24	0.86

* All variables have been standardised (divided by 100 000 before taking logarithms)

Variables	Manufacturing			Services			Trade		
	share	mean	sdv	share	mean	sdv	share	mean	sdv
Hourly earnings by age:									
total	1.00	15.66	3.93	1.00	14.65	5.84	1.00	14.36	4.42
(*Ly*) young (<30)	0.14	12.00	2.46	0.20	11.74	5.51	0.22	10.70	2.42
(*Lm*) middle-aged (30-50)	0.60	15.70	3.98	0.58	14.90	8.04	0.58	14.87	4.52
(*Lo*) old (>50)	0.26	18.99	6.75	0.22	17.90	7.70	0.20	18.58	7.57
Hourly earnings by skills and age:									
(*Ll*) low-skilled	0.52	12.13	2.44	0.51	11.20	2.12	0.50	10.63	1.92
(*Lly*) young	0.17	10.54	1.97	0.25	10.15	1.72	0.30	9.49	1.72
(*Llm*) middle-aged	0.60	12.35	2.53	0.56	11.46	2.39	0.55	11.03	7.49
(*Llo*) old	0.23	12.92	3.08	0.20	11.95	2.88	0.15	11.54	5.76
(*Lh*) high-skilled	0.48	22.13	4.84	0.49	19.94	6.96	0.50	20.62	5.32
(*Lhy*) young	0.11	15.05	4.52	0.16	14.58	6.44	0.11	14.28	0.36
(*Lhm*) middle-aged	0.59	21.73	4.86	0.58	19.88	7.14	0.62	20.36	8.54
(*Lho*) old	0.30	28.00	10.83	0.26	25.96	18.89	0.27	26.66	7.75
Number of observations		8185			4498			3309	

2.4. Results

We start our analysis with the estimation of the production function whose structure has been detailed in point 2.1. Based on the estimated parameters, we will generate and compare the age-productivity and age-earnings pattern for the low-skilled and for the high-skilled workers belonging to different sectors. First, on the basis of median values, we will present the general pattern. Afterwards, we will analyse the density estimations of inter-firm distributions of productivity and earnings. The detailed analysis will be carried out consecutively by skills and then by age within each skill group.

2.4.1. Econometric results

Our estimation procedure consists in estimating three following models:

model (1) with labour differentiated by skills:

$$Y = AK^{\alpha}\left(\delta_s L_l^{\rho_s} + (1-\delta_s) L_h^{\rho_s}\right)^{\frac{\beta}{\rho_s}} \tag{39}$$

model (2) with labour differentiated by age:

$$Y = AK^{\alpha}\left(\delta_y L_y^{\rho_a} + \delta_m L_m^{\rho_a} + (1-\delta_y-\delta_m) L_o^{\rho_a}\right)^{\frac{\beta}{\rho_a}} \tag{40}$$

model (3) with labour differentiated simultaneously by age and skills:

$$\begin{aligned} Y = AK^{\alpha}\Bigg(\gamma\left(\delta_{ly} L_{ly}^{\rho_l} + \delta_{lm} L_{lm}^{\rho_l} + (1-\delta_{ly}-\delta_{lm}) L_{lo}^{\rho_l}\right)^{\frac{\rho_s}{\rho_l}} + \\ +\ (1-\gamma)\left(\delta_{hy} L_{hy}^{\rho_h} + \delta_{hm} L_{hm}^{\rho_h} + (1-\delta_{hy}-\delta_{hm})\, L_{ho}^{\rho_h}\right)^{\frac{\rho_s}{\rho_h}}\ \Bigg)^{\frac{\beta}{\rho_s}} \end{aligned} \tag{41}$$

The estimation results of the production function for each sector are presented respectively in Tables 6 to 9[6]. The first column refers to the results obtained according to the nonlinear least squares method. The second column reports the production function estimates based on the two-stages procedure by Levinsohn and Petrin (2003) controlling for the potential endogeneity. Since parameters enter in the function in a nonlinear way, estimators have only asymptotic validity. The standard errors have been constructed according to a bootstrap approach with 200 replications.

[6]In order to check the validity and robustness of our results, in the appendix we present the results of the estimation of different models with sub-sector dummy variables in manufacturing and services sectors (Tables 20 and 21). The results confirm the robustness of the estimates.

Elasticity of substitution

In models with labour differentiated by skills, the inter-skill substitution parameter ρ_s surprisingly has been found to converge to 1 in all the sectors (see Table 6) which implies perfect substitutability between workers belonging to different skill groups. We suppose that this result might come from the classification on low-skilled and high-skill workers. It is possible that, in fact, there are not much differences in skill levels for certain socio-professional categories. To circumvent this drawback, we have run the estimation with 3 skill groups, taking apart the intermediate personnel but it did not have much impact on the results. In the sequel, estimations are thus made directly under the constraint $\rho_s = 1$.

Table 6: Production function estimates for each sector, labour differentiated by skills, model (1)

Parameters	Manufacturing		Services		Trade	
	NLLS	LP	NLLS	LP	NLLS	LP
c	-2.197*** (0.015)		-2.243*** (0.022)		-2.421*** (0.027)	
α	0.187*** (0.005)	0.301*** (0.047)	0.234*** (0.006)	0.173*** (0.038)	0.118*** (0.008)	0.164*** (0.038)
β	0.829*** (0.008)	0.729*** (0.009)	0.743*** (0.011)	0.699*** (0.023)	0.903*** (0.012)	0.875*** (0.015)
δ_s	0.231*** (0.011)	0.207*** (0.015)	0.190*** (0.033)	0.163*** (0.043)	0.216*** (0.016)	0.216*** (0.019)
ρ_s	1.257*** (0.078)	1.327*** (0.093)	2.408*** (0.322)	2.649*** (0.512)	1.336*** (0.111)	1.328*** (0.118)
No of obs.	8185	8185	4498	4498	3309	3309

Notes: Bootstrapped standard errors in parentheses. *** Significant at 1%, ** significant at 5%, * significant at 10%.

The elasticity of substitution between workers differentiated only by age appears quite different by sector (see Table 7). The substitution parameter ρ_a is not significantly different from zero in services, between zero and one in manufacturing and higher than unity in the trade sector. These results imply different work organization in each sector. They hold in the model with labour differentiated simultaneously by age and skills (see Table 8). There we observe that the substitution parameter ρ_h in the services sector is not significantly different from 0. In trade, the respective parameter for both skill groups tends to converge to 1.

Table 7: Production function estimates for each sector, labour differentiated by age, model (2)

Parameters	Manufacturing		Services		Trade	
	NLLS	LP	NLLS	LP	NLLS	LP
c	-1.947*** (0.022)		-2.067*** (0.036)		-2.287*** (0.039)	
α	0.200*** (0.005)	0.278*** (0.038)	0.240*** (0.006)	0.186*** (0.037)	0.104*** (0.008)	0.159*** (0.038)
β	0.835*** (0.008)	0.726*** (0.010)	0.735*** (0.011)	0.691*** (0.021)	0.921*** (0.013)	0.879*** (0.016)
δ_y	0.314*** (0.018)	0.281*** (0.020)	0.221*** (0.027)	0.238*** (0.036)	0.070*** (0.019)	0.074*** (0.017)
δ_m	0.443*** (0.026)	0.491*** (0.032)	0.479*** (0.057)	0.540*** (0.084)	0.326*** (0.064)	0.357*** (0.072)
δ_o	0.243	0.228*** (0.017)	0.300	0.222** (0.094)	0.604	0.569*** (0.074)
ρ_a	0.367*** (0.074)	0.246*** (0.094)	1.321*** (0.314)	0.955 (1.482)	1.912*** (0.340)	1.848*** (0.366)
No of obs.	8185	8185	4498	4498	3309	3309

Notes: Bootstrapped standard errors in parentheses. *** Significant at 1%, ** significant at 5%, * significant at 10%.

Table 8: Production function estimates for each sector, labour differentiated by age and skills, model (3)

Parameters	Manufacturing		Services		Trade	
	NLLS	LP	NLLS	LP	NLLS	LP
c	-1.294*** (0.021)		-1.538*** (0.037)		-1.538*** (0.036)	
α	0.186*** (0.004)	0.291*** (0.045)	0.222*** (0.006)	0.166*** (0.040)	0.112*** (0.008)	0.159*** (0.036)
β	0.833*** (0.007)	0.736*** (0.009)	0.759*** (0.011)	0.717*** (0.022)	0.911*** (0.012)	0.879*** (0.015)
γ	0.274*** (0.013)	0.254*** (0.015)	0.367*** (0.027)	0.357*** (0.023)	0.226*** (0.021)	0.215*** (0.026)
$1-\gamma$	0.725	0.746*** (0.015)	0.633	0.643*** (0.023)	0.774	0.785*** (0.026)
δ_{ly}	0.437*** (0.034)	0.395*** (0.032)	0.275*** (0.036)	0.282*** (0.030)	0.236*** (0.042)	0.263*** (0.046)
δ_{lm}	0.417*** (0.046)	0.458*** (0.052)	0.497*** (0.075)	0.558*** (0.068)	0.608*** (0.099)	0.673*** (0.124)
δ_{lo}	0.145	0.147*** (0.030)	0.227	0.159** (0.065)	0.155	0.063 (0.121)
ρ_l	0.463*** (0.119)	0.372*** (0.120)	0.810*** (0.286)	0.574*** (0.186)	1.341*** (0.427)	1.039** (0.518)
δ_{hy}	0.247*** (0.029)	0.242*** (0.031)	0.117** (0.061)	0.134 (0.099)	0.209*** (0.032)	0.192*** (0.058)
δ_{hm}	0.405*** (0.036)	0.432*** (0.042)	0.372*** (0.103)	0.388** (0.181)	0.421*** (0.049)	0.427*** (0.091)
δ_{ho}	0.347	0.326*** (0.026)	0.511	0.477* (0.268)	0.370	0.380*** (0.054)
ρ_h	0.725*** (0.122)	0.594*** (0.132)	2.302*** (0.820)	2.065 (10.898)	0.789*** (0.169)	0.792** (0.324)
No of obs.	8185	8185	4498	4498	3309	3309

Notes: Bootstrapped standard errors in parentheses. *** Significant at 1%, ** significant at 5%, * significant at 10%.

The results shown in Table 9 include already all these constraints on parameters ρ_l and ρ_h. We observe that low-skilled workers of different age in services sector are closer substitutes than the high-skilled ones. This finding supports the view that low-skilled employees in positions which do not require intensive training can be substituted relatively easily. Interestingly, in manufacturing, the high-skilled workers belonging to different generations have been found more easily substitutable between each other than the low-skilled. This result might suggest small differences in productivity between younger and older workers, i.e. it is possible that high-skilled manufacturing workers of different age occupy posts that require similar level of competences in general problem solving, while low-skilled younger and older workers qualified for specific tasks, can be substituted less easily.

Table 9: Production function estimates for each sector, labour differentiated by age and skills, constrained model (3)

Parameters	Manufacturing		Services		Trade	
	NLLS	LP	NLLS	LP	NLLS	LP
c	-1.294*** (0.021)		-1.587*** (0.035)		-1.534*** (0.035)	
α	0.186*** (0.004)	0.291*** (0.045)	0.222*** (0.006)	0.165*** (0.040)	0.113*** (0.008)	0.159*** (0.036)
β	0.833*** (0.007)	0.736*** (0.009)	0.751*** (0.011)	0.709*** (0.022)	0.910*** (0.012)	0.878*** (0.015)
γ	0.274*** (0.013)	0.254*** (0.015)	0.405*** (0.027)	0.387*** (0.024)	0.218*** (0.019)	0.213*** (0.022)
$1-\gamma$	0.725	0.746*** (0.015)	0.595	0.612*** (0.024)	0.782	0.786*** (0.022)
δ_{ly}	0.437*** (0.034)	0.395*** (0.032)	0.252*** (0.038)	0.263** (0.030)	0.240*** (0.037)	0.262*** (0.037)
δ_{lm}	0.417*** (0.046)	0.458*** (0.052)	0.430*** (0.071)	0.505 (0.074)	0.668*** (0.085)	0.680*** (0.085)
δ_{lo}	0.145	0.147*** (0.030)	0.318	0.231** (0.079)	0.092	0.058 (0.091)
ρ_l	0.463*** (0.119)	0.372*** (0.120)	1.062*** (0.324)	0.778*** (0.230)	1	1
δ_{hy}	0.247*** (0.029)	0.242*** (0.031)	0.081** (0.028)	0.110 (0.034)	0.222*** (0.032)	0.201*** (0.056)
δ_{hm}	0.405*** (0.036)	0.432*** (0.042)	0.832*** (0.045)	0.802** (0.052)	0.373*** (0.029)	0.385*** (0.038)
δ_{ho}	0.347	0.326*** (0.026)	0.085	0.087* (0.034)	0.404	0.414*** (0.039)
ρ_h	0.725*** (0.122)	0.594*** (0.132)	0	0	1	1
elasticity of substitution : $\sigma=1/(1-\rho)$						
Lly-Llm-Llo		1.59		4.5		$\rightarrow\infty$
Lhy-Lhm-Lho		3.64		1		$\rightarrow\infty$
No of obs.	8185	8185	4498	4498	3309	3309

Notes: Bootstrapped standard errors in parentheses. *** Significant at 1%, ** significant at 5%, * significant at 10%.

Control for endogenity bias

The nonlinear least squares estimates appear to suffer from the endogeneity bias implying existing correlation between productivity and input choices. Interestingly, the existing bias has different character in distinct sectors. In manufacturing and in trade, the NLLS method tends to underestimate the capital coefficient (α) and overestimate the labour coefficients (β). Such situation takes place if capital and labour are positively correlated and labour's correlation with the productivity shock is higher than capital's correlation. On the other hand, in services, both NLLS coefficients α and β tend to be biased up. It might be the case when only labour responds to the shock and at the same time capital and labour are positively correlated[7].

We also observe interesting results regarding the potential endogeneity bias within the labour input. In the model with labour differentiated by skills (model (1) and (3)), the coefficients of low-skilled workers are slightly biased up in all sectors. Among different age categories, the coefficients of old workers (as well as young workers in manufacturing) are overestimated. Although these biases are not statistically significant, they might however indicate that the correlation of these categories of labour with the productivity shock is higher. It could imply that more of this labour type is hired/made redundant in response to the positive/negative productivity shock.

Within the labour differentiated simultaneously by age and skills the NLLS estimates tend to underestimate the middle-aged workers coefficient in all the sectors. For other skill-age categories, the results are more sector-specific. Among the underestimated coefficients suggesting lower correlation with the productivity shock, we find: young low-skilled workers in services and trade, old low-skilled workers in manufacturing, young high-skilled workers in services and senior high-skilled workers in trade. Nevertheless, these biases stay not very significant.

2.4.2. Age-productivity and age-earnings profile: general pattern

According to the methodology presented in point 2.1., we construct the productivity contributions and wage shares for different categories of workers. Thanks to the information on earnings in the dataset, the share of a distinct age group in the wage bill of a given skill category may be easily computed. Based on the estimated parameters values corrected for the endogeneity bias (right columns of Table 9), we address the question of the marginal product of labour. Consequently, we can compare an earnings-productivity pattern for different skill and age categories of workers in three different sectors.

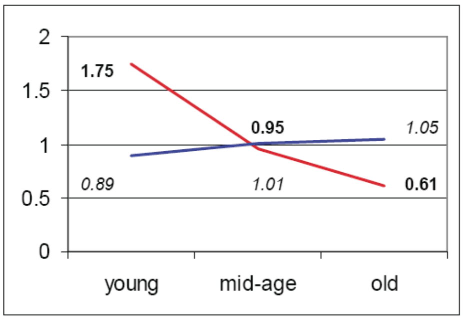
[7] According to Levinsohn and Petrin (2003), these two cases might be the most relevant for short panels because between-firm variation often plays a dominant role in identification and, in this dimension, capital and labour tend to be highly correlated.

A general tendency regarding productivity contributions and wage shares is shown in Table 10 and is given by the median. When the data are not necessarily symmetrically distributed, the median is a form of "average" that gives a better idea of a general pattern than the mean. If data are symmetrically distributed, using either the mean or the median gives almost identical results. In case of skewed distributions, using the mean could be misleading as means are very sensitive to outliers.

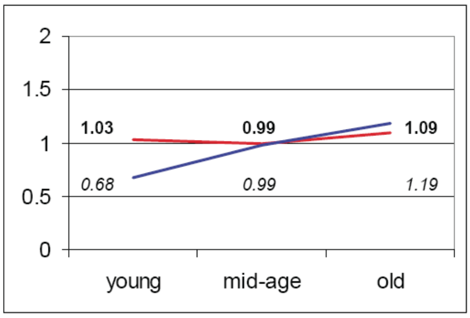
Table 10: Age-productivity and age-earnings pattern

Manufacturing

low-skilled

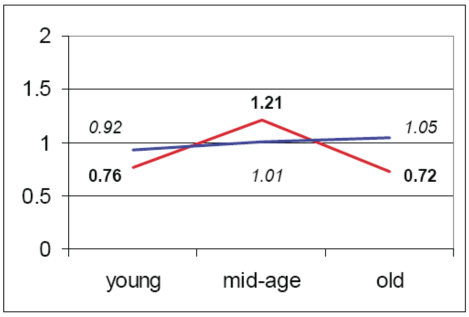


high-skilled

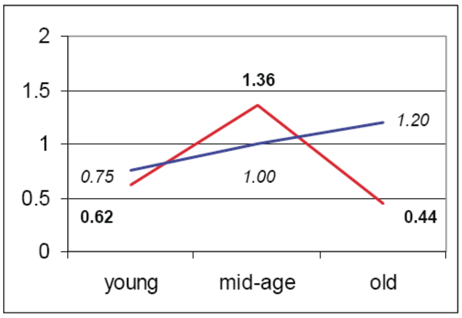


Services

low-skilled

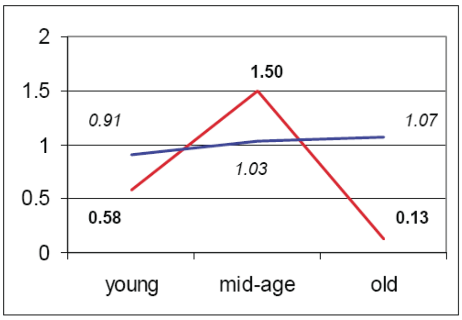


high-skilled

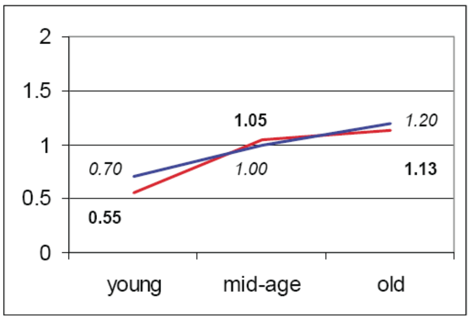


Trade

low-skilled



high-skilled



productivity contribution (median)
wage share (median)

Assuming that there exists an "average enterprise", we observe throughout the sectors and for both skill categories of workers that wage shares vary substantially less than workers' productivity. In manufacturing, the age-productivity and age-earnings profiles are compatible with a deferred compensation system. It might indicate that, in this sector, the effort incentive problem has been regulated in practice by many firms by offering at the start of the career wages under the workers' marginal productivity and compensating this difference in the later periods. On the other hand, in services and in trade, we observe the combined relevance of specific human capital and deferred compensation. For young employees, the productivity profile is steeper than the wage profile suggesting that investments in specific human capital are important at the beginning of employees' careers. For older workers, the wage share is higher than productivity contribution implying rather an incentive based compensation scheme.

Interestingly, for the high-skilled workers in manufacturing, there is not much difference in productivity across the age groups. Though, it is the highest for the oldest employees. In trade, the productivity has a clearly increasing slope. Importantly, in both of these sectors, the profile of wage share of middle-aged and senior workers does not diverge much from the profile of productivity contribution.

At the same time, in the low-skilled category, the estimated productivity is clearly the lowest for the oldest workers. It is possible that certain low-skilled employees, as time is passing, either quit the labour market (e.g. due to early retirement) or upgrade their qualifications and move to the high-skilled occupations. Thus, it could be that senior workers who stay in the low-skilled jobs are those who are not very productive. The opposite phenomenon could be also observed among the high-skilled employees. Seniors working as highly-skilled experts are not an exception in certain jobs. Hence, the high-skilled seniors who are still working tend to be those relatively more productive. In order to control for this selection phenomenon, time series on labour turnover would be needed.

2.4.3. Density estimations

The results for the "average enterprise" are interesting but do not reflect all the complexity of variation in wage shares and productivity contributions across the enterprises. Therefore, we also analyse the shape of the density functions of wage and productivity distributions. In this purpose, we make use of kernel density estimation which is a non-parametric way of estimating the probability density function. It is clearly smoother than some other density estimators such as histogram. The univariate kernel density estimator is computed using:

$$\hat{f}(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left[\frac{x - X_i}{h}\right] \tag{42}$$

where K is the Epanechnikov Kernel function and h is a smoothing parameter called the bandwith (Parzen, 1962).

2.4.3.1. Productivity

The productivity contribution ($MP_{ij}/MP_{i}av$) is defined as a ratio of marginal product of a specific age group (j) over the average labour marginal product of a given skill group (i). If the productivity of a certain age group equals to the skill sector average, this ratio equals to 1. In Tables 11 - 13, this case is expressed as a black vertical line. Since the distribution of productivity across the age groups is highly sector-specific, we analyse each sector separately as follows.

Manufacturing

In manufacturing, as shown in Table 11, the productivity of low-skilled workers across the enterprises is characterised by higher variability than the one of high-skilled employees. In general, the median absolute deviations are higher and there are more positive outliers. If we look closer at different age groups, we can notice that in both skills categories a greater variability in productivity is observed among young and older workers. At the same time, the productivity contribution of the middle-aged group does not vary that much between the firms. Its values are well concentrated around the sector average.

Certain particularities can be observed within each skill category. Among the low-skilled, the young workers appear the most productive. Most of them have productivity contribution exceeding the sector average (>1) and we observe many positive outliers. On the other hand, the great majority of older workers have productivity below the average (<1). Though a few positive outliers occur.

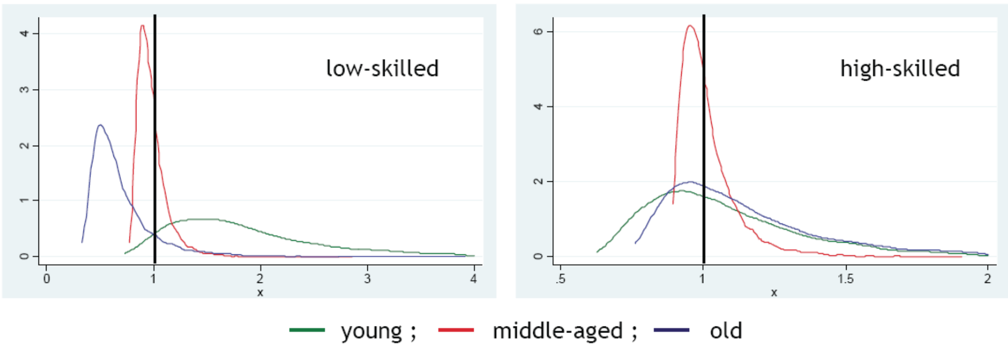
The density estimations concerning the high-skilled workers are quite different. The productivity distributions of different age groups have much more symmetric shape and the median value is quite close to the sector average. In this skill category, the older workers appear the most productive group. More than half of them are more productive than an average high-skilled person.

Services

Table 12 reveals a pattern of productivity distribution in the sector of services. This time, a higher inter-firm variability can be observed for the high-skilled employees. Both, the median absolute deviations as well as positive outliers take much higher values for this type of workers.

