Influence of Mortality and Morbidity on Pension Systems: state of the art and future research agenda

Abstract

In Europe, the birth rates are decreasing and longevity of Europeans is increasing very fast, therefore the population is ageing. To keep the pension systems sustainable and pensions adequate for living standards of welfare states, the EU Member States have reacted by increasing retirement ages and limiting early access to public pensions. Societies as well as policy-makers on national and business levels are faced with the challenge of addressing these changes on the markets of human resources and their implications on working conditions.

This work firstly examines the history and recent rise of an interest in mortality research and describes related retirement age issues, pension policies and the public policy imperatives. Then, the impact of mortality on pension systems performances is discussed. These considerations lead the authors to analyze the need to create better database on EU level and to describe and compare the advances related to the modeling of pension systems.

The article finally provides a future research agenda and outlines the urgent need to improve research infrastructure at EU level to support pension policies, advance the design of more equitable pension systems, and their correct economic evaluation of influence of pension sytems and mortality on pension wealth.

Keywords: longevity, mortality, morbidity, ageing, retirement age, occupational health, pension system

1. Introduction

Regarding mortality there existed 1.000.000 items in Web Of Science as of 7th of October 2019 from which there were 715,136 articles and 49,163 proceedings papers. (The list is at the end). For our study the most relevant Web of Science Categories are demography with 3,472 items and economics with 5,716 items. If we narrow down the papers that include both topics mortality and pensions, we get only 852 items of which there are 766 articles, 16 reviews, 5 editorial materials, 1 book chapter, 81 proceedings papers, 7 meeting abstract, 2 early access papers and 1 correction. Most relevant Web of Science Categories are economics with 261 items, public environmental occupational health (221 items),social sciences mathematical methods (97 items), business finance (92 items), statistics probability (90 items), mathematics interdisciplinary applications (83

items),medicine general internal (40 items), demography (39 items), gerontology (30 items), health policy services (25 items)

2. The ageing problem

2.1 Retirement age and related literature

This article looks at the impact of ageing of workforce (mortality of workforce) on pension systems, which is likely to be of major significance in European economics in the coming decades. Consistently low birth rates and higher life expectancy are transforming the shape of the age pyramid of developed countries. The most important change will be the marked transition towards a much older workforce structure, a development which is already apparent in several EU Member States. The proportion of people of working age in the EU-28 is shrinking while the relative number of those retired is expanding. The share of older persons in the total population will increase significantly in the coming decades, as a greater proportion of the post-war baby-boom generation reaches retirement. This will, in turn, lead to an increased burden on those of working age to provide for the social expenditure required by the ageing population for a range of related services. Europe is ageing. This ageing is associated with the decreasing number of working population 15-64 age old workforce, drastically altering the demographics of Europe. The Directorate- General for Economic and Financial Affairs as department of the European Commission responsible for EU policies promoting economic growth, higher employment, stable public finances and financial stability recently published "The 2018 Ageing Report: Underlying Assumptions and Projection Methodologies" (EC, 2017) which review the demographic developments in the Member States. This report follows "The 2015 Ageing Report" (EC, 2015c) and "The 2015 Pension Adequacy Report" (EC, 2015b) which presents the long-term impact of changes in demographic structure on the public expenditure regarding pensions, health care and long-term care (LTC). According to the Table 2 the European population EU28 will grow from 507,2 million in 2013 to 522,8 million in 2060. There is obvious the age/employment paradox. The percentage of elderly (65+) in European population is forecasted to grow for 10 percentage points (p.p.), while the working age population will drop for 9,4 p.p., during the same period (see Table 2).

Table 2. The changes of demographic structure of EU28 in the period 2013-2060

	Change (%) 2013-2060	2013	2020	2025	2030	2035	2040	2045	2050	2055	2060
EU 28 population [million]	15.6	507.2	512.8	516.0	518.8	521.4	523.7	525.3	525.5	524.5	522.8
Working age population 15-64 [p.p.]	-9.4	66.0	63.9	62.6	61.1	59.6	58.4	57.5	56.9	56.6	56.6
65+ population [p.p.]	10.0	18.4	20.5	22.2	24.1	25.8	27.0	27.7	28.2	28.4	28.4

Source: EC, The Ageing Report 2015.

The working age population and their employers are contributing a certain percentage of added values of their production to the social systems of EU Member States. Ageing of the population imposes stress on these social systems and particularly the availability of future pensions is put under question in mind of the public. Many current employees have doubts regarding their future pension income when they retire. This notion makes citizen less inclined to pay required pension contributions, and that is putting the long-term sustainability of pension system under the question. How EU Member States can design pension system and tax system in such a way to be sustainable, adequate and equitable from the perception of members of the public pension scheme is discussed in this paper.