Table 11: Share in average marginal productivity (manufacturing)

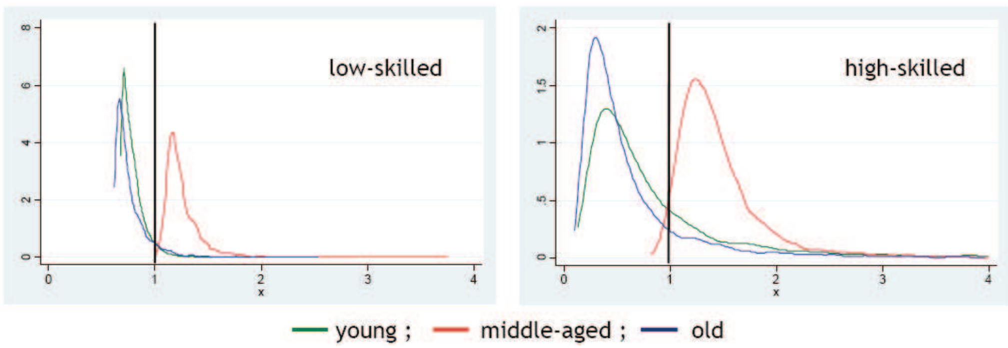
	median	median absolute deviation	min	max
low-skilled				
young	1.75	0.48	0.73	44.44
middle-aged	0.95	0.07	0.77	3.88
old	0.61	0.13	0.33	16.18
high-skilled				
young	1.03	0.17	0.63	7.55
middle-aged	0.99	0.05	0.89	2.77
old	1.09	0.16	0.76	8.96



Nevertheless, this time the productivity profile across the age groups is similar in both skill groups. The middle-aged workers are found clearly the most productive. Almost all of them reach productivity higher than sector average (> 1). In contrast, most of juniors and seniors are characterised by the productivity below the mean. However, there are some positive outliers, especially among the high-skilled workers.

Table 12: Share in average marginal productivity (services)

	median	median absolute deviation	min	max
low-skilled				
young	0.76	0.05	0.68	1.96
middle-aged	1.21	0.07	0.99	3.74
old	0.72	0.06	0.62	2.53
high-skilled				
young	0.62	0.27	0.13	47.11
middle-aged	1.36	0.19	0.83	27.85
old	0.44	0.18	0.09	119.00



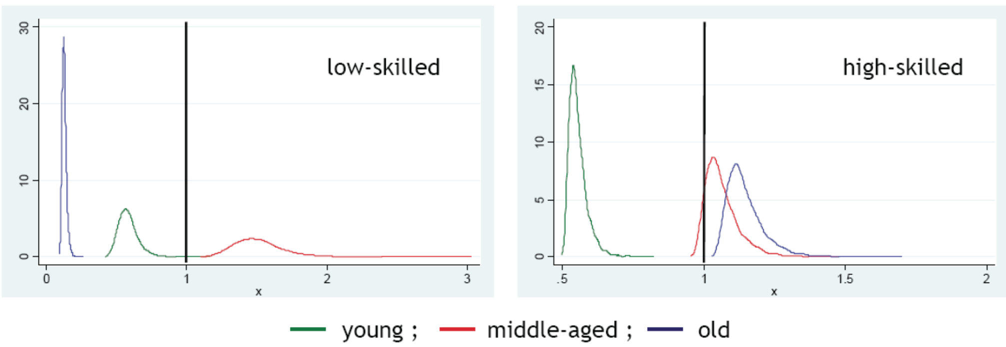
Trade

As can be seen in Table 13, in trade the productivity pattern is very different from those observed in other sectors. First of all, the productivity variability within narrowly defined age groups is much lower. Furthermore, there are large differences between skill groups. Among the low-skilled workers, the productivity distributions almost do not cross each other. The middle-aged workers are the most productive with the productivity contribution over the sector average in all the enterprises. The productivity of young and seniors is considerably lower, well below the sector mean.

A very different situation takes place within the high-skilled category of workers. Here, the senior are the most productive group followed closely by middle-aged workers with very similar productivity distribution. The young high-skilled employees are significantly less productive.

Table 13: Share in average marginal productivity (trade)

	median	median absolute deviation	min	max
low-skilled				
young	0.58	0.04	0.42	1.17
middle-aged	1.50	0.11	1.10	3.03
old	0.13	0.01	0.09	0.26
high-skilled				
young	0.55	0.02	0.49	0.82
middle-aged	1.05	0.03	0.95	1.57
old	1.13	0.04	1.03	1.69



2.4.3.2. Earnings

The distributions of wages in age and skill categories are presented in Tables 14, 15 and 16. The wage share ($W_{ij}/W_i av$) is defined as a ratio of earnings of a specific age group (j) over the average earnings of a given skill group (i). The ratio equals to 1 (expressed in the tables by a black vertical line) if earnings correspond to the sector average.

In all the sectors we observe a very similar pattern. In general, wage rates vary substantially less than workers' productivity. It is in line with empirical evidence against the paradigm of wage and marginal productivity equality (Frank (1984), Campbell and Kamlani (1997)).

Looking separately at two skill classes, we notice that wages of low-skilled workers are less variable than those of the high-skilled. In the low-skilled category, the middle-aged group of workers is characterised by the earnings distribution with the lowest variability, well concentrated around the mean. The earnings variability of young and older workers is very comparable.

Within the high-skilled group we observe more positive outliers, in particular for senior workers, possibly due to better remuneration offered to high-skilled employees with a long tenure. The distribution of earnings for the middle-aged workers is the least variable, followed by young and senior employees.

Table 14: Share in average wage (manufacturing)

	median	median absolute deviation	min	max
low-skilled				
young	0.89	0.05	0.05	2.74
middle-aged	1.01	0.02	0.54	1.49
old	1.05	0.04	0.44	4.79
high-skilled				
young	0.68	0.08	0.01	2.94
middle-aged	0.99	0.05	0.40	2.23
old	1.19	0.13	0.35	8.34

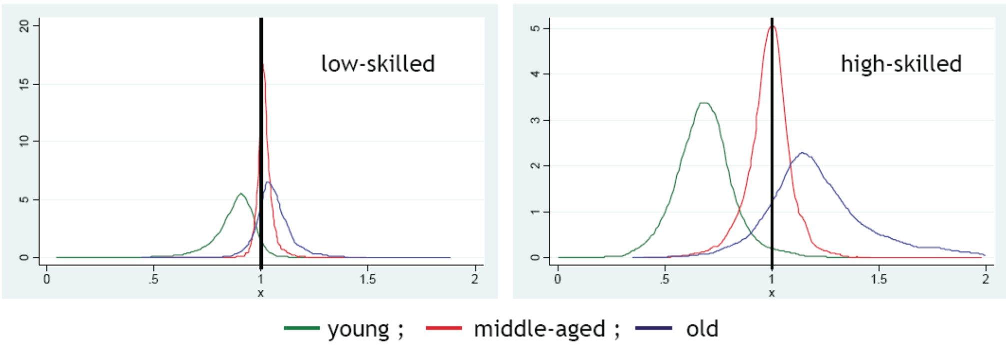


Table 15: Share in average wage (services)

	median	median absolute deviation	min	max
low-skilled				
young	0.92	0.04	0.24	1.43
middle-aged	1.01	0.02	0.78	1.80
old	1.05	0.05	0.34	3.52
high-skilled				
young	0.75	0.08	0.02	5.02
middle-aged	1.00	0.05	0.31	2.23
old	1.20	0.15	0.28	37.84

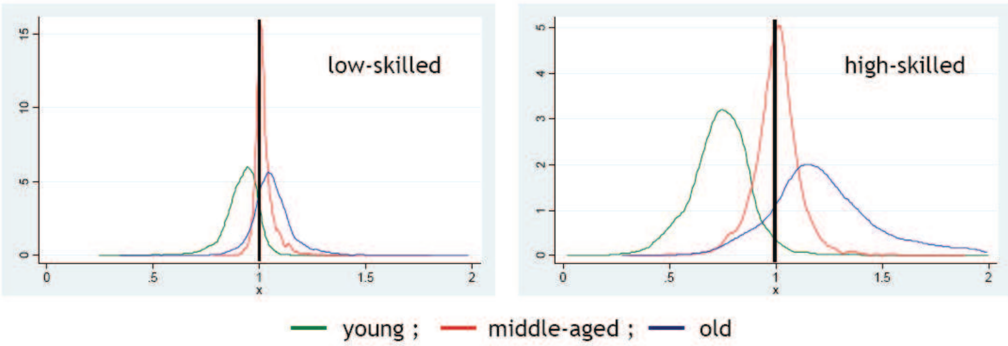
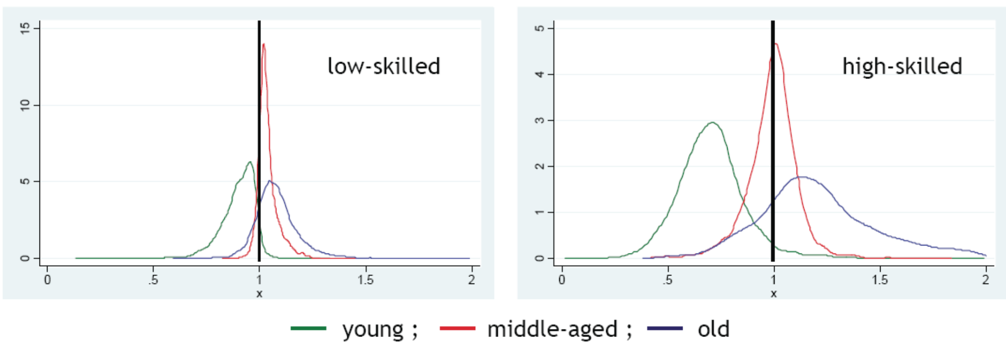


Table 16: Share in average wage (trade)

	median	median absolute deviation	min	max
low-skilled				
young	0.91	0.05	0.13	1.33
middle-aged	1.03	0.02	0.82	1.51
old	1.07	0.05	0.59	2.32
high-skilled				
young	0.70	0.09	0.02	3.75
middle-aged	1.00	0.06	0.42	1.83
old	1.20	0.17	0.38	5.49



2.4.3.3. Productivity/earnings ratio

The most interesting aspect from the perspective of the employer is the workers' productivity in relation to their cost. It is particularly important as for the employers it may present an incentive to exclude some age groups from the labour market and to give preference to the others.

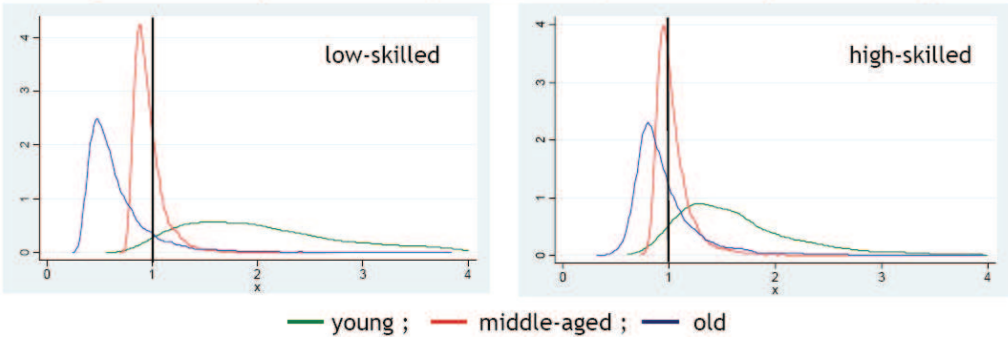
It is possible that some workers having the same productivity are paid differently or that some are paid equally but have different productivities. The most productive workers are not necessarily the most profitable. A firm has incentives to keep those workers who are the best value, that is the employees who produce the most relative to their wages. Therefore, apart of analysing the productivity distribution separately from wages, we consider also the inter-firm distribution of the productivity/earnings ratio with respect to all age and skill groups (see Tables 17, 18 and 19). We define it as $\frac{MP_{ij}}{MP_{i}av}/\frac{W_{ij}}{W_{i}av}$.

It appears that in manufacturing the relative productivity over the wage ratio is the highest for the young, followed by the middle-aged and the old. The possible explanation could be that juniors are paid the least due to employer's incomplete information about the workers' ability at the beginning of their career. At the same time they are highly motivated to work hard expecting higher opportunities in the future. Indeed, the young workers might exert much more effort in order to suggest high ability level and keep their current job and/or get future promotion (Grund and Westergård-Nielsen, 2008). The high variability in distribution for the young comes from the positive outliers.

This productivity/earnings ratio decreases with age for both skill groups. It means that the attractiveness of an employee for the employer decreases with age. Though, it is not so strong for the high-skilled workers. The distribution of the ratio shows higher variability for the older compared to the middle-aged workers. It has a lower median and a significant majority of observations are below the sector average.

Table 17: Ratio of relative productivity over relative wage (manufacturing)

	median	median absolute deviation	min	max
low-skilled				
young	2.02	0.59	0.56	106
middle-aged	0.93	0.07	0.70	4.03
old	0.58	0.13	0.24	17.77
high-skilled				
young	1.53	0.33	0.60	291
middle-aged	1.00	0.07	0.73	3.82
old	0.88	0.13	0.32	10.17



In services sector, we observe lower variability of the ratio among the low-skilled workers. The high variability for the high-skilled comes, among others, from the positive outliers in this group. In both skill categories, the productivity/earnings ratio is the highest for the middle-aged, followed by young and senior workers. Thus, similarly to the pure productivity profile, the middle-aged workers are the most attractive employees. However, the biggest positive outliers are found among the junior workers.

Contrasting results are found in the trade sector as shown in Table 19. For the low-skilled employees, the productivity/earnings ratio is very dispersed across the age groups. Likewise in services, the middle-aged workers are the most attractive, followed by juniors and seniors. Among the high-skilled, for all the age groups the distribution of the ratio converge closely around the mean and does not vary much. Again, the prime-age workers constitute the group whose majority has the ratio of productivity over cost higher than the sector average. They are followed by the older workers, whose distribution is well symmetric around the mean.

Table 18: Ratio of relative productivity over relative wage (services)

	median	median absolute deviation	min	max
low-skilled				
young	0.84	0.08	0.50	4.08
middle-aged	1.20	0.07	0.83	3.63
old	0.68	0.06	0.34	2.44
high-skilled				
young	0.85	0.40	0.13	223.53
middle-aged	1.36	0.21	0.82	35.50
old	0.36	0.14	0.09	67.48

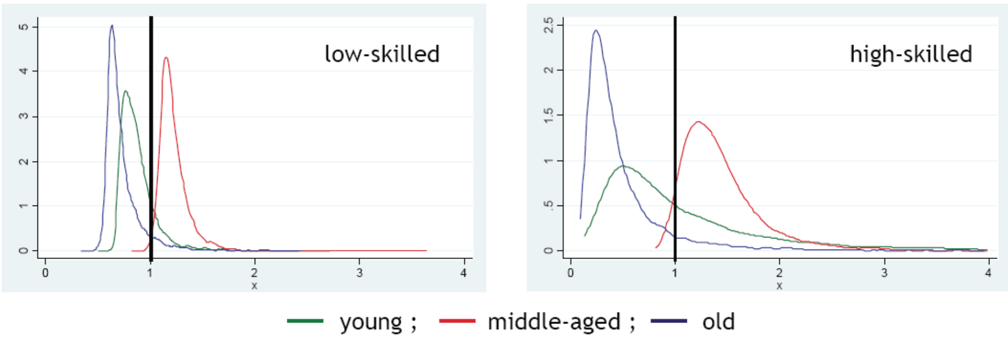
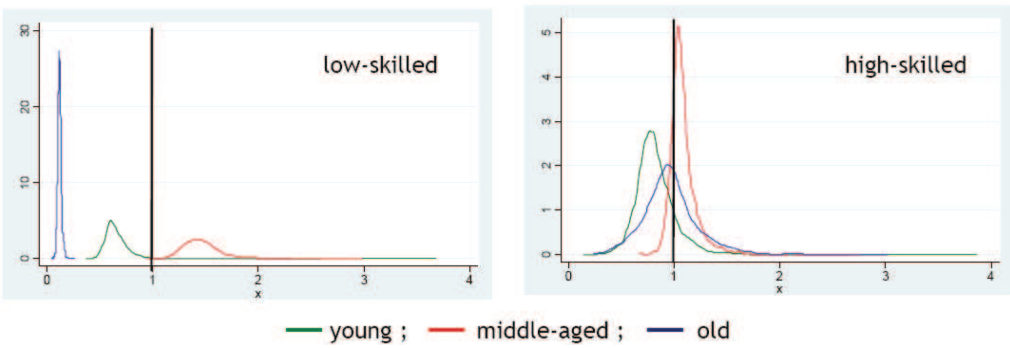


Table 19: Ratio of relative productivity over relative wage (trade)

	median	median absolute deviation	min	max
low-skilled				
young	0.64	0.06	0.37	3.67
middle-aged	1.44	0.10	0.95	2.97
old	0.12	0.01	0.05	0.26
high-skilled				
young	0.80	0.10	0.14	29.40
middle-aged	1.06	0.05	0.67	2.75
old	0.95	0.14	0.23	3.02



2.5. Conclusions

The second part of this chapter revisits the question of the actual profile of marginal productivity across the age groups within the given workforce and its potential equality with profile of earnings. Using the French firm-level data, we estimated the parameters of the production function where the labour input, differentiated simultaneously by age and skills, takes a nested CES functional form. We controlled for the endogeneity bias according to the methodology by Levinsohn and Petrin (2003).

Among the main findings, workers of different age appear to be imperfect substitutes in production. The elasticity of substitution for workers of different age has been found considerably lower than implied by the usually applied additive functional form specification. Our results suggest that wages do not necessarily reflect the actual productivity. Consistent with study by Frank (1984) and Campbell and Kamlani (1997), the wage profile has been found less variable than productivity.

As far as the labour productivity is concerned, its profile across distinct age groups is likely to depend on the skill category. For the low-skilled workers, it has been found the lowest for the seniors. In the high-skill group, the oldest employees in manufacturing and trade are the most productive group. The results for manufacturing sector show that the age-productivity and age-earnings profiles are compatible with a deferred compensation system. It might indicate that the effort incentive problem has been regulated in practice by many firms by offering at the start of the career wages under the workers' marginal productivity and compensating this difference in the later periods. On the other hand, in services and in trade, we observe the combined relevance of specific human capital and deferred compensation.

Relative productivity over wage ratio, an important aspect for the employers, has been found sector-specific. In manufacturing, it is the highest for the young workers and the lowest for the old. Consequently, this discrepancy between productivity and earnings can be a source of employment difficulties for the older low-skilled workers. In services and trade, the ratio is the highest for the middle-aged employees. It is important since when downsizing is necessary, firms have no incentives to retain workers whose productivity exceeds their wages. Moreover, if for the employer, the firm-specific human capital is important, the firm maximizes its profits by laying off from both ends of the age distribution first (Lazear, 1998). It means that in case of the negative productivity shock, the youngest workers who have not yet seen much investment in firm-specific human capital, and the oldest workers are going to retire soon, are the most vulnerable age groups to be laid off.

2.6. Appendix

Table 20: Production function estimates for each sector, labour differentiated by age, sub-sector controls

Parameters	Manufacturing		Services	
	NLLS	LP	NLLS	LP
α	0.222 (0.005)***	0.284 (0.029)***	0.241 (0.006)***	0.189 (0.039)***
β	0.811 (0.008)***	0.679 (0.010)***	0.710 (0.011)***	0.642 (0.024)***
δ_y	0.325 (0.019)***	0.293 (0.023)***	0.275 (0.026)***	0.299 (0.030)***
δ_m	0.450 (0.027)***	0.508 (0.035)***	0.427 (0.048)***	0.425 (0.051)***
δ_o	0.224	0.198 (0.017)***	0.298	0.276 (0.051)***
ρ_a	0.345 (0.075)***	0.188 (0.099)*	0.935 (0.213)***	0.759 (0.176)***
sub-sector controls	*yes*	*yes*	*yes*	*yes*
No of obs.	8185	8185	4498	4498

Notes: Bootstrapped standard errors in parentheses.
*** Significant at 1%, ** significant at 5%, * significant at 10%.

Table 21: Production function estimates for each sector, labour differentiated by age and skills, sub-sector controls

Parameters	Manufacturing		Services			
	no constraints		*no constraints*		$\rho_h=0$	
	NLLS	LP	NLLS	LP	NLLS	LP
α	0.191 (0.005)***	0.283 (0.041)***	0.218 (0.006)***	0.167 (0.042)***	0.219 (0.006)***	0.167 (0.042)***
β	0.827 (0.008)***	0.714 (0.009)***	0.733 (0.011)***	0.668 (0.025)***	0.724 (0.011)***	0.660 (0.025)***
γ	0.279 (0.013)***	0.269 (0.016)***	0.331 (0.025)***	0.324 (0.023)***	0.364 (0.026)***	0.356 (0.026)***
$1-\gamma$	0.721	0.730 (0.016)***	0.669	0.675 (0.023)***	0.635	0.643 (0.026)***
δ_{ly}	0.441 (0.033)***	0.404 (0.033)***	0.342 (0.038)***	0.371 (0.034)***	0.334 (0.038)***	0.365 (0.034)***
δ_{lm}	0.420 (0.046)***	0.465 (0.052)***	0.435 (0.071)***	0.451 (0.062)***	0.387 (0.066)***	0.409 (0.062)***
δ_{lo}	0.138	0.131 (0.029)***	0.222	0.177 (0.055)***	0.278	0.226 (0.060)***
ρ_l	0.437 (0.117)***	0.323 (0.118)***	0.653 (0.234)***	0.473 (0.160)***	0.814 (0.248)***	0.608 (0.172)***
δ_{hy}	0.248 (0.029)***	0.246 (0.032)***	0.211 (0.041)***	0.214 (0.067)***	0.132 (0.028)***	0.144 (0.035)***
δ_{hm}	0.403 (0.037)***	0.435 (0.044)***	0.391 (0.067)***	0.361 (0.091)***	0.696 (0.045)***	0.664 (0.054)***
δ_{ho}	0.348	0.318 (0.027)***	0.398	0.424 (0.132)***	0.172	0.191 (0.037)***
ρ_h	0.726 (0.124)***	0.581 (0.138)***	1.009 (0.288)***	0.984 (3.484)	0	0
sub-sector controls	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
No of obs.	8185	8185	4498	4498	3309	3309

Notes: Bootstrapped standard errors in parentheses.
*** Significant at 1%, ** significant at 5%, * significant at 10%.

Chapter 3: Intergenerational heterogeneity in confidence judgments

Following the analysis of earnings and estimation of productivity for different age groups in the previous chapter, this chapter involves the behavioural analysis of the workforce composed of juniors and seniors. The first section presents the conceptual and methodological problems with the definition and the measurement of overconfidence, with a particular focus on age differences in confidence judgments. The second section describes the design and procedures of the original experiment aimed at studying risk attitudes, workers' self-confidence and propensity to enter the competition, as well as the influence of the group age composition on the latter. All these elements, having an impact on the workers' individual productivity, are particularly important for the employers managing different generations of workers and facing the phenomenon of ageing.

1. Conceptual problems with overconfidence

The realistic judgments are crucial to successful decision making. They require an understanding of the scope and limits of our knowledge. While making important decisions or commitments, a correct assessment of the level of uncertainty and risk might help avoiding costly mistakes. Nonetheless, people are often unjustifiably certain of their beliefs. Experimental evidence suggests that human judgments tend to suffer from *overconfidence*. According to Russo and Schoemaker (1992), few people can accurately evaluate their uncertainty. Lack of this ability results in risk underestimation, missed deadlines and budget overruns.

These might have serious repercussions in many business domains. Barber and Odean (2001) believe that overconfidence strongly explains the high levels of counterproductive trading in financial markets. The investors, who are overconfident, overestimate the actual value of a security and tend to trade more than rational investors. Consequently, such behaviour leads them to excessive trading and lower expected utility (Odean, 1998). In the field of corporate finance, overconfident CEOs are supposed to overestimate their ability to generate returns. As a result, they conduct more mergers than their rational colleagues and, in addition, these mergers tend to be much less favourable (Malmendier and Tate, 2004). Furthermore, it has been argued that overconfidence of entrepreneurs is a cause of an excess market entry accompanied by a high business failure rate (Camerer and Lovallo, 1999). The phenomenon of overconfidence has been an object of research in many different fields. It has been underlined that in medicine, overconfidence in the diagnosis of a patient could lead to inappropriate medical treatment and as a consequence, to patient injury and death (Berner and Graber, 2008). In a juridical environment, an excessively optimistic judgment about the outcome of a trial could result in a bad legal advice (Griffin, 1992; Griffin and Tversky, 1992).

Interestingly, it appears that in some situations or in certain domains people might be underconfident about their possible performance. In a business domain, underconfident person tends to postpone taking a decision or, to follow other people's advice without verifying if it is actually right. Moreover, it has been observed that people tend to believe that events with objectively higher probability, or perceived as controllable, are more likely to happen to them. Kruger and Burrus (2004) suggest that people usually think that they are more likely than the average person to experience common events (such as owning a car) and less likely than the average person to experience rare events (such as owning an airplane).

Due to possible consequences of overconfidence, the understanding of its mechanism has become extremely important. A psychological literature provides us with interesting studies analysing the human process of decision making, probability assessment and judgment under uncertainty (Kahneman et al., 1982). In economics, these issues have attracted attention mostly of experimental and behavioural researchers, although the focus of the studies concerns very different aspects. Some investigate the link between an attitude towards risk, ambiguity and confidence in decision taking. It has been found that persons who are less risk averse and more tolerant for ambiguity, show greater confidence in their decision choice (Ghosh and Ray, 1997). Other studies have been devoted to the analysis of the role of experience and learning. Oskamp (1968), for example, claims that experienced judges are far superior to inexperienced ones, as far as the "appropriateness of confidence" (level of confidence treated jointly with level of accuracy) is concerned. Overconfidence has been also a research subject of multiple gender studies. Overall, women have been found more risk-averse and significantly less overconfident than men. Moreover, as men tend to feel more competent than women do in financial matters (Prince, 1993), it has been observed that men trade more and invest in riskier positions than women (Barber and Odean, 2001). Interestingly, in experimental study with children, Stein et al. (1971) claimed that tasks that are not matching one's sex role result in lower expectations of success and lower confidence.

Despite an important interest in confidence judgments by researchers of different specialities, the relationship between age and overconfidence has still not been sufficiently explored. In this context, we can suppose that experience acquired with age can lead people to better estimate their relative competences and their own limitations. However, it is equally possible that with age people's confidence grows excessively. Overall, the relationship between age and overconfidence remains undetermined due to lack of substantial work on the issue.

This section involves an analysis of different conceptual problems that exist in the research and in the literature on overconfidence. First, in order to better understand this phenomenon, we present its cognitive determinants, explored mainly by the psychologists. Then, we present the most common measurement techniques of overconfidence as well as multiple methodological difficulties that accompany this evaluation. Finally, we address the question of age differences in confidence judgments.

1.1. The cognitive determinants of overconfidence

In spite of extensive research on overconfidence, its source and causes have not been explicitly and unanimously defined. While the existence of the phenomenon is accepted by some researchers without any doubts, some other still debate on its character and its roots.

The determinants of overconfidence have been explored mainly in the field of psychology. Among the reasons for overconfidence, the literature mentions a failure to consider alternative perspectives. It can happen that "persons responsible for making the decision do not want any help, they do not consider what anyone else may think, they are completely sure that they are right" and they are so sure of themselves, that "questions are no longer asked" (Kissinger, 1998). Similarly, overconfidence might also result from the tendency to favour positive over negative information or to prefer arguments *in favour* to the arguments *against* our initial ideas (Koriat et al., 1980). While decision making, we naturally look for the support for our opinion rather than for counterarguments. Additional problem may arise when people do not distinguish between inferences and assertions, general conclusions and relevant facts (Wurzbach, 1991).

Griffin and Tversky (1992) claim that people, while making the intuitive judgments, focus on the strength (e.g. sample proportion) or extremeness of available evidence rather than on its weight (e.g. sample size) or credibility of the information. Consequently, their judgments will be overconfident if a strong impression is built on the basis of limited knowledge and they will be underconfident if despite broad available information its impact is relatively modest.

As prevailing origins of overconfidence Tversky and Kahneman (1974) indicate three heuristics: representativeness, availability and anchoring heuristics, which constitute an important source of cognitive bias while making confidence judgments. The authors claim that, while assessing probabilities of an uncertain event or predicting the value of an uncertain quantity, people rely on a limited number of heuristic principles which reduce the complex tasks to simpler judgmental operations. Although useful in general, these heuristics might lead to serious inaccuracy and miscalculation.

It seems that people usually rely on the *representativeness* when they need to judge a probability that a certain item belongs to a given category, an event originates from a certain process or that a process will generate a certain event. The more resemblance between these two elements exists, the higher will be automatically the evaluation of the mentioned probability. At the same time, people often *neglect the role of sample size*. They tend to expect that any sample, regardless of its size, will represent perfectly well (i.e. statistically significantly) the essential characteristics of the whole population. Consequently, many people express substantial confidence in their own predictions suggested by a good fit between the predicted result and the initially available information. It is called *the illusion of validity*.

The heuristic of *availability* concerns the situations in which people evaluate the likelihood of an event by the ease with which its examples or occurrences can be recalled. Consequently, the probability of an event which is difficult (easy) to imagine may be seriously underestimated (overestimated).

Another often mentioned reason for the observed overconfidence is a phenomenon of *anchoring*. It refers to a tendency "to anchor" the estimate on the initial value and to not adjust away from it sufficiently. Thus, the final answer is biased toward the starting point or the initial idea (Slovic and Lichtenstein, 1971).

However, while analysing the cognitive causes of overconfidence, one should not forget that sometimes overconfidence – like optimism – might have a highly motivational value by enhancing the ability to undertake difficult tasks. An optimistic individual assigns higher probabilities to future events, whereas overconfident person tends to underestimate the volatility of random events (Dubra, 2004). Thus, both may make people to do things that they would not have done otherwise (Griffin and Tversky, 1992).

Though, the overconfident comportment might equally come from the envy to look competent. People often confuse confidence with competence and this drives them to take risky actions or to make not sufficiently verified statements (Russo and Schoemaker, 1992). Burks et al. (2010) show that irrespective of their ability, people might make overconfident statements in order to send positive signals about one's ability to others and in this way receive some social benefits. On the other hand, via increase in their self-esteem, people might also derive their ego utility from being overconfident. This hypothesis has been confirmed, among others, by the reluctance of people to revise downward their beliefs about their true ability (Charness et al., 2011).

1.2. The measurement issues

In the economic literature, the experiments aiming at identification and measurement of overconfidence are usually based on *questionnaires* or *real tasks*. The experiment might concern a *prospective* or *retrospective confidence judgment*. If subjects are asked to evaluate their judgment's accuracy before answering the questionnaire, a rating is called a feeling-of-knowing. A retrospective judgment is called a confidence level rating. In this case, the participants must judge their responses accuracy after having completed the test (for more on this subject see e.g. Reder and Ritter, 1992; Costermans et al., 1992).

Questionnaires most often take a form of a general knowledge test or a set of questions assessing certain type of skills such as a mathematical or a logic quiz. Participants of questionnaires might be asked to make an accuracy judgment about their *absolute performance* (probability of giving the correct answer by their own) or about their *relative performance*, compared to the other participants or a given reference group (probability to be better or worse than the others). Moore and Healy (2008) proposed three distinct definitions corresponding to different ways of considering overconfidence in the literature: (1) overestimation – if overconfidence concerns individual absolute performance, (2) overplacement – when evaluating one's performance relative to others, and (3) overprecision – excessive certainty about accuracy of one's beliefs. The relative placement judgments play an important role in many competitive settings. In many jobs, the professional success simply depends on being better than others. Moreover, people may better understand their relative placement than their absolute performance level. In this context, we can distinguish tests based on *ranking questionnaire* and on *scale evaluation*. They both require from the participants making estimation of their position in the experimental or reference group.

In experiments based on *questionnaires* testing the absolute performance, overconfidence is measured by comparing the number of correct answers with the number of answers that the participant declared to be certain of being correct. Technically, after giving the best answer to each question, a person must rate his or her confidence in its correctness. Judgments are identified overconfident if they exceed the proportion of correct answers.

Relative placement questionnaires are more problematic as they require not only the estimation of participants' own level of skill (people dispose of imperfect knowledge in this aspect, otherwise the overconfidence would not be compatible with rationality) but also the evaluation of the skill distribution within the reference group. Since people have often very little information about others, their evaluation tends to be based on some beliefs that can be updated with time (Benoît and Dubra, 2007).

The evaluation of relative placements might involve ranking oneself in a certain fraction of population e.g. by making a statement "given the distribution of a test score in a population, I place myself in the i^{th} k-cile" or "I have a higher score than $x\%$ of the population". The task might also require comparing oneself to the average (mean or median) person's score using a designated scale[8]. A majority of people declaring to be above the average, although in theory only half can be, indicates overconfidence (see, for example, Svenson, 1981).

Another class of experiments measuring overconfidence are *real tasks* asking participants to take decisions about actions. For example, Koehler (1974) and Hoelzl and Rustichini (2005) provide an evidence of overconfident behaviour using a vocabulary test. Moreover, Hoelzl and Rustichini (2005) observe that overconfidence might change to underconfidence when the difficulty of an experimental task increases and this effect is stronger with monetary incentives. In fact, many empirical works often refer to a seminal paper by Camerer and Lovallo (1999). The authors propose an experiment modelling the process of firm's decision making about a market entry. The participants must decide simultaneously and without communicating whether to enter the market or, taking into account the number of potential competitors, stay out of it. The optimal strategy consists in decision to enter only when the number of expected entrants is below the market capacity. Camerer and Lovallo found out that if competition is based on participants' skill ranking, market entrants are excessively confident, overestimate their chances of success and enter the market much more often. In addition, they seem to neglect the increased level of competition from other participants who also believe to be highly placed in a skill ranking (the authors call this phenomenon "reference group neglect"). It is important to add that the ranking is not revealed until the end of the game, which means that all the entry decision are taken by the participants without knowing their rank. The authors notice that excess entry does not take place if ranking depends on a random drawing. Consequently, according to Camerer and Lovallo, the excessive optimism and overconfidence about one's relative ability is a source of the excessive entry and thus a business failure. According to this explanation, firms are expected to enter the market even if they expect negative industry profits.

This approach has been questioned by Hogarth and Karelaia (2008). The authors claim that judgmental imperfection leading to excess entry does not necessarily imply overconfidence. They show that entrants always exhibit greater confidence than non-entrants, even when all potential entrepreneurs are on average underconfident. Thus, observable excess entry can be simply produced by the imperfect estimates of their true entrepreneurial abilities.

[8] Using a scale either in the estimation of answer correctness or in the relative placement evaluation, one must ensure to choose an appropriate scale format. As underlined by Schwarz et al. (1991), depending on the scale format e.g. from -5 to 5, or from 0 to 10, estimation given by the subjects might differ considerably.

1.3. Methodological difficulties

Intuitively, most people understand what overconfidence is. Nevertheless, the variety of techniques used for its evaluation has revealed existence of multiple methodological difficulties. Frequently, a measurement method applied implies a very specific definition of overconfidence. The most common criticism encountered in the literature is that observed overconfidence might be simply an artefact of a method, question format or item selection applied in a study.

1.3.1. Format dependence

One of the problems accompanying the choice of an assessment set-up has been specified as format dependence (Juslin et al., 1999). It turned out that the realism of confidence depends strongly on the evaluation format. Overconfidence assessed by *interval production* for an uncertain quantity is larger and often of an enormous magnitude whereas an *interval evaluation* (probability judgment that the given intervals include the quantity) shows little or no overconfidence (Juslin et al., 2007).

In questionnaire experiments involving an *interval production*, participants are usually asked to answer questions by providing the best estimate of the answer and a confidence interval. It requires estimating dispersion i.e. a lower and an upper bound of an interval so that it contains the correct answer at a given level of confidence. The most problematic issue concerns the human process of judgment that the answer accuracy and interval production actually correspond to required confidence level. In the literature, it has been widely observed that people's 90 % subjective confidence intervals typically contain the true value about 50 % of the time, indicating extreme overconfidence (McKenzie et al., 2008).

An alternative method involves *interval evaluation* and consists in asking experiment participants to state by themselves a confidence level about the correctness of the given answers. Technically, this might take a form of a full-range or a half-range format. Within the *full-range format*, participants are asked the probability that the given statement or an answer estimate is correct. The possible answer may be between 0 % (certainly false) and 100 % (certainly true). Within an assessment set-up called a *half-range format*, participants need to declare how confident they are that their own answer is exact. The possible response varies between 50 % if guessing and 100 % if certain (Juslin et al., 2007). Interestingly, it has been shown that when participants are provided directly with different intervals and must assess the probability that the true value falls within the interval, the overconfidence bias tends to diminish (Winman et al., 2004).

Concerning the confidence interval production at a confidence level fixed in advance, it seems that estimates of overconfidence may be in this case highly misleading. Russo and Schoemaker (1992) found out that whether managers were asked to provide 50 %, 70 % or 90 % confidence intervals, only few of them were able to provide them realistically. Another example by the same authors concerns a group of financial officers who were asked to solve a test and provide a 90 % confidence interval for an estimated answer to each of the ten questions. Just after the test was completed, but still before the solutions were revealed, the participants were asked to estimate how many of the ten intervals provided would contain the true value. Only one person has answered "nine" according to the required 90 %. Others estimated, on average, 5.6 intervals to contain the true value. It means that the level of participants' confidence about their best answer estimate was much lower than required 90 %. It is particularly important, as in many studies, the fact that people provide confidence intervals that are too tight is considered a clear evidence of overconfidence (Lichtenstein et al., 1982). In this case, the discrepancy between the imposed confidence level and the proportion of intervals that includes the correct value cannot be treated as a proof of overconfidence since the post-test questionnaire verified the true perception of confidence by participants.

Moreover, there might be a difference in overconfidence pattern in evaluation of confidence in the answer accuracy for a single question of a test and assessment of the percentage of correct answers. According to Griffin and Tversky (1992), judgment confidence in single items is evaluated according to arguments for and against a given hypothesis, while an estimated frequency of correct prediction is based on perception of task difficulty, knowledge of the judge, or past experience with similar tasks.

Nevertheless, many studies have adopted this technique to identify overconfidence. They argue that participants being asked to give "a range such that there is a 90 % chance that the correct answer lies somewhere in the range" should obtain approximately 90 % correct answers. Not surprisingly, the results were always the same. For example, in work by Klayman et al. (1999), where the reported confidence level was held constant at 90 %, the correct answer fell inside the participants' confidence ranges about 45 % of the time. Klayman et al. concluded that questions that request subjective confidence judgments based on setting 90 % confidence ranges generate a large overconfidence bias. Instead, they propose a model of confidence judgments in two-alternative task which seems to elicit only little overconfidence (less than 5 % on average). In the two-choice task, questions are e.g. "Who is older: (A) Bill Clinton or (B) Madonna?" After providing the answer, participants need to indicate their confidence level by answering the question "what is the chance that you are right?"

The method stays, however, controversial. It seems straightforward that the two-choice questions generate much less overconfidence than producing a subjective range of confidence intervals to a single question. In fact, it is much easier to compare two elements than precisely estimate only one. To answer correctly the question "who is older: (A) Bill Clinton or (B) Madonna?" we do not need to have so precise knowledge as required to answer "How old is Madonna?". Moreover, the difference between 50 %, 70 % or 90 % confidence intervals might not clear for participants. For those who have no clue about the true answer, how is it possible to make a difference between 50 %, 70 % or 90 % confidence intervals? Another problem concerns the correct definition of the right calibration. It is highly doubtful that "A range such that there is a 90 % chance that the correct answer lies somewhere in the range" needs to correspond to "the proportion of correct answer in the entire test". If participant is guessing answers to all the questions (which corresponds to 50 % confidence level), does it guarantee that half of his answers (50 %) will be correct?

As mentioned above, *too narrow confidence intervals* might simply come from the wrong experiment task formulation imposing the answers accuracy. However, tight confidence intervals might also have different origins. It has been observed that people have a deep aversion to setting wide confidence intervals. They might associate establishing intervals that they consider too broad to showing their incompetence. Thus, they prefer to be wrong rather than considered incompetent. This phenomenon is also supposed to come from a socially rational trade-off between informativeness and accuracy (Cesarini et al., 2006). In this context, experts, compared to novices, appear to provide intervals being narrower and thus more informative as well as better centred on true values (McKenzie et al., 2008).

1.3.2. Better-than-average effect

The *better-than-average effect* denotes the propensity of people to believe that they are better and do better than the average person (Kruger and Mueller, 2002). It is often thought to depict the judgment bias due to overconfidence in the context of evaluation of relative placements. It has been noticed that a vast majority of people place themselves above average, although, in theory, only half can be. Nevertheless, this opinion is not shared by all the researchers. Benoît and Dubra (2007) claim that this phenomenon does not necessarily need to imply overconfidence. The authors argue that due to a process of Bayesian updating of their beliefs, people can rationally rate themselves above the average. As an argument they provide an experimental result where 74 % of participants of math and logic quiz choose to be rewarded based upon their placement (the condition of winning a prize is a score classified in the top half of results obtained by all participants) rather than upon a 50 % chance bet. According to Benoît and Dubra such result, usually interpreted as "74 % place themselves in the top half of test takers", is imprecise if not misleading. Instead, they propose a following interpretation: "74 % believe that there is (at least) 50 % chance that they are in the top half". Consequently, assuming that people learn and after receiving the signal they update their initial beliefs according to Bayes' rule, one cannot exclude the rationality of the participants' choice behaviour.

1.3.3. Task difficulty and hard-easy effect

Recently, some experimental researchers have revealed the existence of a link between perceived over- or underconfidence and *the level of task difficulty*. It seems that people judge their performance and relative placement differently depending if it concerns easy or difficult issues. Pulford and Colman (1997) using a general knowledge test and manipulating the level of questions difficulty, have found that hard questions resulted in significantly higher levels of participants' overconfidence than medium-difficulty and easy questions, which in turn generated an underconfidence bias. Similar results have been obtained by Larrick et al. (2007) who found that difficult tasks tend to produce overconfidence but worse-than-average perceptions, whereas easy tasks tend to produce underconfidence and better-than-average effects.

Moore and Cain (2007), as well as Moore and Healy (2008), provide a simple Bayesian explanation for these phenomena. They argue that as long as people are uncertain about their own or others' performance, their prediction should regress towards the prior belief corresponding to a *guessing value* (e.g. 50 % chance to respond correctly a "yes/no question"). Assuming that one's own performance has no impact on predictions of others' performance, and thus that the latter remains unchanged, a high own test score makes one think to have done better than others. By analogy, obtaining a low test score makes one believe being worse than others. In the authors' own words "when your absolute performance is better (or worse) than your prior expectations, sensible Bayesian inference will lead you to make predictions of others' performances that are between these priors and your current beliefs about your performance".

Using the methodology of the experimental market entry game by Camerer and Lovallo (1999), Moore and Cain (2007) provide experimental evidence that, on simple tests, people believe themselves to be above average and, on difficult tests, to be below average. The experiment participants slightly but significantly underestimate their scores on the simple trivia quiz. However, since they underestimate others' performance even more, as consequence they place themselves above average. By contrast, on the difficult trivia quiz, people considerably overestimate their scores. Though, they perceive themselves worse than average since they overestimate others' scores more than their own.

The concept of the hard-easy effect has been an object of critics by Juslin et al. (2000). The authors claim that with two-alternative general knowledge items there is little or no evidence for an overconfidence bias in human judgment. They further argue that controlling for the methodological problems such as scale-end effects, linear dependency and regression effects brings to elimination of the hard-easy effect.

Furthermore, the frequent use of the particularly difficult trivia questions as a way of investigating overconfidence has also been questioned. Gigerenzer et al. (1991) and Juslin et al. (1997) argued that people make much more accurate judgments in what concerns their natural environment. If questions are more characteristic for the problems that people solve in everyday life, overconfidence tends to disappear. However, it does not seem really surprising that in familiar domains people are better informed and naturally generate rather underconfidence than overconfidence, as it is a case with easy trivia tests.

A new confidence measurement method has been recently proposed by Blavatskyy (2009). The author presents a new incentive-compatible method where individual confidence in own knowledge or ability is determined through observation of a simple choice behaviour by experiment participants who are asked to bet either on own knowledge/ability (which reveals overconfidence) or on an equivalent risky lottery (which signals underconfidence). The author calls the method incentive-compatible meaning that subjects "cannot increase their monetary payoffs through deliberate misreporting of their confidence assessment, through conscious incorrect answering or through strategically chosen low effort".

In economic experiments, participants are often asked to make choices for real money, which is considered as an incentive to reveal their true behaviour and avoid self-presentation bias of attitudinal questions (Smith, 1976). Among the incentive compatible valuation methods are "real choice experiment" and "the non-hypothetical experimental auction". In hypothetical settings, subjects typically do not put enough cognitive effort in the elicitation tasks and do not have an incentive to report their true preferences (Camerer and Hogarth, 1999).

The results by Blavatskyy (2009) show that subjects appear to be predominantly underconfident about their own knowledge. 65 % out of forty-eight subjects are classified as underconfident, 29 % as overconfident and only 6 % as well calibrated.

"The experiment is designed to test individual confidence in own knowledge without self-assessment relative to the reference group because an individual may have little or no information about abilities of other subjects. Individual confidence is measured in a simple decision problem. Initially, subjects receive ten general knowledge questions, each with five possible answers. Subjects are informed that the more questions they answer correctly, the higher is their potential payoff. Having answered all questions, subjects face a choice among three alternatives: 1. One of ten questions is selected at random and the subject receives 50 CHF (US $39) if he or she answered this question correctly and 1 CHF (US $1.28) if his or her answer was incorrect; 2. One card is randomly drawn from a box with ten cards numbered from 1 to 10 and the subject receives 50 CHF when the number on the drawn card is smaller than or equal to n (1 CHF otherwise). n is calculated as a number of questions that the subject answered correctly. Although subjects see the number n, they are not informed that this is exactly the number of their correct answers. 3. Either alternative 1 or alternative 2 is selected (the subject presses button "Both alternatives are the same"). Alternatives 1–3 yield identical distribution of monetary outcomes but subjects are not aware of this fact. Subjects are classified as overconfident (i.e. overestimating own knowledge) if they select alternative 1, as underconfident (i.e. underestimating own knowledge) - if they select alternative 2, and well calibrated - if they select alternative 3. Alternative 1 involves an ambiguous lottery (betting on an uncertain event) and alternative 2 involves a risky lottery (betting on an event with a known probability). Thus, ambiguity averse subjects may be inclined to choose alternative 2 and risk averse subjects may prefer alternative 1." (Blavatskyy, 2009). To control for risk attitudes the author measured risk aversion and ambiguity aversion of every subject.

1.4. Age differences in confidence judgments

Despite an extensive research on confidence judgments, the relationship between age and overconfidence has still not been sufficiently explored. Though, the mechanism and quality of decision making by older people is of high importance for the social policy. Moreover, the very few studies that have addressed the question of age differences in realism of confidence judgments provided ambiguous results. Crawford and Stankov (1996), having tested participants' fluid and crystalized intelligence, argue that older adults are more overconfident in their judgments than younger ones. Kovalchik et al. (2005), analysing self-reported confidence on answers to trivia questions, find that both junior and senior participants display overconfidence at some levels. On the other hand, Pliske and Mutter (1996) and Forbes (2005), exploring confidence judgments via a general knowledge quiz, observed less overconfidence among older adults.

1.4.1. Experience

We can suppose that experience and knowledge acquired with age can lead people to better estimate their relative competence and their own limitations. However, it is equally possible that with age people's confidence grows excessively. Block and Harper (1991) noticed that overconfidence tends to be lower for more familiar issues. Indeed, older adults faced with decisions or judgments in frequently met context may avoid bias in their decisions thanks to previously acquired experience (Peters et al., 2007). Also Russo and Schoemaker (1992) suggest that experience possibly reduces overconfidence as they observed more accurate results on the test questions which were relevant for the participants' job or profession. However, the authors notice that, in spite of experience, overconfidence persists to a certain extent.

We could expect that if good calibration depends on age-sensitive cognitive abilities, then human judgments and decisions will tend to impair with age. Yet, this potential cognitive decline might be compensated by the benefits of accumulated experience (Peters et al., 2007). In fact, the tasks requiring high levels of skill or expertise in various content-specific areas or utilisation of efficient strategies could favour older individuals who have acquired many years of experience in the specific domain. However, in the experimental literature, tasks representing "the pragmatics of intelligence" (Baltes, 1987) or Practical Intelligence (Sternberg and Wagner, 1986) are relatively under-represented.

1.4.2. Cognitive skills

On the other hand, the literature provides numerous examples of age differences in cognitive abilities. Some research suggests that aging is associated with lower efficiency in processing perceived information (Salthouse, 1994). Older adults have been also found more influenced by prior expectancies and less likely to correct their judgments when accurate information regarding the co-occurrence of events was made salient (Mutter and Pliske, 1994). Moreover, there exist some suggestions that older adults rely more on heuristic processing due to cognitive capacity constraints (Johnson, 1990; Klaczynski and Robinson, 2000).