How best to finance livelihood of elderly, have become highly topical issues in recent years in the EU Member States, but legislation is not adequate to protect pensioners from poverty in many countries, and citizens are losing their faith that pension system will provide for them in old age. How important is study of adequate and sustainable pension system show also articles about pension reforms cited in WoS. Their numbers are growing rapidly as presented in Figure 1, but only 26 papers are focused to the adequacy and 127 papers study the sustainability. Both topics have been studied mostly after 2007.

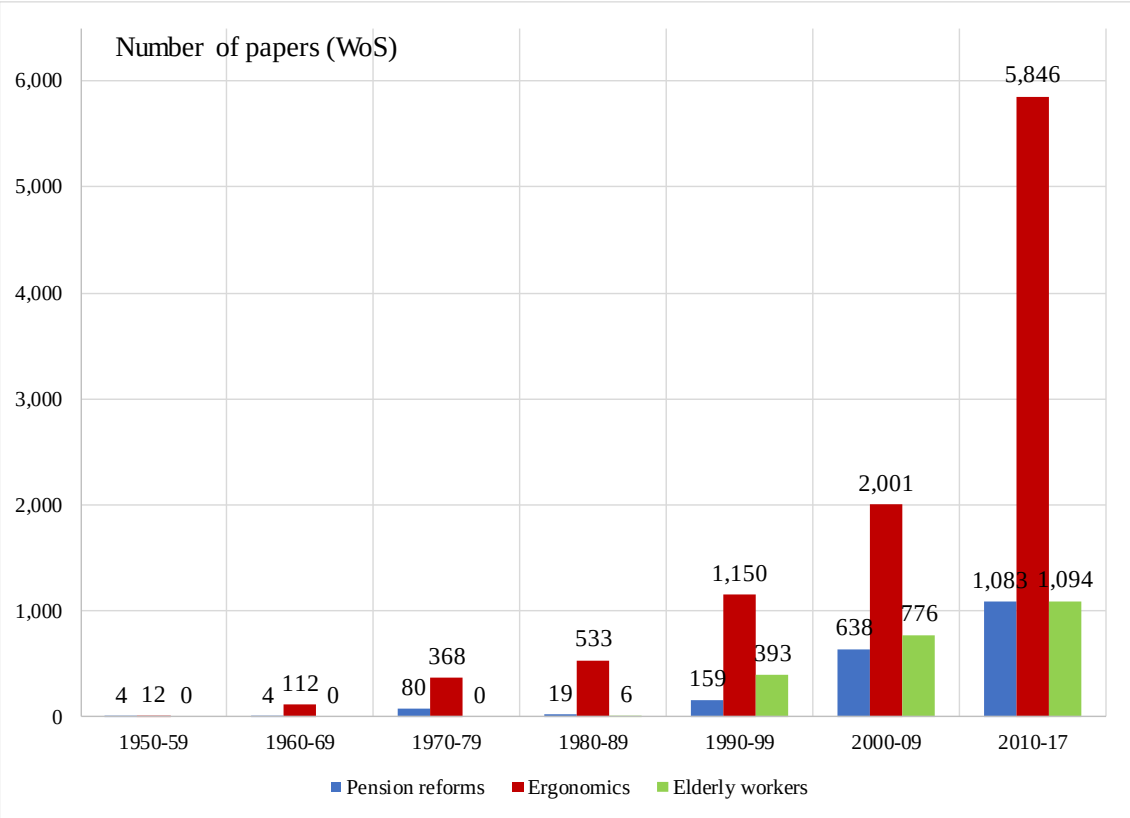

Figure 1. Number of papers in WoS about pension reforms, ergonomics issues, elderly workers.

There is extensive scientific literature available in journals in Web of Science categorization, dealing with the problem of retirement age (8,540 articles from Web of Science Core Collection). The first 100 Web of Science Categories (by record count) shown, are reporting that over 6,000 articles have been published in the journals of gerontology, medicine research, health and nursing. Close to 2,000 articles have been published in economics, business, management, administration and financial journals, but only 296 articles can be found in Industrial Relations & Labor (Monthly Labor Review, Journal of Labor Research, Journal for Labor Market Research, Work Employment and Society, I L R Review, and others), 40 articles in Ergonomics (Journal of Safety Research, Human Factors and Ergonomics in Manufacturing & Service Industries, Accident Analysis and Prevention, Advances in Physical Ergonomics and Safety, Ergonomics, Applied Ergonomics , International Journal of Human-Computer Studies, Travail Human, and International Journal of Industrial Ergonomics), 25 of them published in the last decade and no one before 1990, 31 articles in industrial engineering (among them the previously listed journals in Ergonomics, Journal of Management in

Engineering, Safety Science, and Human Factors) and only 140 articles in operation research and management science including the journals of applied mathematics.