Some other research suggests that ageing is associated with a greater focus on emotional content and on positive over negative information (Peters et al., 2007). Kahneman and Tversky (1979) underline that elderly people, putting greater attention to positive information, may process gain-versus-loss information in decision process differently than younger adults. It might have important implications for their perception of risk.

On the other hand, in some aspects, cognitive age differences appear to be limited or not significant. Chasseigne et al. (1997, 1999) investigated the relation between age and ability to learn direct and inverse probabilistic relationships in Multiple Cue Probability Learning (MCPL) experiments[9]. They found that elderly adults performed as well as young adults in probability learning tasks when the cues had a direct relation with the criterion but performed less well when the cues had a more complex inverse or multiplicative relation with the criterion.

No significant age differences have been identified with respect to cautiousness, risk taking and overall performance in experiments where actual rewards for behaviours have been involved (Charness and Villeval, 2009; Sutter and Kocher, 2007). In the experiment by Okun and Elias (1977) older and younger adults participated in a vocabulary task with a payoff structure varying either directly or inversely with risk. Both age groups turn out to be equally sensitive to the payoff structure and overall expected value.

1.4.3. Age and overconfidence

Age differences in cognitive abilities might have important implications for confidence judgments and assessment of their realism.

Marquié and Huet (2000)investigate to which extent age-related differences in stereotypes and metacognitive beliefs are related to age differences in prospective (feeling-of-knowing) and retrospective (confidence level) judgments. A metacognitive questionnaire (Dixon et al., 1988) was used to assess participants' general and computer knowledge. Half of the questions covered topics in general knowledge (history, geography, literature, arts, science and sports), another half concerned computer science. Test difficulty has been equated across three age groups (66 young, middle-aged and older adults).

The middle-aged and older adults were found to be more underconfident than young adults when rating their feeling-of-knowing, especially for the computer domain. Otherwise, no age difference has been observed in confidence level ratings. The authors conclude that all age groups were equally accurate in FOK and in CL judgments, in both the general and the computer domain.

Apart from the knowledge test, the participants were asked to fulfil a stereotype questionnaire. It was designed to measure the participants' beliefs about the differences between younger and older people in their competence in the general- and computer-knowledge domains. Interestingly, all three age groups expressed the same

[9] This cognitive ability depends on information processing speed and working memory capacity.

opinion that "the young participants are more competent for the computer domain and the older participants for the general domain".

Another study aiming at measuring age differences in confidence judgments, by Hansson et al. (2008), use a test of general knowledge about population of 40 randomly chosen countries. Quiz participants were asked 1) to make their best guess and then produce an 80 % intuitive confidence interval and 2) to make their best guess and then provide a probability judgment that the randomly proposed interval would include the true value. Apart from the test, the cognitive abilities of participants have been measured during a separate session. The cognitive test consisted in examining short-term memory, processing speed, crystallized knowledge and Block Design Test (BDT).

The results confirmed the presence of significant age effects for the short-term memory, speed measures and for the measures of crystallized knowledge. A general ability factor, reflected by all the individual measures, was strongly negatively correlated with age. Once all the other factors were controlled, ageing turned out to favour increase in crystallized knowledge. Besides, the short-term memory and processing speed did not significantly predict overconfidence over the general ability. According to the authors, at least part of the negative influence of increased age on general ability in interval production may be compensated for by a greater domain-relevant knowledge or experience.

Among the main findings, overconfidence was found positively related to age with interval production but not with probability judgment. It is consistent with a study by Chasseigne et al. (1999) and Sanford et al. (1972) that older and younger adults appear to learn and respond to probabilistic information equally well. At the same time, the results confirm the frequently encountered methodological problem of format dependence, which has been underlined in the previous part of the present work.

A wide range of cognitive abilities is supposed to decline with increase in human age. According to Horn-Cattell theory (Cattell, 1941; Horn, 1965) we can distinguish between fluid and crystallized intelligence. The crystallized knowledge rooted in experience (detected through verbal or general knowledge tests) becomes stronger as we age and accumulates new knowledge and understanding. In contrast, fluid intelligence, i.e. abilities that are independent of learning, experience and education such as the ability to think and reason abstractly and solve problems, tend to diminish with age.

In order to explore age differences in the accuracy of confidence judgements, Crawford and Stankov (1996) tested fluid intelligence, crystallized intelligence, short-term memory and visual discrimination of 97 experiment participants. In order to test the ability to maximise their game scores, the participants were asked to give their best guess for each test item, rate their confidence in the answer accuracy and decide whether to submit the item for scoring. In case of submission, they could gain one point if the item was correct, or lose one point if the answer was wrong.

Consistently with the Horn-Cattell theory, older people have been found less successful in tasks involving fluid intelligence and short-term memory, but they performed better than younger participants on tasks of crystallized intelligence.

Regarding the confidence judgement measures, the results showed a small but statistically significant tendency for greater overconfidence for older subjects. However, results of *resolution* and *slope* measures indicate a lower ability of older participants' confidence ratings to discriminate between correct and incorrect items.

Somewhat unexpectedly, the accuracy on the visual discrimination task was slightly positively correlated with age. One of the explanations could be greater caution of older persons in providing the answers as indicated by their slower response times in all types of tasks.

Age differences in the accuracy of confidence judgments have been also explored by Pliske and Mutter (1996). In their experiment, younger and older participants need to make confidence judgments about the correctness of their responses in a two-alternative general knowledge test. The subjects were asked to indicate their confidence level by choosing a number on a scale.

Results indicate that older subjects were significantly more accurate than younger in their confidence judgments. It is consistent with recent theories that suggest that older adults have greater insights into the limitations of their knowledge (Kitchener and King, 1981; Kramer, 1983; Kitchener and Brenner, 1990) as well as with the Horn-Cattell theory that older people typically outperform younger ones on general knowledge tests (Perlmutter, 1978). Furthermore, the elderly appeared marginally less overconfident than younger participants but the age differences in the mean confidence ratings were not significant. However, the authors underline that there was an important variability in the overconfidence scores. Although, on average, older subjects were less overconfident, some of them were extremely overconfident. Thus, the results must be interpreted with caution and not be generalised towards one age group as if it was homogenous.

Another study using a two-alternative trivia general knowledge test is a paper by Kovalchik et al. (2005). Among the participants were healthy elderly individuals (average age 82) and young students (average age 20). They were asked to choose the right answer and provide a confidence judgment of 50, 60, 70, 80, 90 or 100 % certainty. According to the standard methodology, the authors combined all the answers, for each age group, in which subjects gave the same confidence evaluation and calculated how often they were right. Individuals were called well calibrated if the fraction of correct answers corresponded to the stated confidence level.

The results have shown that both age groups were characterised by a certain level of overconfidence, though older individuals not only answered more questions (74 %, compared to 66 % for the young) correctly but they appeared also significantly more accurate than younger participants at 60 % and 70 % reported confidence level.

Interestingly, the distribution of responses showed that older subjects much more often indicated either 100 % (completely certain) or 50 % (completely uncertain) confidence level. The authors argue that this high resolution of confidence evaluation by the elderly suggests highly accurate beliefs about their knowledge and its limitations. It is thus probable that through experience older people learnt to temper their overconfidence and, thus, look more like experts.

1.5. Conclusions

There is a widely held belief that ageing is associated with lower efficiency in processing information and as a result decision making faculties decline with age. However, the few studies that have investigated the relationship between age and the ability to make realistic confidence judgments have not managed to bring conclusive results. The lack of consensus could result from the variety of methods used to measure overconfident attitudes as well as from different samples of participants in terms of age. Nevertheless, it has been noticed that generally overconfidence tends to be lower if judgments concern well known or familiar context (Block and Harper, 1991). It has been confirmed in the experiments measuring age differences in overconfidence. The fact that older participants tend to report more accurate confidence levels (Pliske and Mutter, 1996; Kovalchik et al., 2005) seems to indicate that seniors, thanks to acquired experience, have greater insights into the limitations of their knowledge. That would prove the robustness of their decision behaviour.

The age differences in decision making and overconfidence will be further explored in the next section of this chapter. In an original experimental study inspired by Camerer and Lovallo (1999) we analyse decision efficiency within an age-heterogeneous workforce. In particular, we study risk attitudes, workers' self-confidence and propensity to enter the competition, as well as the influence of the group age composition on this propensity.

2. Ageing, excess entry and overconfidence. An artefactual field experiment in a Swiss bank[10]

One of the consequences of aging societies is that juniors and seniors are more and more often confronted with competition on the labour market. Such situation takes place already while applying for a job. Older workers tend to experience discrimination and be disproportionately represented among the long term unemployed (Walker, 2005). If lucky to be employed, older workers tend to occupy a relatively low status on the labour market. Employers hold rather stereotypical views about the strengths and weakness of older workers. Although they appreciate experience, loyalty and low turnover of senior employees, in fact younger workers are preferred when it comes to hiring decisions (Guest and Shacklock, 2005).

Also in the workplace, individuals belonging to different generations face competition. Within the same enterprise, juniors and seniors might compete for getting involved in a project or being promoted. Nowadays, many employers encourage competition, for example by applying performance-related pay, in order to motivate their employees, keep them innovative and elicit greater productivity and better quality of work (Booth and Frank, 1999; Lazear, 2000; Cuñat and Guadalupe, 2005). The employees, in order to gain employer's appreciation, try to perform better than others and surpass themselves. In particular, over the recent decades, a pressure to prove their qualities has been especially high for senior workers. The technical and organisational changes due to the rapid development of information and communication technologies has required from workers to achieve quickly new skills and competences. Older workers have been more than ever concerned with skills obsolescence especially that employers started to attach less value to their previously accumulated work experience. Moreover, seniors started to be perceived as overly cautious, less competitive, less willing to learn and adapt to new conditions. Nevertheless, the recent studies show that seniors are no more risk averse than juniors and tend to be more cooperative. Both generations seem to respond strongly to competition (Charness and Villeval, 2009).

The objective of this section is to investigate whether juniors and seniors differ in propensity to enter the competition. If seniors are more likely to compete, it could increase their chances to bring profits and consequently make them more attractive for the potential employers who tend to have an image of older workers as less productive. Moreover, since both generations tend to interact in a workplace, we verify whether the age composition of a pool of potential competitors conditions risk-taking behaviour and influences the overall efficiency of decisions. In this purpose we conduct a controlled experiment with the employees of a Swiss bank. We use a market

[10] The section is the result of a collaboration with Thierry Madiès and Marie Claire Villeval.

entry game that is largely inspired by Camerer and Lovallo (1999) and which we adjusted to study the differences between generations. In our experiment, the junior and senior participants need to make a series of decisions on market entry. Given the limited market capacity, only well-ranked players can make profits. Depending on the sequence (Random or Performance), the rank of an entrant is assigned randomly by the computer program or depends on player's performance (relative to other players) in a quiz in general economic knowledge that is administered at the end of the game. In order to make the optimal choice, participants must anticipate the behaviour of other players, the level of their relative abilities, risk attitudes and readiness to compete.

We find that seniors enter the competition significantly more often than juniors. We consider a number of explanations to understand this generation difference in market entry. First of all, we verify whether juniors and seniors are characterised by different level of risk and ambiguity aversion. If seniors are less risk and/or ambiguity averse, it could at least partially explain why they decided to enter the market more often. Otherwise, this decision could be also driven by differences in abilities. However, we find that the age gap in market entry is explained neither by intergenerational differences in attitudes towards risk and ambiguity nor in quiz performance.

Another explanation that we consider is that seniors might be more confident about their relative performance than juniors. In the quiz administered after the market entry game, it turns out that although seniors rather underestimate their individual performance, they believe to be better ranked than juniors. Hence, we test the overconfidence hypothesis to see if these higher expectations about their relative ability are accurate or not. There exist empirical evidence that experience and knowledge acquired with age can lead people to better estimate their relative competence and their own limitations (Peters et al., 2007; Russo and Schoemaker, 1992, Kitchner and Brenner, 1990).

In order to better explain the age gap in market entry, we run a Probit regression controlling for age differences in factors such as overconfidence, risk and ambiguity aversion. We find that even including these controls, age differences are still significant and large. This makes us think that the competition entry gap between juniors and seniors could be in fact driven by the image concern.

Our initial intuition concerning impact of age on the image concern in terms of relative ability was that juniors would take more risk than seniors to show their competence. In reality, we find that seniors enter the market more often than juniors. Nevertheless, they tend to be very pessimist about their own individual result, both in general and compared to other seniors. It is thus possible that by entering the competition, seniors want to improve their image and fight the stereotype as risk-averse and less likely to get involved in competitive tasks. Burks et al. (2010)

suggest that people, induced by social concerns, might behave as overconfident in order to signal a positive image of themselves to others. In particular, we find that the important presence of juniors in a group creates a sort of informal pressure on seniors to prove their competences concerning behaviour in competitive environment. It is likely that seniors get a sort of psychic returns from entering the competition against juniors so that the total expected utility from entering the market is high.

The remainder of this section is organised as follows. In the next subsection, we present our experimental design and procedures. Afterwards, we present and discuss the experimental results before making the final conclusions.

2.1. Experimental design and procedures

Our experiment is composed of five parts. We conducted the sessions in the field.

2.1.1. The tasks

The main game consists of a market entry game inspired by Camerer and Lovallo (1999) and designed to test the overconfidence of the participants according to age and age matching. This game is played in Part 2. Since we are aware that the entry decision may also capture the influence of ambiguity aversion as participants decide without knowing the number of potential competitors on the market[11], we control for risk attitudes and ambiguity aversion in Part 1. The following parts are designed to measure the participants' confidence in their ability and their beliefs about the ability of other participants according to their generation.

A test of attitudes towards risk and ambiguity

In Part 1, we elicited our participants' attitudes toward risk and ambiguity by asking them to choose between certain amounts and drawing a ball from an urn (see Fox and Tversky, 1995, and Appendix 1). Precisely, the participants have to make a first set of 20 decisions between accepting a certain payoff and extracting a ball from an urn. The urn contains 5 blue balls and 5 yellow balls and this is common information. One yellow ball drawn from the urn pays 500 ECU (Experimental Currency Unit, with 100 ECU = 2 CHF = U.S. $2.06), a blue ball pays nothing. The amount of the certain payoff increases from 25 to 500 ECU. Then, the participant has to make a second set of 20 similar decisions, with the same certain amounts, except

[11] Grieco and Hogarth (2004) state that people seek ambiguity when the source of uncertainty is related to their competence while overconfidence, as such, plays no role in excess entry.

that the proportions of the balls of each colour in the urn are now unknown. The switching point in the first set of decisions informs us about the risk attitude of the participants and the difference between the switching point in the risky lottery and in the ambiguous lottery indicates the participants' attitude regarding uncertainty.

In both sets of decisions, a risk neutral participant should choose the random draw until the certain payoff is equal to at least 250 ECU and then choose the certain payoff. In the first set of decisions, a risk averse participant should switch from the lottery to the certain payoff for certain payoffs lower than 250 ECU and a risk seeking participant should switch for certain payoffs higher than 250 ECU. An ambiguity averse participant should switch for lower certain amounts in the second set of decisions than in the first set, while an ambiguity-seeking participant should switch later in the second set of decisions than in the first one. The theoretical predictions are the same for both juniors and seniors.

While decisions are made at the beginning of the session, participants know that the outcome of their decisions will be determined only at the end of the session after completion of all the other tasks. Participants are also informed that one decision in each set of decisions will be randomly drawn for real payoffs at the end of the session.

Eliciting attitudes towards risk and uncertainty informs on whether we observe differences according to the participants' generations, as a stereotype is that older individuals become more risk-averse than young people. But it mainly serves to better identify the motivation of entry decisions in the main game, the market entry game.

The market entry game

Since we are chiefly interested in analysing whether aging helps individuals in better calibrating their beliefs about their skill and adjusting their decisions in an uncertain environment, thanks to a longer return of experience, we have used a market entry game that is largely inspired by Camerer and Lovallo (1999). At the same time, we want to see whether information on age of other players has an impact on strategic behaviour while individual decision making. For this reason, we manipulate the composition of groups in terms of generations.

At the beginning of the game, each participant is endowed with 500 ECU. The game consists of two sequences of nine periods each. Each sequence corresponds to one of two treatments, respectively the "Random" treatment and the "Performance" treatment. As in Camerer and Lovallo (1999), the comparison between the two treatments should inform on the (over-/under-) confidence of the participants. Let us describe the Random treatment first. In each of the nine periods, participants are teamed in groups of ten. At the beginning of each period, they are informed on the composition of their group in terms of generation (number of juniors and seniors). The number of juniors (seniors, respectively) can be 0, 3, 5, 7 or 10. Participants are also told the capacity of the market, i.e. the number of participants in the group who can make profits by entering the market. According to the periods, the capacity can be 2, 4 or 6. Payoffs depend on the decision to enter or not the market and if so, on the rank of the participant among the entrants. A participant who decides not to enter earns nothing and loses nothing. A participant who is ranked above the capacity of the market loses 500 ECU. A participant whose rank is lower than or equal to the capacity of the market makes a profit which amount depends precisely on his rank and on the market capacity, as indicated in Table 22. Whatever the capacity of the market, the total market profits amount to 3,000 ECU. In the Random treatment, ranks are assigned randomly by the computer program to the entrants.

Table 22: Payoff matrix in the market entry game (in ECU)

Rank among the entrants	Market capacity, C		
	C = 2	C = 4	C = 6
1	1,900	1,400	900
2	1,100	900	700
3	- 500	500	500
4	- 500	200	400
5	- 500	- 500	300
6	- 500	- 500	200
7	- 500	- 500	- 500
8	- 500	- 500	- 500
9	- 500	- 500	- 500
10	- 500	- 500	- 500

After being informed on the capacity of the market and on the composition of his group, each participant has first to report his belief about the number of co-participants who will decide to enter the market. Then, he decides on entering or not. At the end of the period, the participant receives a feedback on the total number of entrants in the current period but he is not informed on his rank if he decided to enter.

The only difference between the Performance treatment and the Random treatment is that in the former, ranks in each of the nine periods are assigned according to the participant's performance in a quiz that is administered in the next part of the session, compared with the performance of the other entrants in his group. When they make their decision, participants do not know the content of the quiz. They just know that it consists of four questions related to general economic knowledge. They are given two examples of questions similar to that included in the quiz. The comparison between the two treatments allows us to measure how people condition their risk-taking in such an uncertain environment to the mode of determination of ranks. Specifically, if a participant enters more in the Performance treatment than in the Random treatment for a given market capacity and a given belief regarding the others' decisions, it means that this participant believes he is better than random others.

The originality of our design compared to the one used by Camerer and Lovallo (1999) is that we manipulate the composition of the groups in terms of generation to measure whether individuals condition their entry decision in each treatment i) on their own generation and ii) on the generation of their co-participants. We can also measure iii) whether the latter effect depends on the participant's own generation. From a theoretical point of view, the predictions are the same for both generations. But if seniors are more (less) risk averse than juniors, they should enter less (more) than juniors in both the Random and the Performance treatments. If seniors are overconfident (underconfident) compared to juniors, they should enter more (less) in the Performance treatment than in the Random treatment, and more (less) so than juniors. If participants believe that juniors adopt a more risk-seeking (risk-averse) behaviour, they should enter less (more), the more juniors there are in their group.

At the end of the session, one period out of the 18 periods of the two treatments is drawn randomly for payment. For this period, the computer program calculates the number of entrants. The participant is paid 100 ECU if his prediction regarding the number of entrants in this period was correct. His other payoff for this part depends on the capacity of the market, on his decision to enter and, conditional on this decision, on his rank in this period. Participants are informed on their rank but not on whether this period belonged to the Random or the Performance treatment for a reason that will become clear below.

The measure of confidence

Typically, tests of miscalibration require the subjects to determine confidence intervals at the 10 %, 50 % and 90 % levels and to predict their number of correct answers (Dargnies and Hollard, 2009; Cesarini et al. 2006; Juslin, Winman and Olsson, 2000; Russo and Schoemaker, 1992). Other tests propose the subjects to bet on their knowledge (Blavatskyy, 2009; Goodie, 2005; Fischoff et al., 1977). For the sake of simplicity, for time constraints, and also because the market entry game is devoted to test for overconfidence, we have chosen a very parsimonious incentivised test of confidence[12]. Our experimental settings in Parts 3 and 4 are designed such that we can measure both the ability and the beliefs of our participants on their ability. They allow us to learn the calibration of the participants and to relate this to their generation.

[12]It should be noted that many tests of confidence in psychology do not involve incentives but self-reports (see for example Svenson, 1981).

Part 3 consists of a quiz that includes four questions related to general economic knowledge[13]. All the participants receive the same questions in the same order. For each item, they have to enter their answer that can take any value between 0 and 100. They have also to indicate an interval of confidence for each answer. Precisely, they indicate a minimum value such that they believe the correct answer cannot be lower and a maximum value such that they believe the correct answer cannot be higher than this value. Their precise answer must be included in this interval, otherwise it is rejected by the computer program.

Payoffs for this part are determined in a loss frame as follows. For each item, the participant receives 100 ECU. If the correct answer falls outside of the interval defined by the participant, the 100 ECU are lost. If the correct answer falls inside this interval, the payoff is given by the difference between 100 ECU and the size of the interval provided by the participant. Maximum payoff is of course reached when the participant gives the correct answer and chooses both the lower and the higher bounds of the interval equal to this answer. This procedure ensures that participants are incited to give their best possible answer. It also creates a trade-off between indicating a smaller interval to earn more ECU (provided it includes the correct answer) and choosing a larger interval to increase the chance that it contains the correct answer. This procedure gives us a relative measure of confidence. Indeed, an overconfident (underconfident) risk-neutral participant should indicate a narrower (larger) confidence interval than a well-calibrated participant. Total payoffs in this part are given by the sum of payoffs obtained for each question[14].

Before answering the quiz, participants are reminded that their performance may influence their rank in the previous game. A "distance index" is assigned to each participant according to the correctness of his answers. This index is defined as the mean difference in absolute value between the correct answers and the answers given by the participant. A lower distance index indicates that the answers were more precise (in the extreme, an index of zero would indicate that all the answers were correct). To calculate the rank of a participant in a period of the Performance treatment, the computer program compares the distance index of the entrants in this period. Then, it assigns the first rank to the entrant whose distance index is the lowest, the second rank to the second lowest distance index, etc. At the end of the session, players are informed on their total payoff in this part and on their distance index but only if they ask for this information in a further part of the session.

[13]Questions have been chosen such that most participants have an idea of the correct answer, but an imprecise one. The questions are: How many countries are members of the OECD? What was the Swiss public debt as a percentage of GDP in 2009? What was the proportion of Swiss people with a high degree of satisfaction with life in general in 2006 (in percentage)? What was the share of Swiss exports (as percentage of total exports) to EU 27 in 2009?

[14]This payment scheme was inspired by Dargnies and Hollard (2009), but our procedure differs from theirs in that we do not ask participants to give 10 %, 50 % or 90 % confidence intervals.

In Part 4, we elicit the participants' beliefs regarding their own distance index, the average distance index of the juniors in the session, the average distance index of the seniors, their own ranking in the quiz among the ten participants of their generation, their ranking among the 20 participants of the session. Each correct prediction pays 50 ECU. Since we expect that it is difficult for any participant to report precise estimations, the program displays various categories of indices and ranks[15]. These beliefs provide us with another indication of the participants' confidence in their absolute and relative ability compared with the two generations. Indeed, this informs on whether the participant believes he has provided on average better answers than the other members of his own generation and better than the members of the other generation. In addition, if the participant indicates a rank category in the group of 20 that is not exactly twice the category reported in the group of 10, this indicates that the participant believes he is either more or less able than the other generation. At the end of the session, participants are only informed on their total payoffs for this part. They are not told which answers were accurate.

2.1.2. Experimental procedures in the field

This artefactual field experiment (Harrison and List, 2004) was conducted with 80 employees of a large private bank in Lausanne, Switzerland[16]. Forty juniors (between 22 and 30 years old, mean = 28 years old) and forty seniors (between 48 and 62 years old, mean = 55 years old) participated in a total of four sessions. The Human Resource department recruited the participants via emails and phone calls and took care of balancing the proportions of juniors and seniors[17]. All participants had the same occupation (client advisors), and most of them (82.5%) had no supervisory functions. Participants were invited from various offices located in French-speaking cantons in Switzerland in order to minimize the likelihood that several people interacting daily at work would participate in the same session. The invitation mentioned participation in a scientific experiment initiated and managed by academic researchers during working time. The Human Resource department was aware of not revealing the purpose of the experiment or details of the protocol to the participants.

These sessions were held in a meeting room of the bank in which we reconstituted an experimental laboratory thanks to our Regate Mobile Lab. In particular, mobile

[15]Indices are grouped by five (0-5, 6-10, ...) with a last larger category (45 and more). Ranks are grouped by two (1-2, 3-4, ...).

[16]Crédit Suissse is a Swiss bank and a leading global financial services company, offering clients financial advice in all aspects of private banking, investment banking, and asset management. The headquarters are located in Zurich. It employs 49,900 employees in 405 offices in 55 countries.

[17]It has not been possible to balance the proportions of males and females, but these proportions were similar in both generations (there were 68 % of males among juniors and 70 % among seniors).

fences separated each seat from the next such that the confidentiality of decision was guaranteed, and computers were connected through our own independent wifi network (see Appendix 2). The experiment was computerized using the REGATE program (Zeiliger, 2000). Four sessions were run in two days to avoid the dissemination of information about the content of the experiment. The same experimenters ran all of the sessions. Each session consisted of 20 participants (10 juniors and 10 seniors).

Upon arrival, participants drew a tag from a bag assigning them to a specific computer. At the beginning of the session, the experimentalist reminded all the participants that decisions were anonymous, that no individual data would be communicated to the company, and that the earnings gained during the session were funded by the University research funds. Then, participants had to sign a consent form in which they confirmed their voluntary participation and acknowledged being informed that they could quit at any time without any consequence for themselves. Next, the instructions for the elicitation of risk aversion and attitudes towards ambiguity (Part 1) were distributed and read aloud (see Appendix 1). After all questions were answered in private, participants made their two sets of 20 decisions.

Then, they received a new set of instructions for the market entry game (Part 2). These instructions detailed the two sequences of play corresponding to the Random treatment and to the Performance treatment, without mentioning the order of each sequence. The participants then entered their year of birth on their computer; they also filled out a questionnaire to check their understanding of the instructions and questions were answered privately. When the game started, individuals were informed on the treatment played in the first sequence of play. At the beginning of each period, individuals were matched in a group of 10 participants and they were informed on the composition of their group by generation (number of juniors and seniors). Then, they received information on the capacity of the market. Next, they entered their prediction regarding the number of entrants among their co-participants and they decided to enter the market or to stay out. Once all group members have made their decision, a feedback indicated the total number of entrants in the period but participants were not informed on their rank or their payoff. After each period, participants were rematched in a new group of 10 individuals and the market capacity was changed[18]. After the first nine periods have been completed, participants are informed that the other treatment is implemented in the new sequence of nine periods.

[18]Since this part comprises of 18 periods, it is impossible to observe for each participant his decisions in each market capacity with each group composition in each sequence. Therefore, while all participants are observed in groups with 5 juniors and 5 seniors and in groups with 10 juniors or 10 seniors, half of the subjects are observed in groups with 3 juniors and 7 seniors and the other half are observed in groups with 7 juniors and 3 seniors in each market capacity.

At the end of the previous game, we distributed the instructions for the quiz (Part 3), explaining the calculation of payoffs in this part, the definition of the distance index and how this index serves for determining the individual's rank in the performance treatment in Part 2. We checked for whether people understood the game. We imposed no time constraint to answer the questions. Once all participants took the quiz, they received another set of instructions and they entered their five predictions regarding their absolute and relative performance and that of each generation (Part 4). Next, after receiving new instructions, they decided whether they were willing to receive information on their performance and their rank in the quiz and if they accepted the dissemination of information to others (Part 5). Once all participants have made their decisions, a table was displayed on all the participants' screens during 30 seconds indicating, for each individual who accepted its dissemination, information on his generation, his number of entry decisions in the Performance treatment in Part 2 and his rank in the quiz among the 20 participants of the session. Last, participants received a feedback on their payoffs in each paid part before answering a post-experimental questionnaire[19]. They were also informed on their distance index and on their rank in the quiz if in Part 5 they chose to be informed.

Each session lasted between 110 and 120 minutes, all included. Since we were not allowed to manipulate cash in the firm, participants received their earnings by mail at their personal address. On average, they earned 45.08 CHF (about $46.40). The show-up fee amounted to 15 CHF[20].

2.2. Results

We begin this subsection by analysing the results of a test of attitudes towards risk and ambiguity. Then, we present the fundamental findings of the market entry game. We study the juniors and seniors' attitudes towards competition and try to verify a few hypotheses that could support our observations.

[19]Indeed, participants did not receive any information on their payoffs before the end of the session. At the end of the session, the computer program selected one decision in each of the two sets of decisions in Part 1 and a second draw was made if for the selected decisions the individual had decided to extract a ball from the urn. These payoffs were added to the payoffs from the following parts.

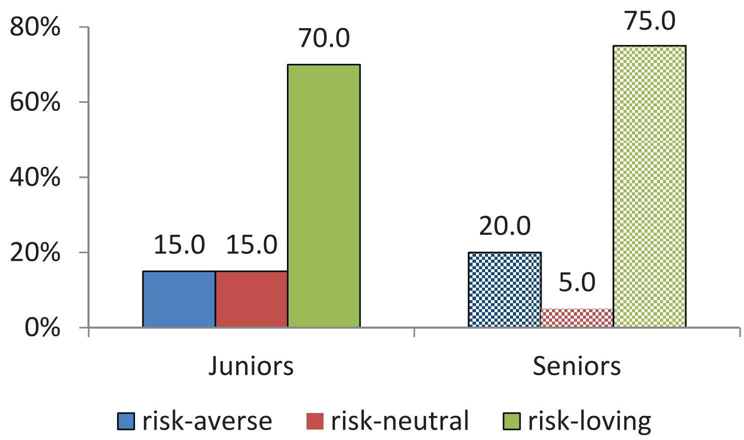
[20]Total payoffs are even higher if one accounts for the fact that all the participants were given a half-day leave to participate (including traveling time).

2.2.1. Attitudes towards risk and ambiguity

The core of our experiment is the market entry game. It is designed in a way that participants must make a decision in a situation implying risk and uncertainty. Thus, the potentially different behaviour of juniors and seniors in the market entry game could be theoretically explained by the intergenerational differences in risk or ambiguity aversion.

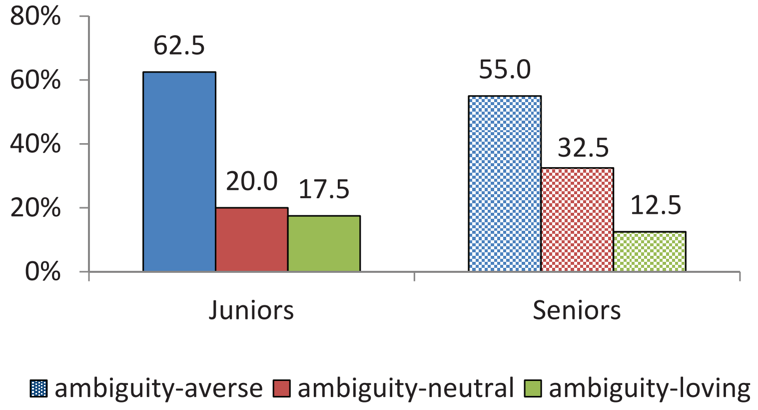
The results of a test of attitudes towards risk and ambiguity show that, in contrast to the stereotype that older persons tend to be more risk-averse than the young, the senior participants of our experiment are even slightly more risk-loving than juniors. On average, they switch from the lottery to the certain payoff for certain payoff higher than 300 ECU, whereas juniors switch at the lower amount of 275 ECU. Interestingly, most of participants in both generations, i.e. 70 % of juniors and 75 % of seniors, can be qualified as risk-loving. The risk-averse persons are much less numerous, they constitute respectively 15 % of juniors and 20 % of seniors. We suppose that this high share of risk-lovers is due to the common job specifics of our participants as bank employees, more exactly as client advisors. Actually, in this domain, workers are often confronted with risk evaluation.

Figure 11: Risk attitudes by generation



At the same time, both generations are ambiguity averse as they both switch from the ambiguous lottery to the certain payoff at 250 ECU which is a lower switching point than in the risky lottery. 62.5 % of juniors and 55 % of seniors are definitely ambiguity-averse, and only 17.5 % of juniors and 12.5 % of seniors can be called ambiguity-loving.

Figure 12: Ambiguity attitudes by generation



The Kolmogorov-Smirnov tests for the equality of distributions across the two generations do not identify any significant differences between juniors and seniors in their attitudes towards risk and ambiguity[21]. Consequently, different level of risk-aversion or ambiguity-aversion between generations cannot be used as an argument explaining different behaviour of juniors and seniors in the following market entry game implying high degree of uncertainty.

The market entry game

2.2.2. Propensity to enter the competition

The decision to enter a market is taken individually by each participant. It is based on information provided at the beginning of each period and on player's expectations. Participants are informed about the number of entrants who can make profits on the market (respectively 2, 4 or 6) and about age composition of their group[22]. In order to make an optimal decision and given the limited market capacity, players need to anticipate the number of other entrants on the market. Furthermore, facing competition from other players, they must judge their own chance to be among those entrants who will make profits. We remind that the rank of the participant among the entrants is assigned a) randomly by the computer program (Random treatment) or b) according to the participant's performance in a quiz in general economic knowledge that is administered later on in the session (Performance treatment). Thus, in the

[21]Similarly, contrary to stereotypes, we find no differences in attitudes towards risk and ambiguity between men and women within both generations. This result is consistent with e.g. Schubert et al. (1999).

[22]Each group is composed of 10 players. The five possible group compositions are the following: 10 juniors, 7 juniors and 3 seniors, 5 juniors and 5 seniors, 3 juniors and 7 seniors, 10 seniors.

latter case, the participants are required to anticipate their relative ability compared to those of other players.

Table 23 lists the proportion of players within each generation who decided to enter the market given its capacity and the age composition of potential entrants.

Table 23: Volume of entrants (in %) by market capacity, group composition and type of treatment (Random / Performance)

Seniors

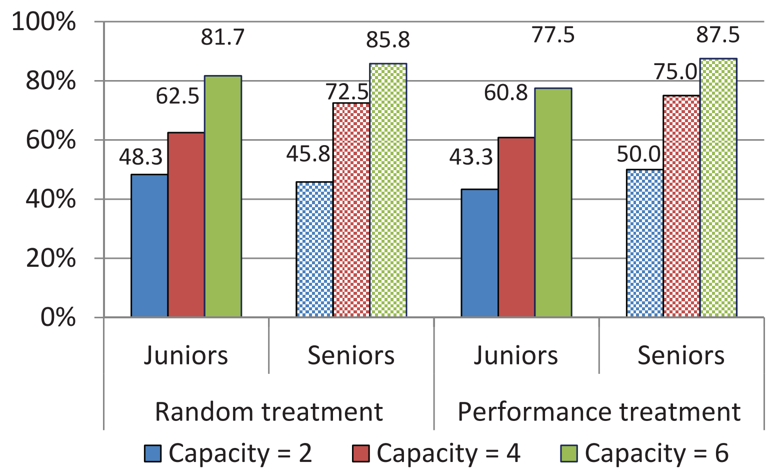
	Random					Performance				
	obs	**total**	C=2	C=4	C=6	obs	**total**	C=2	C=4	C=6
10 seniors	120	**64.0**	45.0	62.5	85.0	120	**68.3**	45.0	70.0	90.0
3 jun 7 sen	84	**67.8**	57.1	67.8	78.6	84	**72.6**	64.3	64.3	89.3
5 jun 5 sen	120	**69.2**	37.5	82.5	87.5	120	**70.0**	45.0	82.5	82.5
7 jun 3 sen	36	**77.7**	50.0	83.3	100.0	36	**77.7**	50.0	91.6	91.6
average	360	**68.0**	45.8	72.5	85.8	360	**71.0**	50.0	75.0	87.0

Juniors

	Random					Performance				
	obs	total	C=2	C=4	C=6	obs	total	C=2	C=4	C=6
3 jun 7 sen	36	**69.4**	66.6	50.0	91.6	36	**61.1**	50.0	58.3	75.0
5 jun 5 sen	120	**65.0**	45.0	70.0	80.0	120	**58.3**	40.0	62.5	72.5
7 jun 3 sen	84	**59.5**	39.3	57.1	82.1	84	**60.7**	42.8	60.7	78.6
10 juniors	120	**65.0**	52.5	62.5	80.0	120	**62.5**	45.0	60.0	82.5
average	360	**64.0**	48.3	62.5	81.7	360	**61.0**	43.3	60.8	77.5

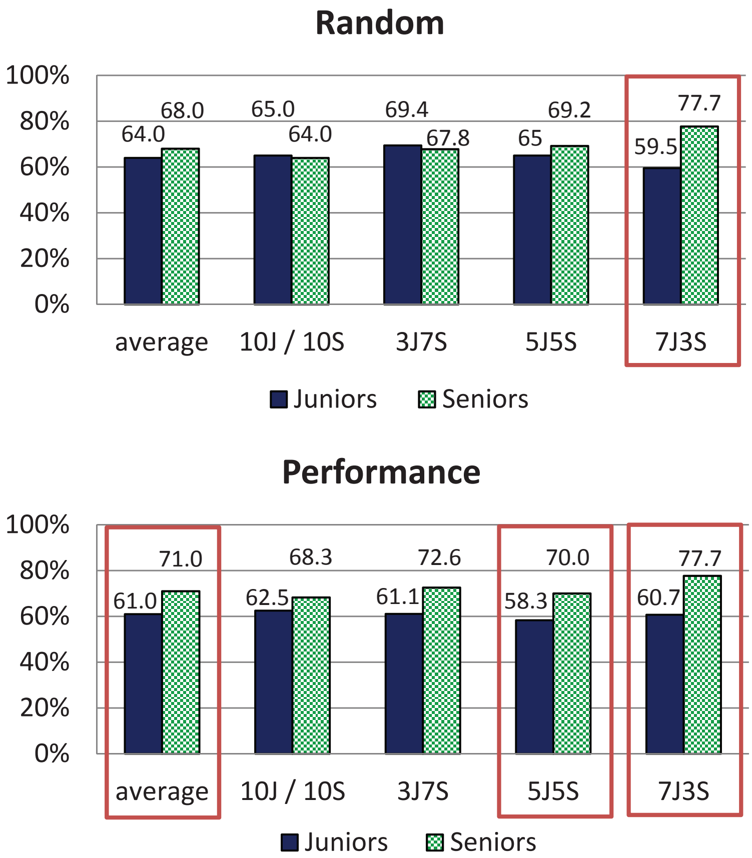
The first impression is that both generations enter excessively in competition. As could be expected, the number of entrants increases with market capacity. However, in all three cases (C = 2, 4 or 6) there are too many entries compared to profits that could be realised on the market (see Figure 13).

Figure 13: Entrants by market capacity (in %)



In the Random treatment, when a chance determines distribution of profits among the entrants, we find no evident difference in the entry rate between juniors (64 % on average) and seniors (68 % on average). However, in the sequence Performance, seniors enter the market significantly more (71 %) than juniors (61 %). The non-parametric Wilcoxon rank-sum test demonstrates that this difference is particularly strong when seniors are in competition with many juniors (see Figure 14).

Figure 14: Entrants by group age composition (in %)



In the equilibrium composition, where each generation accounts for a half of the players, 70 % of seniors enter the market compared to 58.3 % of juniors. When seniors reach the majority, 77.7 % of them decide to compete against 60.7 % of young players. Not significant variations in the entry rate of juniors between different group compositions shows that they are less sensible to the group age-composition effect.

This analysis and descriptive statistics provide our first finding which is the following:

Result 1: When profit depends on the relative performance, seniors enter the market significantly more often than juniors; in particular, when they are in competition against many juniors.

This result suggests that information about generation of other group members might play an important role in decision making. Seniors clearly choose to compete more, especially when they are matched with many juniors. One explanation could be that seniors are more risk-loving. Though, we remember that the tests of attitudes towards risk and ambiguity have not revealed any significant differences between both generations. Moreover, engaging or not in competition is not the same as being more or less risk averse. Many additional factors might have an influence on the decision to compete.

We consider a number of possible explanations for this phenomenon. First, seniors could underestimate the spirit of competition of young people. Consequently, seniors might think that juniors, intimidated by the presence of older and life-experienced adversaries, will not enter the market in mass. Second, seniors could be simply overconfident about their performance and ranking in a quiz. While predicting competition accurately, they might have higher expectations about their relative ability compared to the young. Finally, a purely psychological explanation is possible as well. Facing juniors, seniors might feel obliged to fight against the stereotype and prove that they are not more risk-averse or less prone to engage in competitive tasks than younger generation. Discussing this image concern we will refer to the phenomenon of “social signalling” by Burks et al. (2011).

2.2.3. Beliefs about willingness of others to enter the competition

Seniors could underestimate the willingness of young generation to enter the competition, especially against more experienced colleagues. An excessive entry due to underforecasting the number of other competitors is referred to in the literature as “the blind spots hypothesis” (Camerer and Lovallo, 1999). In order to test this hypothesis, also called “the reference group neglect”, we analyse the prediction of number of entrants and the profit expectations of all the participants. It turns out that 84 % of juniors and 69 % of seniors anticipate correctly that the number of entrants will be higher than market capacity. Nevertheless, an excessive market entry itself is not an obstacle for most of the players to enter the market. 70 % of seniors and 62 % of juniors decide to enter anyway. Moreover, a closer look at the data reveals that predicting the number of entrants is, in fact, not very accurate. Even if players expect excessive entry, 50 % of seniors compared to 39 % of juniors still tend to underestimate the actual number of market entrants. It is particularly striking in Performance part for the group composition of 3 seniors and 7 juniors. In this case 58 % of seniors compared to 36 % of juniors expect the smaller number of entrants than actually observed. Hence, seniors seem to neglect the level of competition of other participants, in particular of junior players.

The predicted number of entrants has a direct influence on the expected average profit. It is a function of forecasted number of entrants and given market capacity. Thus, the fewer entrants one expects, the higher average profit one assumes. Since the maximal total profit on the market amounts to 3000 ECU (for detailed payoff matrix please refer to Table 22), the expected profit per entrant can be expressed as:

$$E\left(\Pi\right) = \frac{3000 - 500\left(predicted\, nb\, of\ entrants - market\ capacity\right)}{predicted\, nb\, of\ entrants} \tag{43}$$

If one forecasts fewer entrants than market capacity, then the expected average profit is simply a sum of positive profits of all potential entrants divided by predicted number of entrants.

The analysis of expected profit per entrant shows that, in the Random treatment, seniors always await significantly higher gains than juniors, regardless of the group composition. In the heterogeneous groups, in the sequence Performance, we observe that as number of juniors increases, the higher profit seniors expect. The discrepancy in anticipated gain between representatives of both generations reaches its maximum for the team of 3 seniors and 7 juniors. Then, the average profit expected by junior entrants is only 244 ECU compared to 468 ECU foreseen by senior entrants. Thus, we can formulate our second result:

Result 2: Seniors expect significantly higher average profit than juniors, especially in Performance treatment, when they must compete against many juniors. It is mainly due to 1) neglecting actual juniors' competitiveness and 2) underestimating the number of entrants. It explains why seniors enter more the market.

2.2.4. Overconfidence hypothesis

The results obtained so far seem to confirm the blind spots hypothesis. However, the overconfidence of players could also have an impact on the decision making. Observed intergenerational differences in the market entry are significant uniquely in the sequence Performance, when profit depends on the relative performance in a quiz in general economic knowledge. Moreover, since the quiz took place once the market entry game had been terminated, all the decisions to enter the market in this sequence had to be based on anticipations of future results and a personal ranking. We remember that seniors tend to enter more in competition in particular when they are matched with many juniors. Is it then possible that seniors are simply overconfident about their result in a quiz and their ranking vis-à-vis juniors?

In order to answer this question, we compare the achieved result with the expected one. First, we measure the average difference between the correct answers and the answers provided by the players. We call this measure a "distance index". The analysis of the quiz results shows that performance of both generations in a quiz was equally good. The average "distance index" was 16.2 for juniors and 15.7 for seniors. Consequently, we observe also no significant differences in the ranking of participants' performance.

Once the quiz completed, all the participants have been asked to predict their results. We observe that both generations are convinced that seniors performed better. Juniors predict larger "distance index", i.e. higher inaccuracy for their own generation. Using another indicator, a rank category in the group of 20 (mix of juniors and seniors) compared to a rank in the group of 10 (age homogenous), reveals that seniors believe to be better ranked than juniors. In this way, juniors and seniors expect that older players are relatively more able. This conviction seems to justify why in the Performance part seniors enter the market significantly more than juniors. Thus, our next result is as follows:

Result 3: Both generations are convinced that seniors performed better in a quiz. Seniors might assume that juniors will recognize this superiority and will not be willing to compete against them in the game.

2.2.5. Image concern

Curiously, in our experiment, both generations tend to underestimate their individual abilities. When reporting their post-quiz beliefs about the obtained results, 80 % of seniors and 57 % of juniors declared their "distance index" larger than the actual one. Prediction of the rank in their own generation reveals that only 32 % of seniors and 45 % of juniors consider themselves as better than average. Thus, apparently, seniors have lower self-perception. Compared to juniors, they are also more pessimist in the judgment of abilities of both generations (predictions of juniors' and seniors' average distance index). As suggested by Burks et al. (2010), seniors could behave as overconfident in order to send a positive signal on their value to others. Therefore, we formulate the following result:

Result 4: Seniors have lower self-perception. By entering the competition, they might want to improve their image and fight the stereotype as risk-averse and less likely to get involved in competitive tasks. The important presence of juniors in the group might create additional pressure on seniors to prove their competences.

2.2.6. Probit model

Finally, in Table 24, we analyse the determinants of players' decision to enter the market using a Probit model with clustering of subjects and robust standard errors. Since each of 80 participants takes a decision through 18 periods, we dispose of the panel database of 1440 observations in total. We estimate the model on pooled data from all the sessions. We run separate regressions for Random and Performance treatments to see if different factors play a role in these two cases. Similarly, for each treatment, we run the same regressions on the sub-samples of juniors and seniors. The dependent variable is the decision to enter or not to enter the market. The explanatory variables include individual characteristics i.e. participant's age and gender, whether one is a manager, risk-loving or ambiguity averse and whether one expects too many other entrants. Moreover, we suppose that if players possess strong beliefs about lower competitiveness or lower confidence of the opposite generation, it may have a positive impact on their own decision to enter the market. Therefore, we include dummy variables corresponding to different group compositions joining together juniors and seniors (3 juniors + 7 seniors, 5 juniors + 5 seniors, 7 juniors + 3 seniors) or including only juniors (10J) or only seniors (10S). We control also for the market capacity, period and the order of the sessions (whether Random or Performance treatment has been run first). In the regression concerning only Performance treatment, we include in addition indices for over- or underestimation of one's own performance as explicatory variables.