2.2 Pension reform - the mechanisms of adaptation to demographic change

The steady decrease in births and increasing life expectancy in the last century had a strong influence on changes in the population's age structure in Europe. Table 2 is presenting rapid growth in the share of the population over the age of 65 years. The ageing index as an indicator of the relationship between the number of 65-year-olds and older with respect to the number of younger than 15 years old already exceeds 100, and by 2070 it is expected to exceed 200 (EC, 2017). If we look at the dynamics of the age structure of the EU – 28 in the second half of the twentieth century and its projection for 2060, we can find that the share of the active population that is of age 15 to 64 years old have started to decrease intensively at the beginning of 21st century. While the proportion of young decreases, providing a moderate decline in dynamics in the proportion of young people, the proportion aged 65 years and over and in particular the proportion aged 80 and over is rising sharply, endangering the pension systems of Europe, requiring also proper reorganization and predominately additional financial resources for health care for the elderly and even a new approach to care for ageing Europeans.

These policies are opening a new economy, named "Silver Economy" or "Longevity Economy" as a set of economic activities linked to the production of goods and services targeting the old inhabitants (Beblavý et al. 2015; Guerin and Berrut, 2016), therefore important research topics of production economics. This term is new and the Oxford Economics definition of the Longevity Economy is "the sum of all economic activity serving the needs of over 50 and including both the products and services they purchase directly and the further economic activity this spending generates" (Oxford Economics, 2014).

In the next decade we can expect that under "Silver Economy" or "Longevity Economy" more papers will be published also in scientific literature, dealing with the problems of strategic measures of states to stimulate the private sector and researchers to explore the opportunities emerging from an ageing society, and respond of researchers and enterprises through innovation, adapting thus the economy to the new demographic structures, and promoting economic development, as is forecasting by Felix (2007).

Increased proportion of the elderly population causes many challenges with which our existing institutions are unable to cope and in which appropriate solutions must be found as soon as possible. The process of the ageing population subtly undermines good relations between generations and calls for new or at least revised social contracts and new intergenerational relations in society (Börsch-Supan, 2013, 2015). But we are witnesses of the inability of many States to ensure an acceptable social structure which is often measured by the portion of the population living below the poverty line. Trends show that increasing life expectancy together with falling birth rates influence a rapid ageing of workforce and represents a challenge for public policy in general, as well as new requirements of social partners, unions and employers, especially in the development of new pension schemes and improvements of working environment, because the combination of demographic trends in mortality and birth rate means that many pension systems face a reduction of contributions to the public pension schemes and increase the total amount of pensions paid out to the retired workers (Börsch-Supan, 2013, 2015). These trends so far require for changing the rules and adjusting parameters of the pension schemes to retain pension funds balanced. Therefore, it is necessary:

- to raise the retirement age further or
- to reduce the ratio between pensions and net salaries
- by raising contribution rates or
- a reduction in the percentage of salary in gross out payments.

The question is how to index salary from the past or only consider prices rises or just wage growth or a combination of them.

The question as well is, or will the pension fund when it starts payments of pensions is indexed to the increase of retail prices or the growth of the average wage in the economy (Schmitt and Starke, 2016).

Since public pension plans are in the form a law, it is difficult to change the parameters of the pension plan and requires the consent of all social partners or at least these changes occur with longer time delays (Börsch-Supan, 2015). Due to the lengthy processing of coordinating and enactment of new parameters of the pension plan, in particular, because the purchasing power is specifically difficult to decrease, the deficit of the pension fund transfers to the state budget deficit (Schmitt and Starke, 2016). Mentioned demographic trends prompted many countries in the last years to introduce

automated links between demographic or economic movements changing the values of parameters of pension systems (Börsch-Supan, 2013, 2015). This important new feature is interesting for researchers for economic and political reasons. Automatic adjustment means that the funding of pensions protects against demographic and economic risks. It provides logical and current rules for changes – such as reduction of pensions – which otherwise would be politically difficult to introduce, but expose to risk the adequacy of pensions and reliability of production.

The problems with the sustainability of pension funds in many European countries (for example also in Italy) are resolved with an automated adjusting mechanism included in pension schemes for regulating outflow and inflow into funds (Börsch-Supan, 2015). However, the automatic adjustments may reduce the reliability of production because of decreasing functional capacities of the workforce, and also the suitability of pension income for retirees, increasing the risk of poverty among the retired population (Börsch-Supan, 2015). In the case of automatically raising the retirement age, workers cannot retire when their physical and mental abilities fall under the threshold to exercise their profession. Such a situation causes a burden on the employer if workers cannot retire. Therefore new solutions in ergonomics which would enable older workers to stay longer in employment are needed. Otherwise, it can also mean an increase in unemployment or requests for disability retirement, which increases the burden on other social transfers and added increases to the uncertainty for employees. Therefore the financial problems of the budget are not resolved if industrial engineering will not contribute more to solve the problem of rising retirement age.