Table 24: Probit model: the average marginal effects

Random

	All		Juniors		Seniors	
Male	0.016	(0.062)	0.020	(0.071)	-0.022	(0.091)
Seniors	0.166***	(0.056)				
Risk-loving	0.014*	(0.008)	0.052***	(0.012)	-0.004	(0.007)
Ambiguity aversion	-0.016***	(0.006)	-0.010	(0.009)	-0.014**	(0.007)
Market capacity	0.095***	(0.011)	0.081***	(0.016)	0.106***	(0.015)
Excessive entry (prediction)	0.027**	(0.012)	0.006	(0.022)	0.031**	(0.012)
Managers	-0.167***	(0.061)	-0.202***	(0.060)	-0.208**	(0.095)
Homog (5J5S, 10J or 10S)	-0.007	(0.039)	0.004	(0.052)	-0.013	(0.058)
Group3S7J	-0.009	(0.048)	-0.043	(0.057)	0.076	(0.075)
Group3J7S	0.016	(0.042)	0.039	(0.082)	0.009	(0.049)
Order	0.058	(0.072)	-0.121	(0.094)	0.191*	(0.101)
Period	-0.012**	(0.006)	-0.005	(0.006)	-0.017*	(0.009)

Performance

	All		Juniors		Seniors	
Male	0.005	(0.065)	0.061	(0.093)	-0.059	(0.063)
Seniors	0.235***	(0.118)				
Risk-loving	0.006	(0.007)	0.027**	(0.012)	-0.006	(0.008)
Ambiguity aversion	-0.015**	(0.007)	-0.002	(0.011)	-0.020***	(0.004)
Market capacity	0.090***	(0.012)	0.082***	(0.019)	0.096***	(0.015)
Excessive entry (prediction)	0.028**	(0.012)	0.002	(0.020)	0.033***	(0.011)
Managers	-0.101	(0.091)	-0.067	(0.089)	-0.354***	(0.115)
Homog (5J5S, 10J or 10S)	0.021	(0.041)	0.054	(0.054)	0.008	(0.060)
Group3S7J	0.067	(0.037)	0.059	(0.047)	0.103*	(0.062)
Group3J7S	0.007	(0.046)	-0.034	(0.070)	0.048	(0.047)
Order	-0.070	(0.073)	-0.098	(0.110)	-0.040	(0.095)
Period	-0.009*	(0.005)	-0.007	(0.006)	-0.010	(0.009)
Self-ranking within one's own generation (prediction)	-0.113***	(0.025)	-0.139***	(0.052)	-0.078***	(0.030)

Our first fundamental finding is that being a junior or being a senior has indeed a crucial influence on the decision to enter the market. The regressions results show that the age of participant, all other things being equal, is significant and has a strong effect: 16.6 % in the sequence Random and 23.5 % in the sequence Performance. Consequently, seniors are much more likely to enter the market than juniors. Interestingly, we observe that while risk aversion discourages market entry among the juniors, it is rather ambiguity aversion that plays a role for the seniors. Thus, while young players base their decision on the individual perception of risk, seniors seem to take into account rather environmental uncertainty. In fact, factors such as behaviour of other players decide in large extent about the ambiguity of the situation. On the other hand, we find no evidence of the gender effect. It is rather the position in a company's hierarchy that reveals differences in decision making. Managers in both generations turn out to be more prudent and enter more seldom in competition. Consequently, as data analysis has proved, they obtain higher profits.

In Performance treatment, the fact of being a manager plays an important role only among the seniors.

An interesting result is that prediction of excessive entry appears positively correlated with the entry decision of senior players. It seems to confirm our hypothesis of image concern according to which seniors, expecting many other players to enter the competition, enter as well in order to signal that they are equally ready to compete.

Moreover, in the regression concerning Performance treatment, we include additional variable – an expected ranking within one's generation in a quiz in general economic knowledge. Placing oneself as less good in one's own generation is evidently negatively correlated with market entry. However, controlling for other variables that could indicate players' overconfidence about one's absolute or relative performance turned out not to be significant. Actually, since participants were asked to estimate their performance after that the game and the quiz have been finished, this ex-post evaluation could not have any impact on their market entry decision. While entering the market, people based their decision rather on their expected future performance in a quiz. It is possible that the expected performance would be higher than the post-quiz evaluation. Unfortunately, we do not have the information about one's performance expectations at the beginning of the game. There was a risk that it would influence players' decisions about market entry.

Finally, we observe that both generations behave as rational agents by entering more eagerly when the market capacity is higher. It is not surprising as then there is statistically more chance to make positive profits. At the same time, we notice a slight "learning effect". As the game progresses, participants correct their behaviour and enter the market less and less.

In general, we do not observe much difference between both treatments concerning the list of factors influencing market entry decision. The interesting exception is the variable indicating group composition of 3 seniors and 7 juniors which becomes significant for senior participants in the sequence Performance. It means that when the ranking of participants depends on relative ability rather than on pure chance, players pay attention to the age composition of their competitors in the market entry. Consequently, seniors enter the market more when they are grouped with many young people.

2.2.7. Decisions efficiency and group composition

This assertive comportment of seniors is associated to higher profit expectations. The simple comparison of expected and realised profit per entrant shows that 26 % of juniors and only 17 % of seniors made correct predictions. One third of juniors (34

%) and almost half of seniors (47 %) anticipated excessive profits. 40 % of juniors and 36 % of seniors thought than profit would be lower.

In order to compare players' behaviour and game strategy in terms of efficiency, we compare the individual gains obtained by juniors and seniors as a result of the market entry decisions. In general, we find no significant difference in individual profits, neither in Random, nor in Performance treatment.

However, when we analyse the profits obtained by each generation in different group compositions, we notice that the age mix of other competitors influences the players' game strategy and thus their profits. Tables 25 and 26 show, respectively, the average profit per participant and the average profit per entrant for different match of juniors and seniors. The Wilcoxon rank-sum test reveals the significant gain differences between generations only for the sequence Performance. When seniors are in majority, they obtain much higher profits than juniors who make losses on average. However, it turns out that when seniors are matched with many juniors, their common strategy to enter the market does not bring the expected result. In this group composition, seniors do not make higher profits than juniors. On the other hand, the heterogeneous group composition that maximises individual gains of juniors and seniors is the one with juniors and seniors in equal proportions. In this case, on average, junior participant (entrant) obtains 132 ECU (226 ECU) and senior participant (entrant) gains 227 ECU (324 ECU). This leads to the next important result:

Result 5: The situation of competition between juniors and seniors is efficiency-enhancing, i.e. the profits of both generations are maximised, when a pool of competitors is balanced in terms of generation.

Table 25: Average realised profit per participant

	Random				Performance			
	obs	total	Juniors	Seniors	obs	total	Juniors	Seniors
10 seniors	120	179	-	**179**	120	158	-	**158**
3 jun 7 sen	120	158	**161**	**157**	120	154	**-67**	**249**
5 jun 5 sen	240	165	**207**	**122**	240	**179**	**132**	**227**
7 jun 3 sen	120	175	**200**	**117**	120	171	**220**	**55**
10 juniors	120	175	**175**	**-**	120	187	**187**	**-**
average	720	169	190	149	720	171	151	192

Table 26: Average realised profit per entrant

	Random				Performance			
	obs	total	Juniors	Seniors	obs	total	Juniors	Seniors
10 seniors	77	279	-	**279**	82	232	-	**232**
3 jun 7 sen	82	232	**232**	**232**	83	223	**-109**	**343**
5 jun 5 sen	161	245	**318**	**177**	154	**279**	**226**	**324**
7 jun 3 sen	78	269	**336**	**150**	79	259	**363**	**71**
10 juniors	78	269	**269**	**-**	75	300	**300**	**-**
average	476	256	296	219	473	261	249	271

2.3. Conclusions

In the perspective of ageing, the cooperation and competition between different generations of workers is a major challenge for the enterprises. In this context, the issue of managing the intergenerational teams is particularly important (Hamilton, Nickerson and Owan, 2001; 2004). In this section we have studied risk attitudes, self-confidence and propensity to enter the competition within the age-heterogeneous workforce. In particular, we looked at how group age composition has an impact on the individual decision to enter the competition. As far as we know, these questions have not yet been studied in the literature. In this purpose we used a market entry game that is largely inspired by Camerer and Lovallo (1999) and which we adjusted to study the differences between generations.

Although no significant differences in attitudes towards risk and ambiguity have been found between both generations, the market entry game reveals interesting discrepancies between juniors and seniors with regard to their expectations and strategic behaviour. We find that information on age of others players has an important impact on decision to enter the competition. Although both generations predict excessive entry, seniors enter the market significantly more often. Moreover, they are more willing to enter the competition when they are matched with many juniors.

We propose several explanations for this phenomenon. First of all, seniors tend to underestimate actual juniors' willingness to compete by strongly underestimating the number of entrants when matched with many juniors. Older players seem also very confident about their relative performance in a quiz on general economic knowledge. Indeed, both generations are convinced that seniors got better results in the quiz than juniors. Consequently, seniors might enter more the market, hoping that juniors will recognize this superiority and will not be willing to compete against them in the game. Finally, the high propensity to enter the competition by seniors could be motivated by the willingness to fight against the stereotype of their generation as shy and less productive workers. Due to this negative image, seniors were largely discriminated on the labour market over last thirty years. In our experiment, seniors enter the competition in excess as if they wanted to prove that they are not more risk-averse or less prone to engage in competitive tasks than younger generation. However, the excessive entry of seniors turns out to be inefficient i.e. it brings them lower profits than they expected. We find that both generations maximise their individual profits when the group composition is balanced in terms of age. Hence, we can conclude that in the situation of competition, equilibrium between both generations helps in better calibration.

2.4. Appendix 1: Instructions

We thank you for participating in this experiment on decision-making. Throughout the session, your earnings are expressed in ECU (Experimental Currency Units) with the following conversion rate:

100 ECU = 2 CHF

This session consists of several parts. We have distributed the instructions for the first part; you will receive the instructions for the next parts once the first part will be completed. Please read these instructions carefully.

At the end of the session, your payoffs in ECU from the different parts will be added up and converted into Swiss Francs. You will also receive a show-up fee of 15 CHF. You will be paid individually and in private.

Throughout the session, it is strictly forbidden to communicate with the other participants.

Part 1

Part 1 consists in two sub-parts.

- **Description of the 1st sub-part**

Imagine an urn that contains 10 balls, **5 yellow balls and 5 blue balls**.

You must make 20 successive choices between extracting a ball from this urn with replacement (for each decision, there are always the same 10 balls in the urn) or earning a certain amount of money.

If you extract a yellow ball from the urn, you earn 500 ECU; if you extract a blue ball from the urn, your earn 0 ECU.

We propose you **20 certain amounts possible, from 25 ECU to 500 ECU**; the certain amount increases by 25 ECU at each new decision.

You must indicate on your computer screen for each decision if you prefer receiving the certain amount or extracting a ball from the urn.

The following Table will appear on your screen:

1	O I choose the certain amount of 25 ECU	O I choose to extract a ball
2	O I choose the certain amount of 50 ECU	O I choose to extract a ball
3	O I choose the certain amount of 75 ECU	O I choose to extract a ball
4	O I choose the certain amount of 100 ECU	O I choose to extract a ball
5	O I choose the certain amount of 125 ECU	O I choose to extract a ball
6	O I choose the certain amount of 150 ECU	O I choose to extract a ball
7	O I choose the certain amount of 175 ECU	O I choose to extract a ball
8	O I choose the certain amount of 200 ECU	O I choose to extract a ball
9	O I choose the certain amount of 225 ECU	O I choose to extract a ball
10	O I choose the certain amount of 250 ECU	O I choose to extract a ball
11	O I choose the certain amount of 275 ECU	O I choose to extract a ball
12	O I choose the certain amount of 300 ECU	O I choose to extract a ball
13	O I choose the certain amount of 325 ECU	O I choose to extract a ball
14	O I choose the certain amount of 350 ECU	O I choose to extract a ball
15	O I choose the certain amount of 375 ECU	O I choose to extract a ball
16	O I choose the certain amount of 400 ECU	O I choose to extract a ball
17	O I choose the certain amount of 425 ECU	O I choose to extract a ball
18	O I choose the certain amount of 450 ECU	O I choose to extract a ball
19	O I choose the certain amount of 475 ECU	O I choose to extract a ball
20	O I choose the certain amount of 500 ECU	O I choose to extract a ball

- **Description of the 2nd sub-part**

This sub-part is similar to the previous one, except that we use a new urn and you do not know its composition.

You must again make 20 decisions between receiving a certain amount or extracting a ball from the new urn. The certain amounts are the same as in the previous sub-part. The new urn also contains 10 balls, yellow balls and blue balls.

However in contrast with the previous sub-part, you do not know the number of yellow balls and blue balls in the urn.

How are payoffs determined in this part?

At the end of the session, the computer program will randomly draw one of your 20 decisions in the first sub-part and one of your 20 decisions in the second sub-part. Each decision has the same chance to be selected. You should therefore give the same attention to each decision.

For each randomly selected decision:

- If you have chosen the certain amount, we will add this amount to your other earnings in the experiment;
- If you have chosen the random draw, the computer program will extract one ball. If it is yellow, 500 ECU will be added to your other payoffs; if it is blue, you will earn 0 ECU.

If you have any question regarding these instructions, please raise your hand and do not speak aloud. We will answer your questions in private.

Part 2 *(distributed after Part 1 was completed)*

You receive an initial endowment of 500 ECU in this part.

This part consists of 18 periods during which you must decide to enter or not a market.

These 18 periods are grouped in two sequences of 9 periods each.

- The "random draw" sequence,
- The "performance" sequence.

Your computer screen will indicate if you start with the Random sequence or the Performance sequence. The two sequences will succeed automatically. You are informed on your screen of the current sequence.

1. Description of the Random sequence

- **Description of each period**

1. At the beginning of each of the 9 periods of this sequence, you are grouped with 9 other participants. You do not receive any information about these participants except for their generation (« junior » ou « senior »).

2. Then, each group member is informed on the value of a number "C". Imagine that C is the market capacity, i.e. the number of participants who can make profits on this market. C can take values 2, 4 or 6. For example, if C = 4, then 4 participants who decided to enter the market will be able to make benefits. The other participants who decided to enter will lose 500 ECU.

3. Next, we will ask you to estimate the number of the other group members who will enter the market (between 0 and 9, you excluded).

4. Then, you have to decide if you enter or not the market.

* If you decide not to enter, you do not earn anything and you do not lose anything either.

* If you enter, your payoff depends on the market capacity and your rank among the participants from your group who have decided to enter (the "entrants"). We explain below how your rank is assigned to you.

The Table that has been distributed indicates for each market capacity the payoffs of the entrants (in ECU) according to their rank. Please look at this Table.

For example, suppose the market capacity is 2 (C=2) and you have decided to enter. If you have the first rank among the entrants, you earn 1900 ECU. If you have the second rank among the entrants, you earn 1100 ECU. If you have the third rank and beyond, you lose 500 ECU.

5. At the end of each period, you are informed on the number of other members of your group who have decided to enter the market during this period (between 0 and 9).

- **Determination of ranks**

In the Random sequence, the ranks of the entrants are randomly determined by the computer program. For example, if there are 5 individuals who decide to enter the market in a period, the program will assign randomly a rank between 1 and 5 to these entrants. If the market capacity is 4 (C=4) and your randomly determined rank is 5, then you make a loss.

You do not know your rank when making your entry decision.

- **What does change from one period to the other in this sequence?**

- the composition of your group of 10 participants,
- the market capacity, C (i.e. the number of entrants who can make on the market),
- the payoffs associated with each rank as indicated in the Table we have distributed. We invite you to consult this Table throughout the game,
- your rank if you decide to enter the market.

2. Description of the « performance » sequence

This sequence consists also of nine periods. Each period is similar to the Random sequence except for one thing: **the ranks of the entrants do not depend of a random draw any more**.

The ranks of the entrants depend on their relative performance in a quiz of general economic knowledge that will be presented to you in Part 3.

For a given period, the computer program will compare at the end of the session the performance in the quiz of each entrant on the market. The entrant who will have given on average the answers the closest to the correct answers will get the first rank. The entrant who will have given on average the worst answers to the quiz will get the last rank among the entrants. In case of ties, ranks are assigned randomly among the ex-aequo entrants.

In the quiz, the questions are similar to the following ones:

* What is the current rank of Switzerland in the world in terms of Gross Domestic Product?

* which percentage of its GDP does the deficit of Greece represent in 2009?

Since the quiz is administered in the next part, you do not know your rank when you decide to enter the market or not. You can just have a belief on your rank.

3. Determination of payoffs in this part

At the end of the session, the computer program will select randomly one period out of 18. Each period has the same chance to be selected for payment. It is therefore important to give the same attention to each of your 18 decisions.

- For this period, the program calculates the number of participants who decided to enter the market in your group of 10 participants. If your prediction of the number of entrants in this period is exact, you earn 100 ECU.
- If you decided to enter, the program assigns you a rank and compares your rank to the rank of the other entrants in your group. If your rank is lower or equal to the capacity of the market, C, you make a benefit and you earn the amount corresponding to your rank for this capacity. If your rank is higher than the market capacity you lose 500 ECU.
- If you decided not to enter, you do not earn and you do not lose anything.
- Your total payoff in this part is therefore equal to:

500 ECU (your initial endowment)

+ 100 ECU if your prediction of the number of entrants in the selected period is exact

+ the ECU earned /or/ the ECU lost due your decision to enter the market in the selected period.

At the end of the session, you are informed on your payoffs. If you entered the market, we also inform you about your rank among the entrants.

You are not informed on whether, in this period, your rank depended on a random draw or on your relative performance in the quiz.

We invite you to read again these instructions and to answer the comprehension questionnaire that has been distributed. If you have any question, please raise your hand and we will answer your questions privately.

Table for the determination of payoffs in Part 2 (in ECU)

Rank among the entrants	Market capacity, C		
	C = 2	C = 4	C = 6
1	1,900	1,400	900
2	1,100	900	700
3	- 500	500	500
4	- 500	200	400
5	- 500	- 500	300
6	- 500	- 500	200
7	- 500	- 500	- 500
8	- 500	- 500	- 500
9	- 500	- 500	- 500
10	- 500	- 500	- 500

Note: The market capacity indicates the number of participants in the group of 10 who can make profits if entering the market. C = 2 indicates that 2 entrants can make profits; C = 4 indicates that 4 entrants can make profits; C = 6 indicates that 6 entrants can make profits.

Please refer to this Table during the 18 periods of this part.

Part 3 *(distributed after Part 2 was completed)*

This part consists of 4 questions on general economic knowledge.
Your performance in this quiz allows you to make additional earnings. It also serves to the determination of your performance rank in the previous part.

- **The task**

- For each question, you must provide an answer that is comprised in between 0 and 100 (included) by moving a scrollbar on your screen.
- You must also define a confidence interval for your answer. Please indicate a minimum value such that you think that the correct answer cannot be lower than this value. Please also indicate a maximum value such that the correct answer cannot be higher than this value. Your answer must be included in this interval, otherwise it will be rejected by the program.

Here is an example of the scrollbar that will be displayed on your screen below each question:

- **Determination of payoffs in this Part**

For **each** question, you receive an initial endowment of 100 ECU.

Your payoff for each question is determined by the size of the interval that you have defined and the inclusion of the correct answer in this interval.

Thus,

- If the interval that you have defined does not include the correct answer that has been registered in the computer program, you lose your 100 ECU for this question.
- If the interval includes the correct answer, your payoff for this question is equal to: 100 ECU – the width of the chosen interval.

For example, suppose the correct answer to a question is 19.

a) If your answer is 12 and your interval is defined between 10 and 20 (its width is 10), your payoff is: 100 – 10 = 90 ECU.
b) If your answer is 12 and your interval is defined between 5 and 50, your payoff is: 100 – 45 = 55 ECU.
c) If your answer is 12 and your interval is defined between 10 and 15, you lose your 100 ECU.

Therefore, the more precise your answers, the higher your payoffs.

Your total payoff in this part is given by the sum of your payoffs for the four questions.

How are calculated the ranks of the entrants in the Performance sequence of the precious part?

We calculate your **« distance index».**

This distance index is equal to the mean difference in absolute value between the correct answers and the answers you have given to the four questions in this part. The intervals you have indicated are not taken into account in the calculation of your distance index.

The better your responses, the lower (thus, the better) your distance index. An index of 0 means that all your answers are exact.

To determine the entrants' ranks in their group in each period of the Performance sequence of the previous part:

- The computer program compares and ranks the entrants' distance indices in each group;
- It assigns ranks to entrants as a result of this comparison, from the best rank (the 1st) assigned to the entrant with the lowest distance index in his group to the last rank assigned to the entrant with the highest index.

Let's take the previous example where the correct answer is 19.

a) If your answer is 12, then the difference in absolute value between the correct answer and your answer is equal to: |19-12| = 7.

b) If your answer is 30, then the difference is: |19-30| = 11.

The distance index is the mean value of these differences in the four questions.

Information

At the end of the session,

- You are informed on your total payoff in this part;
- You are informed of your distance index only if you ask to know it in a further part.

If you have any question, please raise your hands and we will answer your questions in private.

Part 4

Please indicate, among the proposed categories, your expectations about:

- your distance index (i.e. the mean difference in absolute value between the correct answers and your answers to the four questions in the previous part)
- the average distance index of the 10 juniors in the session
- the average distance index of the 10 seniors in the session
- your performance rank in the quiz among the 10 participants of your generation (i.e. juniors or seniors) given by the comparison between the distance indices
- your performance rank in the quiz among the 20 participants in the session.

Each correct prediction pays you 50 ECU.

At the end of the session, you will be only informed of your total payoff in this part.

Part 5

1) Please indicate on your computer screen if you are willing to know or not to know, at the end of the session, your distance index.

2) Please indicate if you are willing to know or not to know, at the end of the session, your performance rank in the quiz among the 20 participants given by the comparison of the distance indices.

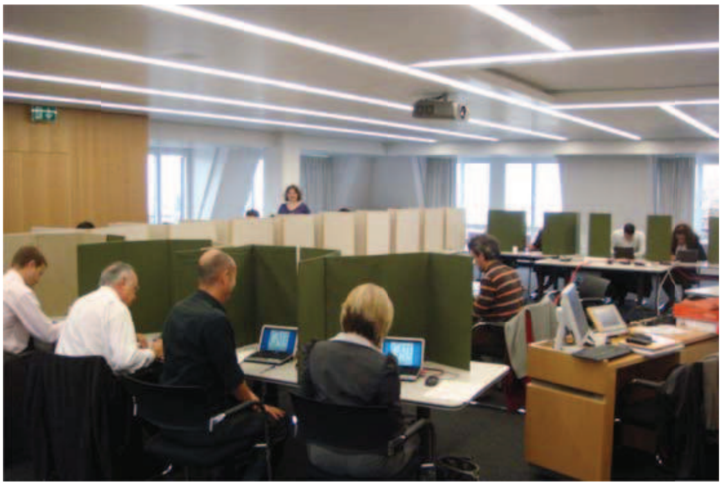
3) Please indicate if you accept or not that we disseminate to the other participants the three following pieces of information:

- the number of times (between 0 and 9) you decided to enter the market in the Performance sequence in Part 2 (when your rank depended on your relative performance)
- your performance rank in the quiz among the 20 participants
- your generation.

A Table will disseminate anonymously these pieces of information relative to those who have accepted this dissemination. In this Table, you will not be able to see any information concerning you personally.

After answering a final questionnaire, you will be informed on your screen of your earnings in each part of this session.
Please remain seated until we invite you to leave your cubicle and do not communicate with the other participants.

2.5. Appendix 2: The experimental laboratory in the company



General conclusions

The process of population ageing will affect the size and the composition of the labour force. While the active population and the share of young workers are shrinking, the average age of the employees is increasing. Due to calling for prolongation of working life, in the near future enterprises are expected to accommodate the increasing share of senior employees. However, although the supply of older workers will increase in the coming years, their employment rates will depend on the actual level of demand. In particular, the situation of older workers on the labour market may be undermined when aging drives a negative wedge between the workers' productivity and earnings. The increasing age-earnings pattern, characterised by lower wages for juniors and higher wages for seniors, is accompanied by serious doubts about the true productivity profiles. Indeed, there is no consensus in theoretical as well as empirical studies on the actual relationship between earnings, productivity and age. In addition, while some theories underline the efficiency of deferred compensations contracts according to which seniors are paid above their productivity levels (Lazear 1979; Carmichael, 1983), many empirical works indicate the negative implications of wage-productivity gap for older workers (Hutchens, 1986; Zwick, 2008; Heywood et al., 2010).

The research work presented in this thesis aims at estimating the actual profile of productivity for different age groups (chapter 2). The originality of this study is twofold. First, the estimated econometric model allows the imperfect substitution between different age and skill categories of workers. Up to now, workers belonging to different age groups were always assumed to be perfect substitutes. In order to evaluate labour productivity, we estimate the production function with a nested constant-elasticity-of-substitution (CES) specification in labour. Second, the labour force has been differentiated not only by age (as it is usually done) but also by skills. It allowed us observing the pattern of productivity for the young, mid-age and older workers separately within the low-skilled and the high-skilled category.

Among the main findings, we found that, in contrast to what is usually assumed, workers of different ages are imperfect substitutes in production. Thus, the aging process will certainly affect relative wages of younger and older workers. It can be expected that when young workers become scarcer, their relative wage will rise. Consequently, since employment decisions hinge on perceptions of workers' productivity and the costs of employing them, the changes in relative wages of juniors and seniors might considerably modify the relative level of attractiveness of different age groups for the employers. However, whether it actually happens, also depends on the labour market institutions.

Furthermore, thanks to the decomposition of workforce in our model into two skill groups, we have found that labour productivity is highly dependent on skill level of workers. In the low-skilled category, the older workers appear the least productive, whereas the high-skilled senior employees tend to be the most productive group. Thus, an important signal for the employers is that if we focus on skill diversity of the workforce, age becomes less of an issue. This result suggests that the development of the "continuing education" from the beginning of the career and especially more encouragement and training offered to senior workers could improve their employment rate.