Therefore, there is a need to strengthen social safety nets for the elderly, which determines a suitable lower limit of pensions and provide complimentary social transfers to benefit pensions in the event when an individual pension income falls below the poverty line (Börsch-Supan, 2015). A coordination mechanism is often complex and could create uncertainty about future pension rights. Among the activities, that the individual can adjust to these new pension models: or work longer or increase savings are those among employers, who can contribute to additional occupational pension fund and investments in ergonomics, and those among employees, also in the form of capital funded pensions and investments to housing with possibilities to benefit after retirement from housing equity withdrawal - HEW (Bogataj, 2013; Bogataj and Aver, 2013; Bogataj and Bogataj, 2015). These automatic adjustment mechanisms are intended directly or

indirectly to achieve financial sustainability, but they have a great impact on planning for retirement because raising the age of retirement means workers need to work longer and for companies, this represents dealing with ageing human resources, creation of additional occupational pension funds, investments in collaborative robots (cobots) and other ergonomic achievements for better working environment in old age, and policies to attract younger workers from foreign countries, or to move production activities where the supply of workforce is higher.

2.3 The employment ratio of older workers

2.3.1 The recent approaches

The key issue in the financing debate is how people should fund their living and lodging expenses and what share of pension income should be provided as deffered personal wages and how much by public funding (Agostini et al., 2016). To respond to this challenge, the European Commission (EC, 2000, 2004, 2012, 2015b, 2015c, 2016; EU-OSHA et al., 2017; EPC(AWG) and EC_DG ECFIN, 2001, 2006, 2007, 2009, 2012, 2015) and Member States (Virtanen et al, 2017; Bonasia and de Siano, 2016; Loichinger and Skirbekk, 2016; Nyvlt, 2015) as well as OECD (Alonso-Ortiz, 2014, OECD, 1998, 2003, 2011, 2012, 2014, 2015) set out a number of recommendations and acts. At the same time the studies of the public health researchers wrote about warning and risks related to extended working lives (Edger, Cooper and Coffey, 2017; Stafford et al., 2017; Reeuwijk et al., 2017). Sustainability of pension systems requires raising the retirement age and/or decrease in pension benefit for new retirees. The especially unsolved question in many countries is how to solve the pension problem for those citizens that were not in employment long enough throughout their working-age period (Börsch-Supan, 2013, 2015). In the paper there are open some questions regarding the proper retirement age, acceptable for workers, there employers who contribute to their deferred wages, and society which contribute to the social system through taxes and fees, in order to design of pension system in ageing society, to be sustainable and adequate and suggest the model for economic evaluation of decision on proper retirement age.

In the public pay-as-you-go systems the indicator which could measure the adequacy of the pension system as investment mechanism for intertemporal transfer of purchasing power is the real internal rate of return. Therefore, one of the important aspects regarding adequate pensions is the impact of the growth of life expectancy at 65+ and growth of

average contributory period with associated pension reforms on the internal rate of return for public pay-as-you-go pension systems. Therefore it is important to analyze the EU Member States demographic structure regarding possibilities that internal rate of return zero or higher would be achieved and would stay as one of accepted measure of the adequacy of the systems. On this base the society should answer the question what kind of contribution rate and how high retirement age is required to achieve this goal.

2.3.2 The historical overview of the employment ratio – what we can learn

The retirement age of industrial workers in national pension schemes was changing in the history. In many OECD countries, after 1970 employment rates of older people decreased significantly. By 1995 the employment rate for males aged 55–64 years was about 80 percent in Switzerland and Japan but only 34 percent in Belgium and France (Schmitt and Starke, 2016). Due to increasing longevity, closing the early exit options from the labour market became European policy since late 1990s. The decision to retire early is mainly made by individual workers and is influenced by various circumstances, often as low job satisfaction, poor health, and depreciation of skills (Wahrendorf et al., 2013).