However, we cannot forget that the ratio of the productivity with relation to earnings remains the most relevant indicator of workers' value for the employers. When this ratio differs across age groups, it means that employment of workers belonging to certain age categories is more profitable than others. In particular, the discrepancy between productivity and earnings is supposed to be a source of employment difficulties for older workers. Our empirical results indicate that the mid-age workers (except in manufacturing sector) are those who tend to have the highest productivity/earnings ratio. This fact is important for employers since when facing negative productivity shocks, firms have no incentives to retain other workers whose productivity exceeds their wages.

Though, the real problem is a bit more complex. When discussing about the optimal earnings and productivity profiles, there exist opinions that ideally wages should correspond to workers' productivity at any age. However, certain theories prove the rationality of a discrepancy between productivity and earnings along the working life of an individual. Let us suppose that a person is pursuing a career in the same enterprise. Then, paying her below the marginal productivity when young and above it when old (keeping neutrality over the life cycle) can be absolutely reasonable for the effort incentive reasons (Lazear, 1979). In reality, due to high labour turnover, at present, many employers are mainly interested in the current productivity of their workforce. Consequently, even if a young workers are expected at one point to produce more that they costs, in case of economic downturn, they might be the first to become redundant as they have not yet seen much investment in firm-specific human capital. Anyway, no one can guarantee how long they will stay in the company before changing job. Thus, nowadays, in the process of employee-employer matching on the labour market, there is a certain discrepancy in goals and time perspectives. The employee cares about the net present value of his wage stream over the lifetime and the employer cares about the current value of worker's marginal productivity over the time he spends in the enterprise.

One of the solutions to improve the employment of older workers could be via changing the managerial attitudes. Paradoxically, as younger workers become relatively scarcer in the next few decades, employers may be forced to turn more often to older workers. It is likely to induce new attitudes and policies (Smeaton and Young, 2007). The practice has shown that imposing certain behaviour on employers by politicians does not always bring the expected results. For example, the anti-discriminatory legislation implemented in order to protect young and older workers suffering from some prejudice, brought about a stigmatisation of these age groups on the labour market (Mercat-Bruns, 2002). Employers started considering these workers as "problematic groups" and it did not stay without an influence on their hiring and employment decisions. The similar effect had a policy to encourage early retirement. As a result, workers who reached retirement age started to be sometimes considered automatically useless. The repercussions of these problems could be observed also in the results of our experimental study (chapter 3). We could observe that senior participants demonstrated excessive propensity to enter the competition. The analysis of the results suggests that this behaviour of seniors could be explained by the envy to signal the image of them contrasting with the stereotype. Seniors have seemed to communicate that they are not more risk-averse or less prone to engage in competitive tasks than younger generation.

When searching for the optimal age mix of workers, employers should not forget that age diversity is a potential source of improved performance. Older workers tend to have an advantage over younger ones in firm-specific human capital and in the general human capital that is best learned on the job. Younger workers are more likely to have the edge in the general human capital that is best acquired through formal schooling. It is some mixture of young and old that is likely to produce the most productive work environment (Lazear, 1998). This point let us think about the possible directions of further research aiming at helping the employers to make the best decisions while managing, hiring and motivating their ageing workforce. The natural extensions include the development of the econometric model estimated in the second chapter which could be further enhanced by exploring the relative efficiency of different age compositions of employees and investigating the process of transfer of knowledge between juniors and seniors using the experimental methods.

Regarding the estimation of productivity and earnings profile by age, the model presented in chapter 2 could be further improved by using longer time periods. It would allow the comparison of productivity patterns between different cohorts. Furthermore, the information on labour turnover, provided that this type of data is available, would help to eliminate the potential auto-selection bias according to which seniors that are still working are those who are more productive. Also, the functional form could be specified differently, taking into account bigger number of "thinner" age groups, or allowing more skills categories.

Two important aspects could be further investigated applying the experimental approach. First, one could address the question of relative efficiency of age-homogenous and age-heterogeneous groups of workers in a real effort task. We could expect that thanks to complementary skills, a mix of juniors and seniors would be more efficient. On the other hand, age-homogenous groups might have an advantage due to stronger group identification and lower communication cost. This could be tested experimentally in the field.

Another issue that merits more examination is the transfer of knowledge and know-how between generations. In a firm, it is important that seniors coach younger workers so that their know-how is not lost when they retire. At the same time, older workers could better keep up with developments by learning new techniques and other skills from younger workers. An experimental study could explore both of these streams of knowledge transfer. It could be tested under which conditions workers are ready to share their know-how with the members of other generations and whether this willingness is age-specific. Moreover, it would be interesting to see whether the decision of knowledge sharing is mainly driven by one's own strategic considerations or, on the opposite, by other-regarding preferences.

References

Abowd, J. M., Kramarz, F., and Margolis, D. N. (1999). High wage workers and high wage firms. *Econometrica*, 67(2):251–334.

Abraham, K. G. and Farber, H. S. (1987). Job duration, seniority, and earnings. *American Economic Review*, 77:278–297.

Ackerberg, D. A., Caves, K., and Frazer, G. (2006). Structural identification of production functions. Working paper.

Agell, J. and Lundborg, P. (1995). Theories of pay and unemployment: Survey evidence from swedish manufacturing firms. *Scandinavian Journal of Economics*, 97(2):295–307.

Akerlof, G. and Katz, L. (1989). Workers' trust funds and the logic of wage profiles. *Quarterly Journal of Economics*, 103:525–36.

Akerlof, G. and Yellen, J. (1990). The fair-wage effort hypothesis and unemployment. *Quarterly Journal of Economics*, 105:255–283.

Akerlof, G. A. and Yellen, J. L. (1986). *Efficiency Wage Models of the Labor Market.* Cambridge University Press, New-York.

Altonji, J. and Shakotko, R. (1987). Do wages rise with job seniority ? *Review of Economic studies*, 54:437–459.

Altonji, J. G. and Spletzer, J. R. (1991). Worker characteristics, job characteristics, and the receipt of on-the-job training. *Industrial and Labor Relations Review*, 45:58–79.

Andersson, B., Holmlund, B., and Lindh, T. (2002). Labor productivity, age and education in swedish mining and manufacturing 1985-96. Working paper, Uppsala, Sweden.

Arellano, M. and Bond, S. (1991). Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. *The Review of Economic Studies*, 58:277–297.

Arellano, M. and Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, 68(1):29–51.

Arrow, K., Chenery, H., Minhas, B., and Solow, R. (1961). Capital-labor substitution and economic efficiency. *The Review of Economics and Statistics*, 43(3):225–250.

Aubert, P. and Crépon, B. (2003). Âge, salaire et productivité. Documents de travail G2003/06, Institut National de la Statistique et des Études Économiques, Paris.

Aubert, P. and Crépon, B. (2004). Âge, salaire et productivité : La productivité des salariés décline-t-elle en fin de carrière? Working paper, Institut National de la Statistique et des Études Économiques, Paris.

Aubert, P. and Crépon, B. (2006). Age, wage and productivity: Firm-level evidence. Working paper.

Aubert, P. and Crépon, B. (2007). Are older workers less productive? firm-level evidence on age-productivity and age-wage profiles. Working paper.

Aubert, P., Crépon, B., and Zamora, P. (2006). Le rendement apparent de la formation continue dans les entreprises: effets sur la productivité et les salaires. Documents de travail G2006/03, Institut National de la Statistique et des Études Économiques.

Auer, P. and Fortuny, M. (2000). Ageing of the labour force in oecd countries: Economic and social consequences. Employment Paper 2000/2.

Australian.Computer.Society.Ageism.Task.Force (2010). Improving age diversity in the ict workforce. Research report.

Baker, G., Gibbs, M., and Holmstrom, B. (1994). The wage policy of a firm. *Quarterly Journal Economics*, 109(4):921–955.

Baltes, P. B. (1987). Theoretical propositions of life-span developmental psychology. on the dynamics between growth and decline. *Developmental Psychology*, 3:611–626.

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

Barber, B. M. and Odean, T. (2001). Boys will be boys. gender, overconfidence and common stock investment. *The Quarterly Journal of Economics*, 1:262–292.

Barrel, A. P. (1995). Training, wage growth, and job performance: Evidence from a company database. *Journal of Labor Economics*, 12:401–425.

Barrington, L. and Troske, K. R. (2001). Workforce diversity and productivity: An analysis of employer-employee match data. The Conference Board Economics Program Working Papers 01-02.

Barron, J. M., Black, D. A., and Loewenstein, M. A. (1989). Job matching and on-the-job training. *Journal of Labor Economics*, 7:1–19.

Barron, J. M., Black, D. A., and Loewenstein, M. A. (1993). Gender differences in training, capital, and wages. *Journal of Human Resources*, 28:343–364.

Bartel, A. P. and Borjas, G. J. (1977). Middle-age job mobility: Its determinants and consequences. Nber working paper 161.

Bartel, A. P. and Borjas, G. J. (1981). *Studies in Labor Market*, chapter Wage growth and job turnover: an empirical analysis. New York: National Bureau of Economic Research.

Bartel, A. P. and Sicherman, N. (1993). Technological-change and retirement decisions of older workers. *Journal of Labor Economics*, 11(1):162–183.

Barth, E. (1997). Firm-specific seniority and wages. *Journal of Labor Economics*, 15(3):495–506.

Becker, G. and Stigler, G. (1974). Law enforcement, malfeasance and the compensation of enforcers. *Journal of Legal Studies*, 3:1–18.

Becker, G. S. (1962). Investment in human capital: A theoretical analysis. *Journal of Political Economy, University of Chicago Press*, 70(5):9–49.

Becker, G. S. (1964). *Human capital.* New York: Columbia University Press.

Becker, G. S. (1975). *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education.* New York: National Bureau of Economic Research.

Beckmann, M. (2007). Age-biased technological and organizational change: Firm-level evidence and management implications. Working papers 2007/05, Faculty of Business and Economics - University of Basel.

Behaghel, L., Caroli, E., and Roger, M. (2011). Age biased technical and organisational change, training and employment prospects of older workers. Iza discussion paper no. 5544.

Ben-Porath, Y. (1967). The production of human capital and the life cycle of earnings. *Journal of Political Economy, University of Chicago Press*, 75:352–365.

Bennington, L. and Tharenou, P. (1998). *Older workers: Myths, evidence and implications for Australian managers*, volume 3. John Wiley & Sons, Brisbane.

Benoît, J.-P. and Dubra, J. (2007). Overconfidence? Mpra paper no. 5505.

Berner, E. S. and Graber, M. L. (2008). Overconfidence as a cause of diagnostic error in medicine. *The American Journal of Medicine (2008) Vol 121 (5A), S2-S23*, 121(5A):S2–S23.

Bewley, T. F. (1999). *Why Wages Don't Fall During a Recession.* Harvard University Press.

Bishop, J. H. (1990). Job performance, turnover, and wage growth. *Journal of Labor Economics*, 8(3):363–386.

Blavatskyy, P. R. (2009). Betting on own knowledge: Experimental test of overconfidence. *Journal Risk Uncertain*, 38:39–49.

Block, R. A. and Harper, D. R. (1991). Overconfidence in estimation: Testing the anchoring and adjustment hypothesis. *Organizational Behavior and Human Decision Processes*, 49:188–207.

Blundell, R. and Bond, S. (1998). Gmm estimation with persistent panel data: an application to production functions. In *Eighth International Conference on Panel Data.*

Blundell, R. and Bond, S. (2000). Gmm estimation with persistent panel data: an application to production functions. *Econometric Reviews*, 19(3):321–340.

Blundell, R., Bond, S., and Windmeijer, F. (2000). Estimation in dynamic panel data models: improving on the performance of the standard gmm estimator. Working Papers W00/12, Institute for Fiscal Studies.

Bond, S. and Söderbom, M. (2005). Adjustment costs and the identification of cobb douglas production functions. Working paper, Institut for Fiscal Studies.

Booth, A. L. and Frank, J. (1999). Earnings, productivity, and performance-related pay. *Journal of Labor Economics*, 17(3):447–463.

Borowczyk-Martins, D. and Vandenberghe, V. (2010). Using firm-level data to assess gender wage discrimination in the belgian labour market. Technical report, Institut de Recherche Economiques et Sociales de l'Université catholique de Louvain, Discussion Paper.

Bosman, E. A. (1993). Age-related differences in the motoric aspects of transcription typing skill. *Psychology and Aging*, 8(1):87–102.

Breton, M., St-Amour, P., and Vencatachellum, D. (2006). Inter- vs intra-generational production teams: A young worker's perspective. CIRANO Working Papers 2002s-57, CIRANO.

Brooke, L. (2003). Human resource costs and benefits of maintaining a mature-age workforce. *International Journal of Manpower*, 24(3):260–283.

Brooke, L. and Taylor, P. (2005). Older workers and employment: managing age relations. *Ageing and Society*, 25:415–429.

Brown, J. N. (1989). Why do wages increase with tenure? on-the-job training and life-cycle wage growth observed within firms. *American Economic Review*, 79:971–991.

Börsch-Supan, A. (2008). *The Impact of Global Aging on Labor, Product, and Capital Markets*. Population Council, New-York, population aging, human capital accumulation, and productivity growth edition.

Börsch-Supan, A. and Weiss, M. (2011). Productivity and age: Evidence from work teams at the assembly line. Working paper, Mannheim Research Institute for the Economics of Aging.

Buck.Consultants (2007). The real talent debate: Will aging boomers deplete the workforce? Report, Buck Consultants.

Bun, M. J. and Windmeijer, F. (2007). The weak instrument problem of the system gmm estimator in dynamic panel data models. Discussion paper no. 07/595, University of Bristol, Department of Economics.

Burks, S. V., Carpenter, J. P., Goette, L., and Rustichini, A. (2010). Overconfidence is a social signaling bias. IZA Discussion Papers 4840, Institute for the Study of Labor (IZA).

Caju, P. D., Fuss, C., and Wintr, L. (2007). Downward wage rigidity for different workers and firms - an evaluation for belgium using the iwfp procedure. Working Paper Series 840, European Central Bank.

Camerer, C. and Lovallo, D. (1999). Overconfidence and excess entry: an experimental approach. *American Economic Review*, 89(1):306–318.

Camerer, C. F. and Hogarth, R. M. (1999). The effects of financial incentives in experiments: A review and capital-labor-production framework. *Journal of Risk and Uncertainty*, 19 (1-3):7–42.

Campbell, Carl M, I. and Kamlani, K. S. (1997). The reasons for wage rigidity: Evidence from a survey of firms. *The Quarterly Journal of Economics*, 112(3):759–89.

Card, D. and Lemieux, T. (2001). Can falling supply explain the rising return to college for younger men? a cohort-based analysis. *The Quarterly Journal of Economics*, 116(2):705–746.

Carmichael, L. (1983). Firm-specific human capital and promotion ladders. *The Bell Journal of Economics*, 14(1):251–258.

Cattell, R. B. (1941). Some theoretical issues in adult intelligence testing. *Psychological Bullentin*, 38:592.

Cesarini, D., Sandewall, O., and Johannesson, M. (2006). Confidence interval estimation tasks and the economics of overconfidence. *Journal of Economic Behavior & Organization*, 61(3):453–470.

Charness, G., Rustichini, A., and van de Ven, J. (2011). Overconfidence, self-esteem, and strategic deterrence. Technical report, paper presented during workshop EMIR (Experiments on Motivation, Incentives, and Rationality) in Lyon.

Charness, G. and Villeval, M. C. (2009). Cooperation and competition in intergenerational experiments in the field and in the laboratory. *The American Economic Review*, 99(3):956–978.

Charness, N. (1981a). Aging and skilled problem-solving. *Journal of Experimental Psychology-General*, 110(1):21–38.

Charness, N. (1981b). Search in chess - age and skill differences. *Journal of Experimental Psychology-Human Perception and Performance*, 7(2):467–476.

Charness, N. and Bosman, E. (1990). *Handbook of the Psychology of Aging*. Academic Press.

Chasseigne, G., Grau, S., Mullet, E., and Cama, V. (1999). How well do elderly people cope with uncertainty in a learning task? *Acta Psychologica*, 103:229–238.

Chasseigne, G., Mullet, E., and Stewart, T. R. (1997). Aging and multiple cue probability learning: The case of inverse relationships. *Acta Psychologica*, 97(3):235–252.

Ciccone, A. and Peri, G. (2003). Skills' substitutability and technological progress: U.s. states 1950-1990. CESifo Working Papers 1024, CESifo.

Cohn, A., Fehr, E., Herrmann, B., and Schneider, F. (2011). Social comparison in the workplace: Evidence from a field experiment. IZA Discussion Papers 5550, Institute for the Study of Labor (IZA).

Colonia-Willner, R. (1998). Practical intelligence at work: relationship between aging and cognitive efficiency among managers in a bank environment. *Psychology and Aging*, 13 (1):45–57.

Costermans, J., Guy, L., and Ansay, C. (1992). Confidence level and feeling of knowing in question answering: the weight of inferential processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18(1):142–150.

Crawford, J. and Stankov, L. (1996). Age differences in the realism of confidence judgments: and crystallized intelligence. *Intelligence*, 25(2):93–109.

Crépon, B., Deniau, N., and Pérez-Duarte, S. (2002). Wages, productivity, and worker characteristics: A french perspective. Working paper.

Crépon, B., Deniau, N., and Pérez-Duarte, S. (2003). Productivité et salaire des travailleurs âgés. *Revue Française d'Economie*, 18(1):157–185.

Cuñat, V. and Guadalupe, M. (2005). How does product market competition shape incentive contracts? *Journal of the European Economic Association*, 3(5):1058–1082.

Dargnies, M. P. and Hollard, G. (2009). Incentives to learn calibration: a gender-dependent impact. *Economics Bulletin*, 29(3):1820–1828.

Daveri, F. and Maliranta, M. (2007). Age, seniority and labour costs: lessons from the finnish it revolution. *Economic Policy*, 22(49):117–175.

de Hek, P. and van Vuuren, D. (2010). Are older workers overpaid? a literature review. Cpb discussion paper no. 165.

de Zwart, Frings-Dresen, M., and van Dijk., F. (1995). Physical workload and the ageing worker: A review of the literature. *International Archives of Occupational and Environmental Health*, 68:1–12.

Dearden, L., Reed, H., and Reenen, J. V. (2006). The impact of training on productivity and wages: evidence from british panel data. *Oxford bulletin of economic and social research*, 68(4):397–421.

Desmet, R., Jousten, A., and Perelman, S. (2005). The benefits of separating early retirees from the unemployed: Simulation results for belgian wage earners. Cepr discussion paper no. 5077.

Dickens, W. and Flynn, J. (2001). Heritability estimates versus large environmental effects: The iq paradox resolved. *Psychological Review*, 108(2):346–369.

Dorn, D. and Sousa-Poza, A. (2010). 'voluntary' and 'involuntary' early retirement: an international analysis. *Applied Economics, Taylor and Francis Journals*, 42(4):427–438.

Dostie, B. (2006). Wages, productivity and aging. Discussion Paper 2496, IZA Discussion Paper No. 2496.

Dubra, J. (2004). Optimism and overconfidence in search. *Review of Economic Dynamics*, 7(1):198–218.

Duffy, J. and Papageorgiou, C. (2000). A cross-country empirical investigation of the aggregate production function specification. *Journal of Economic Growth*, 5:87–120.

Duffy, J., Papageorgiou, C., and Perez-Sebastian, F. (2004). Capital-skill complementarity? evidence from a panel of countries. *Review of Economics and Statistics*, 86(1):327–344.

Duffy, S. and Smith, J. (2010). Preference for increasing wages: How do people value various streams of income? MPRA Paper 23559, University Library of Munich, Germany.

Duncan, G. J. and Hoffman, S. (1979). On-the-job training and earnings differences by race and sex. *Review of Economics and Statistics*, 61:594–603.

Dupuy, A. (2004). *Assignment and Substitution in the Labour Market*. PhD thesis, Maastricht University.

Farber, H. S. (1994). The analysis of interfirm worker mobility. *Journal of Labor Economics*, 12(4):554–593.

Fenstermacher, K. S. and Kleiner, B. H. (1999). The relationship between age and seniority in american industry. *Management Research News*, 22(6):13–17.

Fischoff, B., Slovic, P., and Lichtenstein, S. (1977). Knowing with certainty: The appropriateness of extreme confidence. *Journal of Experimental Psychology: Human Perception and Performance*, 3(4):552–564.

Forbes, D. P. (2005). Are some entrepreneurs more overconfident than others? *Journal of Business Venturing*, 20:623–640.

Fox, C. R. and Tversky, A. (1995). Ambiguity aversion and comparative ignorance. *The Quarterly Journal of Economics*, 110(3):585–603.

Frank, R. (1984). Are workers paid their marginal products? *The American Economic Review*, 74 (4):549–571.

Fukao, K., Kambayashi, R., Kawaguchi, D., Kwon, H. U., Kim, Y. G., and Yokoyama, I. (2006). Deferred compensation: Evidence from employer-employee matched data from japan. *Discussion Paper*.

Garen, J. (1988). Compensating wage differentials and the endogeneity of job riskiness. *The Review of Economics and Statistics*, 70(1):9–16.

Garibaldi, P., Martins, J. O., and van Ours, J. (2010). *Health, Longevity and Productivity*. Oxford University Press.

Göbel, C. and Zwick, T. (2009). Age and productivity - evidence from linked employer employee data. Zew discussion paper no. 09-020.

Ghosh, D. and Ray, M. R. (1997). Risk, ambiguity, and decision choice: Some additional evidence. *Decision Sciences*, 28(1):81–104.

Ghosheh, N. (2008). Age discrimination and older workers: Theory and legislation in comparative context. Conditions of work and employment series no. 20, ILO.

Gigerenzer, G., Hoffrage, U., and Kleinbölting, H. (1991). Probabilistic mental models: A brunswikian theory of confidence. *Psychological Review*, 98:506–528.

Gohmann, S. F., Myra, J., McCrickard, M., and Slesnick, F. (1998). Age-earnings profiles estimates: Do they change over time? *Journal of Forensic Economics*, 11:(3):173–188.

Goodie, S. A. (2005). The role of perceived control and overconfidence in pathological gambling. *Journal of Gambling Studies*, 21(4):481–502.

Grieco, D. and Hogarth, R. (2004). Excess entry, ambiguity seeking, and competence: An experimental investigation. Economics Working Papers 778, Department of Economics and Business, Universitat Pompeu Fabra.

Griffin, D. and Tversky, A. (1992). The weighing of evidence and the determinants of confidence. *Cognitive Psychology*, 24:411–435.

Griffin, P. (1992). The substitutability of occupational groups using firm-level data. *Economics Letters*, 39(3):279–282.

Griliches, Z. and Mairesse, J. (1995). Production functions: The search for identification. NBER Working Papers 5067, NBER Working Paper No. 5067.

Griliches, Z. and Ringstad, V. (1971). *Economies of scale and the form of the production function*. Amsterdam: North-Holland Publishing Company.

Grund, G. and Westergård-Nielsen, N. (2008). Age structure of the workforce and firm performance. *International Journal of Manpower*, 29(5):410–422.

Guest, R. and Shacklock, K. (2005). The impending shift to an older mix of workers: Perspectives from the management and economics literatures. *International Journal of Organisational Behaviour*, 10(3):713–728.

Haegeland, T., Ronningen, D., and Salvanes, K. (2007). Adapt or withdraw? evidence on technological changes and early retirement using matched worker-firm data. Research department discussion paper no. 509, Statistics Norway.

Haltiwanger, J. C., Lane, J. I., and Spletzer, J. R. (1999). Productivity differences across employers: The roles of employer size, age, and human capital. *The American Economic Review*, 89(2):94–98.

Hamilton, B., Nickerson, J., and Owan, H. (2003). Team incentives and worker heterogeneity: An empirical analysis of the impact of teams on productivity and participation. *Journal of Political Economy*, 111(3):465–497.

Hamilton, B. H., Nickerson, J. A., and Owan, H. (2004). Diversity and productivity in production teams. Working paper.

Hansen, Z., Owan, H., and Pan, J. (2006). The impact of group diversity on performance and knowledge spillover – an experiment in a college classroom. NBER Working Papers 12251.

Hansson, P., Rönnlund, M., Juslin, P., and Nilsson, L.-G. (2008). Adult age differences in the realism of confidence judgments. overconfidence, format dependence, and cognitive predictors. *Psychology and Aging*, 23(3):531–544.