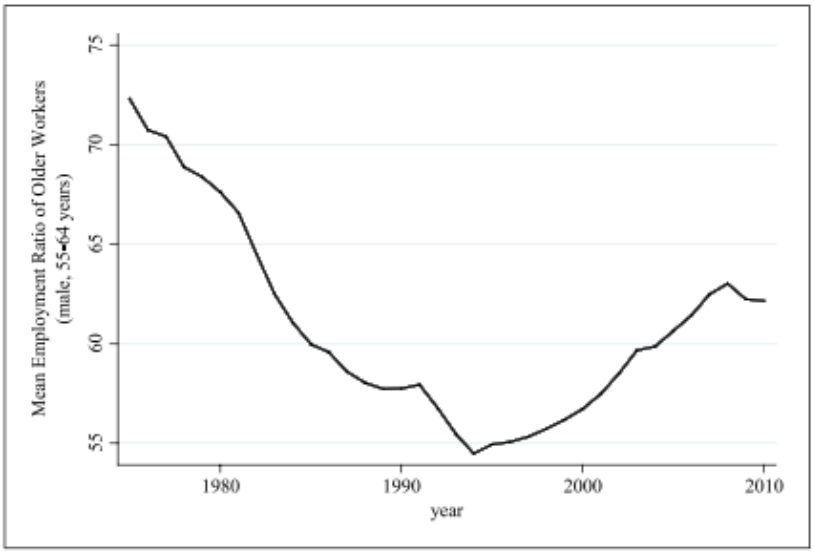

Figure 2. Mean employment ratio of older workers (male, 55–64 years) in highly developed EU countries 1975–2010 (Source: OECD Labour Force Data).

But there are also many other incentives embedded in the national social security system and organizational pension schemes which provide pathways for early exit from the workforce (Börsch-Supan, Brugiavini, and Croda, 2009; Engelhardt, 2012). According to Schmitt and Starke (2016) it is the structure of industrial relations and sectoral politics

that explain cross-national differences in early retirement. They found out that early exit is greater in countries with decentralized industrial relations, which indicates a sectoral rather than class-based logic. They also realized that costs of industrial restructuring are shifted from sectors exposed to global competition to sheltered and service sectors which leads to higher early exit rates. This effect is low in states of highly centralized industrial relations (Trampusch, 2005; Ebbinghaus, 2006; Hartlapp and Kemmerling, 2008).

As we see in Figure 2, the retirement age is being raised in the last decades, with decline in time of recession. However, many industrial workers are not able to work until they have reached the increased retirement age. This problem is decreasing social security, increasing workers anxiety regarding the future and influencing the quality of products and timing of production processes. Disruptions and lower quality items produced in one activity cell of a supply chain can have a ripple effect throughout entire supply chain. To solve this problem, we should

1. put in place supplementary or complementary pension schemes, which would compensate firms for the depreciated ability of their elder workers to work,
2. attract new migration flows of young workers or to move production in the countries with younger workforce or
3. to invest in ergonomics for workers with additional investments in supporting robots.

It is necessary to develop occupational pension schemes to support business organizations and the entire supply chain with the possibilities of early retirement of such workers in the period between predetermined retirement age and the newly specified (increased) retirement age (under the new pension legislation). The trade-off between higher contributions to supplementary occupational pension schemes, investments in ergonomics, investments in relocation of activities, regarding added values should be considered (Bogataj and Bogataj 2017a, 2017b).

3 Functional decline of the ageing workforce and impacts on the manufacturing system

3.1 Decline in cognition

The majority of members of workforce who are over the age of 55 do not expect to retire until well after the historically determined retirement age. There are many positive but also more negative consequences that come with these older workers remaining working in the same workplaces as in young ages. As they age, physical decline and cognitive changes occur. Several studies have already documented a decay of cognitive functions (Raz, 2000; Solbakk et al., 2008, Prakash et al, 2009), as well visual problems (Bucur, Madden, and Allen, 2005) and physical (motor) capacities (Cole, 1991; Ketcham et al., 2001, 2002; Lindberg et al., 2009). According to Salthouse (1990, 1994, 2012), Jenkins and Hoyer, (2000) and Rogers, Fisk and Hertzog (1994), older adults learn new skills more slowly than younger adults and do not reach the same level of working performance. Ageing causes changes to the brain size, vasculature, and cognition. The brain shrinks with increasing age (Peters, 2006). After 50s or 60s the dopamine system in the brains begins to break down causing decreased cognitive functioning (Braver et al., 2001, 2014). Braver is describing in detail the rapid declines in episodic and working memory, as well as about losing abilities of attention control, and execution of duties, with the episodic memory declines being the most prominent. He describes how decreased functioning occurs over time in both understanding context as well as maintaining information. Following the study of Keys and White (2000) we can conclude that the decline in cognition with age experienced by many workers is often attributed to the decline in processing speed of the dopamine system. Due to the declining speed of information processing in the brain the old workers are experiencing a significant decline in psychomotor speed and executive performance, including increasing variance in performance. Kolev, Falkenstein and Yordanova (2005) have studied the correlation between ageing and error processing. On the bases of their time- frequency analysis of error-related potentials they have concluded that in some cases we cannot differ in the rate of errors committed by younger and older adults; although, reaction times were longer in older adults in majority of cases. But the general results indicated that the older adults did have both qualitative and quantitative declines in error processing. According to Kolev et al., this decline can result in a decreased quality and quantity of work and increased variability associated with a lower awareness of errors. Bucur et al. (2005) noted the impact of varying brain frequencies on visual processing, disabling proper division older workers of attention between two different types of tasks. All of described physiological declines, presented also in Figure 3, correlate to a decreased level of working performances in quality and quantity and also increase variability of these

performances in observed time windows. There is a threshold at which workers fall in category at which are no longer able to perform their duties on their workplace.