Harrison, G. and List, J. (2004). Field experiment. *Journal of Economic Literature*, 42:1013–1059.

Hashimoto, M. (1981). Firm-specific human capital as a shared investment. *The American Economic Review*, 71(3):475–482.

Heckman, J. J. (1976). A life-cycle model of earnings, learning and consumption. *Journal of Political Economy*, 84(4):S11–S44.

Hellerstein, J. and Neumark, D. (2004). Production function and wage equation estimation with heterogeneous labor: Evidence from a new matched employer-employee data set. Nber working paper 10325.

Hellerstein, J. and Neumark, D. (2007). *Hard to measure goods and services: essays in honor of Zvi Griliches*, chapter Production function and wage equation estimation with heterogeneous labor: evidence from a new matched employer-employee data set. University of Chicago Press.

Hellerstein, J. K. and Neumark, D. (1995). Are earnings profiles steeper than productivity profiles? evidence from israeli firm data. *Journal of Human Resources*, 30:89–112.

Hellerstein, J. K., Neumark, D., and Troske, K. R. (1999). Wages, productivity, and worker characteristics: Evidence from plant-level production functions and wage equations. *Journal of Labor Economics*, 17(3):409–446.

Heywood, J. S., Jirjahn, U., and Tsertsvardze, G. (2010). Hiring older workers and employing older workers: German evidence. *Journal of Population Economics*, 23(2):595–615.

Hoelzl, E. and Rustichini, A. (2005). Overconfident: do you put your money on it? *the Economic Journal*, 115:305–318.

Hogarth, R. and Karelaia, N. (2008). Entrepreneurial success and failure: confidence and fallible judgment. Ssrn working paper.

Horn, J. L. (1965). Fluid and crystallized intelligence. a factor analytic and developmental study of the structure among primary mental abilities. Unpublished doctoral dissertation, University of Illinois, Champaign.

Horn, J. L. and Cattell, R. B. (1966). Refinement and test of the theory of fluid and crystallized intelligence. *Journal of Educational Psychology*, 57(5):253–270.

Hotchkiss, J. L. (1998). Cross-sectional evidence for the job-matching model. *Applied Economics Letters*, 5(2):121–25.

Hoyer, W. J. and Lincourt, A. E. (1998). *Aging and the development of learning.* Handbook of implicit learning, Thousand Oaks, CA: Sage.

Hutchens, R. M. (1986). Delayed payment contracts and a firm's propensity to hire older workers. *Journal of Labor Economics*, 4:439 – 457.

Hutchens, R. M. (1989). Seniority, wages and productivity: A turbulent decade. *Journal of Economic Perspectives*, 3 (4):49–64.

Hutchens, R. M. (2006). Job opportunities for older workers: When are jobs filled with external hires? Articles & chapters, paper 72, Cornell University ILR School.

Ilmakunnas, P. and Maliranta, M. (2005). Technology, labour characteristics and wage-productivity gaps. *Oxford Bulletin of Economics and Statistics*, 67 (5):623–645.

Ilmakunnas, P., Maliranta, M., and Vainiomaki, J. (2000). The roles of employer and employee characteristics for plant productivity. Econometric Society World Congress 2000 Contributed Papers 1349, Econometric Society.

Iranzo, S. and Peri, G. (2006). Schooling externalities, technology and productivity: theory and evidence from u.s. states. Technical report, NBER Working Paper Series 12440.

James, M. (2001). Out of shorts and into the boardroom. *Management Today*, pages 14–19.

Joe, C. and Yoong, P. (2004). Harnessing the knowledge assets of older workers: A work in progress. Report, Decision Support in an Uncertain and Complex World: The IFIP TC8/WG8.3 International Conference.

Johnson, M. M. S. (1990). Age differences in decision making: A process methodology for examining strategic information processing. *Journal of Gerontology: Psychological Sciences*, 45:75–78.

Johnson, P. (1993). *Labor markets in an ageing Europe*, chapter Aging and European economic demography. Cambridge University Press, Cambridge.

Johnson, R. W. (2007). Managerial attitudes toward older workers: A review of the evidence. Technical report, The Urban Institute Discussion Paper 07-05.

Jorgenson, D. W., Christensen, L. R., and Lau, L. J. (1973). Transcendental logarithmic production frontiers. *Review of Economics and Statistics*, 55:28–45.

Jovanovic, B. (1979). Job matching and the theory of turnover. *Journal of Political Economy*, 87:972–990.

Juslin, P., Olsson, H., and Björkman, M. (1997). Brunswikian and thurstonian origins of bias in probability assessment: On the interpretation of stochastic components of judgment. *Journal of Behavioral Decision Making*, 10:189–209.

Juslin, P., Wennerholm, P., and Olsson, H. (1999). Format dependency in subjective probability calibration. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 28:1038–1052.

Juslin, P., Winman, A., and Olsson, H. (2000). Naive empiricism and dogmatism in confidence research: A critical examination of the hard-easy effect. *Psychological Review*, 107:384–396.

Juslin, P., Winman, A., and Olsson, H. (2007). The naive intuitive statistician: A naive sampling model of intuitive confidence intervals. *Psychological Review*, 114:678–703.

Kahneman, D., Slovic, P., and Tversky, A. (1982). *Judgments under uncertainty: heuristics and biases*. Cambridge University Press.

Kahneman, D. and Tversky, A. (1979). Prospect theory: an analysis of decision under risk. *Econometrica*, 47(2):263–292.

Kalwij, A., Alessie, R., and Knoef, M. (2009). Individual income and remaining life expectancy at the statutory retirement age of 65 in the netherlands. Working paper no. 033, Network for Studies on Pensions, Aging and Retirement.

Kaplan, K. (2001). Better with age. *Sales and Marketing Management*, 153(7):58–62.

Kissinger, J. A. (1998). Overconfidence: A concept analysis. *Nursing Forum*, 33(2):18–26.

Kitchener, K. S. and Brenner, H. G. (1990). *Wisdom and reflective judgment: Knowing in the face of uncertainty*. Cambridge University Press.

Kitchener, K. S. and King, P. M. (1981). Reflective judgment. concepts of justification and their relationship to age and education. *Journal of Applied Developmental Psychology*, 2:89–116.

Klaczynski, P. A. and Robinson, B. (2000). Personal theories, intellectual ability, and epistemological beliefs: Adult age differences in everyday reasoning biases. *Psychology and Aging*, 15:400–416.

Klayman, J., Soll, J. B., Gonzalez-Vallejo, C., and Barlas, S. (1999). Overconfidence: It depends on how, what, and whom you ask. *Organizational Behavior and Human Decision Processes*, 79:216–247.

Koehler, R. A. (1974). Overconfidence on probabilistic tests. *Journal of Educational Measurement*, 11(2):101–108.

Koriat, A., Lichtenstein, S., and Fischhoff, B. (1980). Reasons for confidence. *Journal of experimental psychology: Human Learning and Memory*, 6(2):107–118.

Kotlikoff, L. J. and Gokhale, J. (1992). Estimating a firm's age-productivity profile using the present value of workers' earnings. *The Quarterly Journal of Economics*, 107(4):1215–1242.

Kovalchik, S., Camerer, C. F., Grether, D. M., Plott, C. R., and Allman, J. M. (2005). Aging and decision making: A comparison between neurologically healthy elderly and young individuals. *Journal of Economic Behavior and Organization*, 58:79–94.

Kramer, D. A. (1983). Post-formal operations? a need for further conceptualization. *Human Development*, 26:91–105.

Kremer, M. and Thomson, J. (1998). Why isn't convergence instantaneous? young workers, old workers, and gradual adjustment. *Journal of Economic Growth*, 3:5–28.

Kruger, J. and Burrus, J. (2004). Egocentrism and focalism in unrealistic optimism (and pessimism). *Journal of Experimental Social Psychology*, 40:332–340.

Kruger, J. and Mueller, R. A. (2002). Unskilled, unaware, or both? the better-than-average heuristic and statistical regression predict errors in estimates of own performance. *Journal of Personality and Social Psychology*, 82(2):180–188.

Lallemand, T. and Rycx, F. (2009). Are young and old workers harmful for firm productivity? Technical report, CEB Working Paper N° 09/002.

Lam, D. (1989). Population growth, age structure, and age-specific productivity. does a uniform age distribution minimize lifetime wages? *Journal of Population Economics*, 2:189–210.

Larrick, R., Burson, K., and Soll, J. (2007). Social comparison and confidence: When thinking you're better than average predicts overconfidence (and when it does not). *Organizational Behavior and Human Decision Processes*, 102(1):76–94.

Lazear, E. P. (1979). Why is there mandatory retirement? *Journal of Political Economy*, 87(6):1261–1284.

Lazear, E. P. (1981). Agency, earnings profiles, productivity, and hours restrictions. *The American Economic Review*, 71(4):606–620.

Lazear, E. P. (1998). *Personnel Economics for Managers*. John Wiley & Sons.

Lazear, E. P. (2000). Performance pay and productivity. *American Economic Review*, 90(5):1346–1361.

Lengermann, P. A. (2002). Is it who you are, where you work, or with whom you work? reassessing the relationship between skill segregation and wage inequality. Technical Paper TP-2002-10, U.S. Census Bureau.

Levinsohn, J. and Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *Review of Economic Studies*, 70:317–341.

Lichtenstein, S., Fischhoff, B., and Phillips, L. D. (1982). *Calibration of probabilities: the state of the art to 1980*. Cambridge University Press.

Loewenstein, G. and Sicherman, N. (1991). Do workers prefer increasing wage profiles? *Journal of Labor Economics*, 9 (1):67–84.

London, M. (1996). Redeployment and continuous learning in the 21st century: Hard lessons and positive examples from the downsizing era. *Academy of Management Executive*, 10(4):67–79.

Luong, M. and Hébert, B.-P. (2009). Age and earnings. Catalogue no. 75-001-X 5-11, Statistics Canada.

Macnicol, J. (2006). *Age discrimination: An historical and contemporary analysis*. Cambridge University Press.

Malcomson, J. M. (1999). Individual employment contracts. In Ashenfelter, O. and Card, D., editors, *Handbook of Labor Economics*, volume 3 of *Handbook of Labor Economics*, chapter 35, pages 2291–2372. Elsevier.

Mallier, A. and Shafto, T. A. C. (1992). *The economics of flexible retirement*. Academic Press, London and San Diego.

Malmberg, B., Lindh, T., and Halvarsson, M. (2008). Productivity consequences of workforce ageing - stagnation or a horndal effect. *Population and Development Review*, 34:238–256.

Malmendier, U. and Tate, G. (2004). Who makes acquisitions? ceo overconfidence and the market's reaction. NBER Working Paper 10813.

Manning, A. (2003). *Monopsony in motion: Imperfect competition in labor markets.* Princeton University Press.

Marquié, J. C. and Huet, N. (2000). Age differences in feeling-of-knowing and confidence judgments as a function of knowledge domain. *Psychology and Aging*, 15(3):451–461.

Marschak, J. and Andrews, W. H. (1944). Random simultaneous equations and the theory of production. *Econometrica*, 12 (3-4):143–205.

Maurer, T. J. (2001). Career-relevant learning and development, worker age, and beliefs about self-efficacy for development. *Journal of Management*, 27(2):123–140.

McConnell, C. R. and Brue, S. L. (1994). *Contemporary Labor Economics.* New York: McGraw-Hill, 12th edition.

McEvoy, G. M. and Cascio, W. F. (1989). Cumulative evidence of the relationship between employee age and job performance. *Journal of Applied Psychology*, 74:11–17.

McKenzie, C. R. M., Liersch, M. J., and Yaniv, I. (2008). Overconfidence in interval estimates: What does expertise buy you? *Organizational Behavior and Human Decision Processes*, 107:179–191.

Mercat-Bruns, M. (2002). Discrimination fondée sur l'âge et fin de carrière. *Retraite et société*, 36(2):109–135.

Min, J. C. and Kleiner, B. H. (2001). How to hire employees effectively. *Management Research News*, 24(12):31–38.

Mincer, J. (1958). Investment in human capital and personal income distribution. *Journal of Political Economy*, 66(4):281–302.

Mincer, J. (1962). On-the-job training: Costs, returns and some implications. *Journal of Political Economy*, 70(5) Part 2:S50–S79.

Mincer, J. (1970). The distribution of labor incomes: A survey with special reference to the human capital approach. *Journal of Economic Literature, American Economic Association*, 8(1):1–26.

Mincer, J. (1974). *Schooling, Experience and Earnings.* NY: Columbia University Press.

Mincer, J. (1988). Job training, wage growth, and labor turnover. Nber working paper no. 2690.

Mincer, J. (1997). Changes in wage inequality, 1970-1990. *Research in Labor Economics*, 16:1–18.

Mincer, J. and Jovanovic, B. (1981). *Studies in Labor Market*, chapter Labor mobility and wages. New York: National Bureau of Economic Research.

Moberg, D. J. (2002). The aging workforce: Implications for ethical practice. *Business and Society Review*, 106(4):315–329.

Moore, D. A. and Cain, D. M. (2007). Overconfidence and underconfidence: When and why people underestimate (and overestimate) the competition. *Organizational Behavior and Human Decision Processes*, 107:179–191.

Moore, D. A. and Healy, P. J. (2008). The trouble with overconfidence. *Psychological Review*, 115:505–517.

Mortensen, D. T. and Pissarides, C. A. (1994). Job creation and job destruction in the theory of unemployment. *Review of Economic Studies*, 61(3):397–415.

Munnell, A. H., Sass, S. A., and Soto, M. (2006). Employer attitudes towards older workers: Survey results. Work opportunity briefs, Center for Retirement Research.

Odean, T. (1998). Volume, volatility, price, and profit when all traders are above average. *Journal of Finance*, 53(6):1887–1934.

OECD (2003). Ageing and employment policies: Sweden. Report.

OECD (2005). Ageing and employment policies: United states. Report.

OECD (2006). Live longer, work longer. Report.

OECD (2007). Trends in severe disability among elderly people: assessing the evidence in 12 oecd countries and the future implications. Health working paper no. 26.

OECD (2009). Ageing and employment policies - statistics on average effective age of retirement. Report.

Okun, M. A. and Elias, C. S. (1977). Cautiousness in adulthood as a function of age and payoff structure. *Journal of Gerontology*, 32:451–455.

Olley, G. S. and Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, 64(6):1263–1297.

O'Mahony, M., Robinson, C., and Vecchi, M. (2005). Heterogeneity of the labour input: methodological issues in constructing labour quality measures. Euklems consortium meeting helsinki, EUKLEMS.

O'Neill, G. L. (1998). *Managing performance and remuneration.* Business and Professional Publishing, Warriewood, NSW, managing an ageing workforce edition.

Oskamp, S. (1968). The relationship of clinical experience and training methods to several criteria of clinical prediction. *Psychological monographs*, 76(28):1–21.

Parzen, E. (1962). On estimation of a probability density function and mode. *The Annals of Mathematical Statistics*, 33(3):1065–1076.

Paul, R. J. and Townsend, J. B. (1993). Managing the older worker: Don't just rinse away the gray. *The Academy of Management Executive*, 7(3):67–74.

Perlmutter, M. (1978). What is memory aging the aging of? *Developmental Psychology*, 14:330–345.

Peters, E., Hess, T., Västfjäll, D., and Auman, C. (2007). Adult age differences in dual information processes: Implications for the role of affective and deliberative processes in older adults' decision making. *Perspectives on Psychological Science*, 2(1):1–23.

Pissarides, C. A. and Wadsworth, J. (1994). On-the-job search: Some empirical evidence from britain. *European Economic Review*, 38(2):385–401.

Pliske, R. M. and Mutter, S. A. (1996). Age differences in the accuracy of confidence judgments. *Experimental Aging Research*, 22:199–216.

Postel-Vinay, F. and Robin, J.-M. (2001). The distribution of earnings in an equilibrium search model with state-dependent offers and counter-offers. *International Economic Review*, 43(4):1–26.

Prendergast, C. (1999). The provision of incentives in firms. *Journal of Economic Literature*, 37(1):7–63.

Prince, M. (1993). Women, men, and money styles. *Journal of Economic Psychology*, 14:175–182.

Productivity.Commission (2005). Australia's health workforce. Report.

Prskawetz, A. and Fent, T. (2007). Workforce ageing and the substitution of labour: The role of supply and demand of labour in austria. *Metroeconomica*, 58(1):95–126.

Prskawetz, A., Fent, T., and Guest, R. (2005). Workforce aging and labor productivity. the role of supply and demand for labor in the g7. Working paper, Vienna Institute of Demography.

Pulford, B. D. and Colman, A. M. (1997). Overconfidence: Feedback and item difficulty effects. *Personality and Individual Differences*, 23(1):125–133.

Reder, L. M. and Ritter, F. E. (1992). What determines initial feeling of knowing? familiarity with question terms, not with the answer. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 18(3):435–451.

Remery, C., Henkens, K., Schippers, J., and Ekamper, P. (2003). Managing an aging workforce and a tight labor market: views held by dutch employers. *Population Research and Policy Review*, 22:21–40.

Rønningen, D. (2007). Are technological change and organizational change biased against older workers? firm-level evidence. Discussion Papers 512, Research Department of Statistics Norway.

Roger, M. and Wasmer, M. (2009). Heterogeneity matters: labour productivity differentiated by age and skills. Pse working paper 2009-51.

Roodman, D. (2006). How to do xtabond2: An introduction to "difference" and "system" gmm in stata. Working paper no. 103, The Center for Global Development.

Russo, J. E. and Schoemaker, P. J. (1992). Managing overconfidence. *Sloan Management Review*, 33:7–17.

Rybash, J. M., J., W., Hoyer, and Roodin, P. A. (1986). *Adult cognition and aging: Developmental changes in processing, knowing and thinking.* Pergamon General Psychology Series. Allyn and Bacon.

Salthouse, T. A. (1984). Effects of age and skill in typing. *Journal of Experimental Psychology: General*, 13:345–371.

Salthouse, T. A. (1987). *Age, experience, and compensation.* Norwood, NJ.: Ablex.

Salthouse, T. A. (1989). *Aging and skilled performance*, volume Acquisition and performance of cognitive skills. Wiley & Sons.

Salthouse, T. A. (1990). *Cognitive competence and expertise in aging*, volume Handbook of the psychology of aging (3rd Ed.). Academic Press.

Salthouse, T. A. (1994). The nature of the influence of speed on adult age differences in cognition. *Developmental Psychology*, 30:240–259.

Sanford, A. J., Griew, S., and O'Donnell, L. (1972). Age effects in simple prediction behaviour. *Journal of Gerontology*, 27:259 – 264.

Schaie, K. (1996). *Intellectual development in adulthood.* Cambridge University Press.

Schubert, R., Brown, M., Gysler, M., and Brachinger, H. W. (1999). Financial decision-making: Are women really more risk-averse? *The American Economic Review, Papers and Proceedings of the One Hundred Eleventh Annual Meeting of the American Economic Association*, 89(2):381–385.

Schwarz, N., Knäuper, B., Hippler, H. J., Noelleneumann, E., and Clark, F. (1991). Rating scales: numeric values may change the meaning of scale labels. *Public Opinion Quarterly*, 55:570–582.

Skirbekk, V. (2003). Age and individual productivity: A literature survey. MPIDR Working Paper 2003-028, Max Planck Institute for Demographic Research, Rostock, Germany.

Skirbekk, V. (2008). Age and productivity capacity: Descriptions, causes and policy options. *Ageing Horizons*, 8:4–12.

Slovic, P. and Lichtenstein, S. (1971). Comparison of bayesian and regression approaches to the study of information processing in judgment. *Organizational Behavior and Human Performance*, 6:641–744.

Smeaton, D. and Vegeris, S. (2009). Older people inside and outside the labour market: A review. Research report 22, Policy Studies Institute, Equality and Human Right Commission.

Smeaton, D. and Young, V. (2007). Work in the future: employers and workplace transformation. Report, Equal Opportunities Commission.

Smith, S. (2006). The retirement-consumption puzzle and involuntary early retirement: Evidence from the british household panel survey. *The Economic Journal*, 116:C130–C148.

Smith, V. L. (1976). *Bidding and Auctioning Institutions: Experimental Results*. Cambridge University Press.

Spitz-Oener, A. (2006). Technical change, job tasks, and rising educational demands: Looking outside the wage structure. *Journal of Labor Economics*, 24(2):235–270.

St-Amour, D. (2001). Realizing the value of old workers. *Canadian Manager*, 26(3):1–26.

Stein, A. H., Pohly, S. R., and Mueller, E. (1971). The influence of masculine, feminine and neutral tasks on children's achievement behavior, expectancies of success, and attainment values. *Child Development*, 42:195–207.

Steinberg, M., Walley, L., Tyman, R., and Donald, K. (1998). *Too old to work?* Business and Professional Publishing, Warriewood, NSW, managing an ageing workforce edition.

Sternberg, R. J. and Wagner, R. K. (1986). *Tacit knowledge and intelligence in the everyday world*, volume Practical intelligence: nature and origins of competence in the everyday world. Cambridge University Press.

Stevens, M. (2003). Earnings functions, specific human capital, and job matching: Tenure bias is negative. *Journal of Labor Economics*, 21(4):783–805.

Stiglitz, J. E. (1975). Incentives, risk, and information: Notes towards a theory of hierarchy. *Bell Journal of Economics*, 6(2):552–579.

Sutter, M. and Kocher, M. (2007). Trust and trustworthiness across different age groups. *Games and Economic Behavior*, 59(2):364–382.

Svenson, O. (1981). Are we all less risky and more skillful than our fellow drivers? *Acta Psychologica*, 47(2):143–148.

Taber, C. (2008). Ben-porath model. Department of economics, University of Wisconsin-Madison.

Taylor, P. E. and Walker, A. (1994). The ageing workforce: Employers' attitudes towards older people. *Work Employment and Society*, 8(4):569–591.

Thesmar, D. and Thoenig, M. (2000). Creative destruction and firm organization choice. *The Quarterly Journal of Economics*, 115(4):1201–1237.

Thornton, R. J., Rodgers, J. D., and Brookshire, M. L. (1997). On the interpretation of age-earnings profiles. *Journal of Labor Research*, 18(2):351–365.

Topel, R. (1986). Local labor markets. *Joumal of Political Economy*, 94:S111–S143.

Topel, R. (1991). Specific capital, mobility, and wages : wages rise with job seniority. *Journal of Political Economy*, 99(1):145–175.

Topel, R. H. and Ward, M. P. (1992). Job mobility and the careers of young men. *The Quarterly Journal of Economics, MIT Press*, 107(2):439–79.

Tversky, A. and Kahneman, D. (1974). Judgment under uncertainty: heuristics and biases. *Science*, 185:1124–1131.

Valsecchi, I. (2000). Job assignment and promotion. *Journal of Economic Surveys*, 14(1):31–51.

van Ours, J. C. and Stoeldraijer, L. (2010). Age, wage and productivity. Technical report, CentER, Department of Economics of Tilburg University, Discussion Paper, No 2010-12.

Walker, A. (2005). The emergence of age management in europe. *International Journal of Organisational Behaviour*, 10 (1):685–697.

Warr, P. and Pennington, J. (1993). *Views about age discrimination and older workers.* Institute of Personel Management.

Warr, P. B. (1994). *Age and job performance.* Taylor & Francis, Bristol, work and ageing: a european prospective edition.

Weiss, A. (1991). *Efficiency Wages Models of Unemployment, Layoffs and Wage Dispersion.* Princeton, New Jersey: Princeton University Press.

Winman, A., Hansson, P., and Juslin, P. (2004). Subjective probability intervals: How to cure overconfidence by interval evaluation. *Journal of Experimental Psychology: Learning Memory, and Cognition*, 30:1167–1175.

Worth, E. (1995). In defense of targeted erips: Understanding the interaction of life-cycle employment and early retirement incentive plans. *Texas Law Review*, 74(2):411–445.

Wurzbach, M. E. (1991). Judgment under conditions of certainty. *Nursing Forum*, 26(3):27–34.

Yamaguchi, S. (2007). The effect of match quality and specific experience on career decisions and wage growth. mimeo, McMaster University.

Yearta, S. K. and Warr, P. (1995). Does age matter? *Journal of Management Development*, 14(7):28–35.

Zeiliger, R. (2000). A presentation of regate, internet based software for experimental economics. http://www.gate.cnrs.fr/ zeiliger/regate/regateintro.ppt, Lyon: GATE.