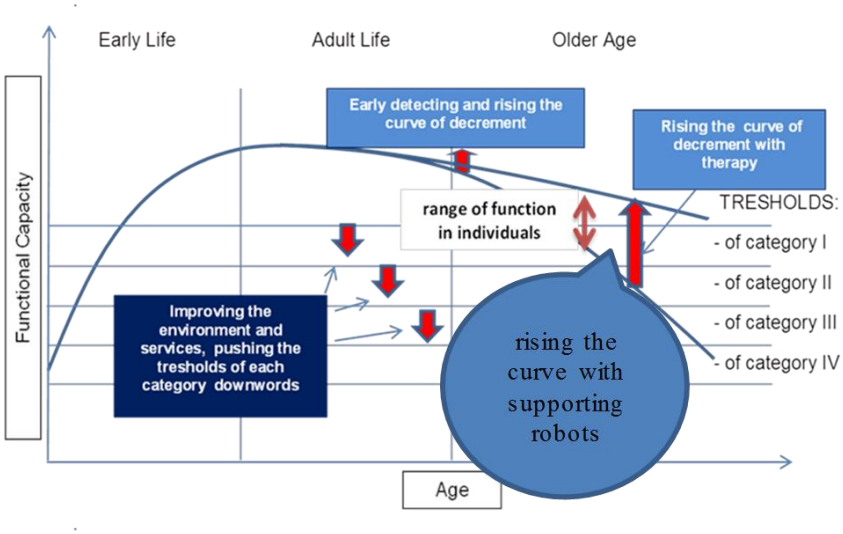

Figure 3. Functional decline of the ageing workforce (from: Bogataj and Bogataj, 2017a)

Based on their statistical analysis, Lemaire, Arnaud, and Lecacheur (2004) and recently Dalecki et al. (2017) concluded that older adults require longer estimation time to solve a computational problem and had decreased accuracy by ageing, having particularly problems when the task was more complex. Namely, because of rapid advances of modern technologies, employees should control more and more complex production and logistic processes in which they have to control multiple displays. They have to operate simultaneously many input devices. To keep efficiency and quality of their work on required level, not only cognitive, but also physical abilities are required (Salthouse, 2012; Smith, Sharit, and Czaja, 1999; Dalecki et al, 2017).

In the studies listed above it was recognized that all age groups are flexible enough regarding choosing the right strategy. The authors also noted that older adults are extremely adaptable as they became just as efficient with the use of the computer tool, as younger persons involved in testing in less than one hour of exercising (Charness et al., 2004; Jastrzembski et al., 2005). About tasks that required more complex executive functioning, the conclusions are that such tasks had greater age discrepancy in

performance variability, with more frequent and larger performance variabilities in the older participants.

But the declines of functional capacities of the ageing process really depend on individual people. Decreased functioning of metabolism, loss of autonomy, osteoporosis, decreased social support (like losing husband or wife and other nearest and dearest), as well as the psychosocial factors increase in functional decline (Rowe and Kahn, 1985). It is also noted in several papers (Glass et al., 1995) that adults who remain productive into their late old ages will experience the least functional decline. Also protective marriage and high level of mastery were preventative against productivity decline in their statistical analysis and conclusions.

3.2 Work-related musculoskeletal disorders and absence from work

Main reason for decline in productivity of older workers is increase of absence from work due to ill health. Mayor reason for ill health of older workers is related to musculoskeletal disorder. The studies of work-related musculoskeletal disorders (WMSDs) are mainly focused on interventions to prevent and control it. The studies are directed to

- workplace: considering man-machines coordination and processes,
- schedules of activities and rotation of workers,
- skills, information and additional training.

Workplaces are mainly designed for young and healthy workers, therefore with ageing the discrepancies between capacities of older workers and demands of employers are often increasing. Cole and Beck, (1994), Ketcham et al. (2001) and Lindberg et al., (2009) found that a range of kinematic and dynamic parameters differed substantially between young and older participants in typical laboratory tasks.

According to Landau et al. (2008) musculoskeletal disorders are steadily increasing by ageing of workers performing assembly jobs which frequently involve highly repetitive, short-cycle operations in assembly processes. They have identified long-term cumulative effects: Older workers suffer of lumbar spine or head–neck–shoulder symptoms and the upper limbs problems, despite low demands imposed by their present jobs. Therefore ergonomic improvements are important also for younger workers to avoid cumulative effect. By increasing the official retirement age the number of workers qualifying for disability pensions on grounds of musculoskeletal disorders, like spinal

disease and strain injuries is increasing (Landau et al., 2008; Schaub et al., 1997). To avoid early retirement, ergonomic solutions and support by cobots are advised and medical danger points in assembly processes should be identified and eliminated by modification of the work model (Landau, et al., 2008). These activities are also the consequence of required implementation of the EU Framework Directive (89/391/EEC) and the accompanying specific directives regarding safety and health protection or the EU Machinery Directive (98/37/EEC) regarding basic safety requirements for design, construction, operation and disposal of machinery.

Savinainen et al (2004) exposed as solution to the problem of age-related decline, higher skills of older workers. Based on their longitudinal studies Ilmarinen (2012), identified three groups of factors liable to increase the risk of a decline in performance of older workers: (a) excessive physical exertion, (b) stressful or dangerous working conditions and (c) bad work organisation. Shephard (2000) outlined age-related trends in personal characteristics, capabilities and skills and made proposals for worksite modification. Aittomaki et al. (2005) addressed association between advancing age and poor performance in physically demanding work. But little has been done on the question of subjectively perceived disease symptoms in workers on assembly lines.

A correlation between age and productivity depends on workplace and physical characteristics of workers in relation to their incline to different kind of musculoskeletal disorders (Landau et al., 2008). Figure 4 show that productivity at 22% of workplaces in EU is increasing with ageing of workers. In this group are mainly managers and highly educated and skilled professionals, at some workplaces (around 23%) the productivity is age-neutral, like productivity of clerical support workers, also workers at some services and salesman, while for employed in armed forces, forestry and fishery workers, machine operators and assemblers the productivity is decreasing by ageing.

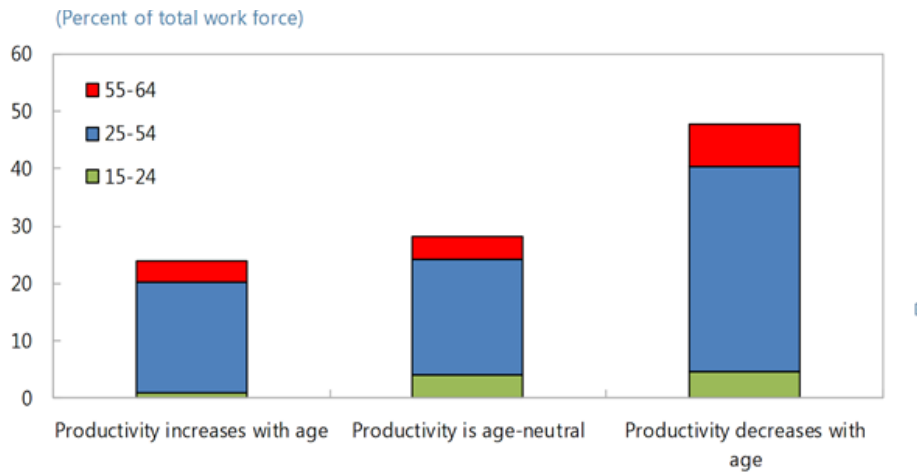

Figure 4. EU28: Workforce decomposition by occupations, 2015 (Source: Aiyar et al., 2016)

There are many solutions to solve the problem when worker fall under the threshold of abilities to continue his work at his workplace. One of the solutions to relocate him/her on less demanding workplace; second is to give him better supporting environment like collaborative robots, enable him work for shorter working time per day or to enable him to retire.

3.3 Increase of age-related operator deficits in statistics of experiments in realistic environment of instrument-control task

Dalecki et al. (2017) like previously Verhaeghen and Cerella, (2002), Bock and Hagemann, (2010), Bock and Züll, (2013) and Salthouse (2012), have pointed out that while studying the impact of ageing on productivity and quality of products the parameters in decision support models should be taken from statistics of experiments in the realistic environment of instrument-control task. Namely, the majority of previous research has used standardized laboratory tasks, which may not be valid indicators. The results might be substantially different when assessed in a realistic environment versus in the laboratory. Also studies of the age-related performances in more realistic tasks like about drivers (Kramer et al., 2007) and air traffic (Nunes and Kramer, 2009), confirm their observations. Already the earlier studies based on experimental setups using complex human-machine systems or life-support control setups, found age-related deficits of performance and pointed out that "age-related performance assessments based on simple functions might underestimate the difficulty elderlies have when performing more complex and realistic tasks" (Riviere and Thakor, 1996; Smith, Sharit, and Czaja, 1999). Dalecki et al. (2017) estimated that in older cohorts of their statistical analysis of

complex tasks, the instrument-control task efficiency was 70% lower than in young cohorts. This age decrement was more pronounced than that in laboratory tasks and in the simple realistic tasks. This finding conforms with the complexity theory of ageing for which Cerella et al. (1980) proved that age-related mental slowing reduces task performance in proportion with task difficulty. It is always higher in realistic complex environment versus simpler realistic or laboratory type tasks. A longer contact time at the input devices of older cohorts in a realistic scenario has been reported as very significant also in an earlier study (Bock and Steinberg, 2012), but in this study the age difference observed was substantially smaller (190 ms) compared to the report of Dalecky et al. (400 ms, which). Finally, Dalecky et al. concluded that age-related changes of control task efficiency was associated also with a decay of motivation was also found in the works of Braver et al., (2001, 2014). Also Hess (2014) reported that older participants were less interested than young ones to perform the task well. All mentioned statistics and conclusions need the answer to the question to prolong the retirement age or not and to invest in supporting environment for older workers or relocate the activities in region where more young employees are available.

5. Future research agenda

In the light of the considerations discussed before, we have made an attempt to understand what directions that might be fruitful for future research on "ageing workforce" in order to address the current problems of industrial systems not yet assessed by the large traditional literature. In particular the following aspects would be of interest to be investigated (arising from the literature review presented in this work together with our previous discussion):

There is a lack in real data collection and analysis in order to study how ageing workers perceive and work in EU, how their age affects their performances and how the adoption of assistive technologies influence the entire work flow in different industrial sectors. These kind of data are urgently needed and necessary in order to provide operation managers with novel and adequate business models and business strategies dedicated to elderly workers management in manufacturing environments.

There is need for development of new quantitative models able to include age-related aspects right from the beginning of the analysis. The future models must design age-friendly systems, i.e. systems that reflect the needs of the elder workers and the difference between them (skills, human diversity, physical characteristics, pathologies, etc.). Towards this purpose, it is necessary to put new efforts in providing new pension system design and balancing models age-oriented, able to differentiate mortality and morbidity of different occupational groups.

Influence of new technologies supporting age-friendly working environments, by efficiently integrating Industry 4.0 smart solutions, collaborative and work-assistance equipment.

Actuaries could contribute their knowledge to develop new decision support models able to guide managers in finding the optimal retirement schemes and right level of investment in expensive technologies able to assist elderly workers. Recently, the optimal level of professional pensions, social contributions and investments in ergonomics has been determined by a decision support model based on MRP theory and actuarial mathematics (Bogataj et al. 2017, Bogataj and Bogataj, 2017a, Battini et al. 2017). Further developments need to be done in this direction.

Finally, in EU there is a need for new guidelines in order to create occupational pension schemes "workplace oriented". Each job, but especially physically demanding works are in contingency of functional decline of workers, therefore contributions to occupational pension schemes should depend on the type of workplace and job executed by the worker. The classification of physically demanded job is very poor in any of European member states. Due to functional decline, many workers will not be able to work till increased retirement age and companies could provide early retirement occupational pension from the moment when worker cannot perform his work properly and cannot achieve required productivity.

Conclusion

The present survey and analysis finds strong evidence that the ageing workforce issue is increasingly more relevant and discussed in literature, reflecting the changes that have been happened in EU manufacturing systems and EU population in the last half of century. Incremental steps have been made in the last years by engineers, operation managers and ergonomists to incorporate ageing factors in the design of workplaces and production process. However, this literature review clearly shows that the numbers of works related to this topic in engineering and technical journals are even very low. For this reasons, important new challenges are expected in the near future in order to face the ageing problem by an engineering and operational point of view. In particular the following aspects need to be investigated in the close future: to collect and analyze new real data concerning the effects of ageing on manufacturing systems, to provide new quantitative models age-oriented to design production and assembly systems, to develop new age-friendly working environments, by efficiently integrating Industry 4.0 smart solutions at an affordable investment cost, to create new decision aid models and decision support systems able to guide managers in finding the best resource management strategy and to finally elaborate new guidelines in order to support changes and improvements in EU occupational pension schemes.

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ENVIRONMENTAL STUDIES (1,473)
PSYCHIATRY (13,209)
SUBSTANCE ABUSE (3,644)
ENGINEERING ELECTRICAL ELECTRONIC (1,439)
ENTOMOLOGY (12,902)
OPHTHALMOLOGY (1,371)
NUTRITION DIETETICS (12,479)
AGRONOMY (3,457)
ALLERGY (1,334)
TOXICOLOGY (11,845)
PSYCHOLOGY MULTIDISCIPLINARY (3,447)
PSYCHOLOGY SOCIAL (1,255)
BIOCHEMISTRY MOLECULAR BIOLOGY (11,723)

Morlatity and pensions:

Table 1. The number of articles in WoS Core Collection about mortality and pensions

Years	1990-99	2000-09	2010-17

Source: Web of Knowledge