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# Stocktaking of activities in active aging and work environment in policy, science and industry — The German case

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ABSTRACT

Demographic change is one of the important future societal challenges and its effects like an aging society has a significant impact on national policy decisions due to its different determinants like e.g. falling birth rates, aging baby boomers and skill shortages. Even though this development is not new, appropriate approaches to address this social trend are unfortunately still lacking. Within the German Foresight Process I, the field of 'aging research' was identified as one of seven new future fields whose potential for national scientific research and innovation activities has not yet been quantified. However, so far, current progress in policy, science and industry seems in some respects largely unconnected or isolated. This paper provides an overview of these activities in the work environment context, conducing analyses covering the use of innovation policy measures, the topic discussions in scientific publications and the realizations in corporate contexts. The aim is to provide an integrated picture of the state of the different concepts in the field of 'active aging' in the different sub areas of a 'national' innovation and technology system in the case of Germany.[1]



## 1. Introduction

In the late 1990s, the World Health Organization defined 'active aging' as a '… process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age' (WHO, 2002, p. 12). So, all conceivable factors that affect how individuals and populations age besides health care should be considered recognized (WHO, 2002, p. 13; Walker, 2006; Kalache and Kickbusch, 1997). The term 'active aging' gives a more comprehensive understanding than 'healthy ageing' and refers to continuing participation in social, economic, cultural, spiritual and civic affairs.

With regard to the above-mentioned definition of active aging, work is one of the three aspects of the economic determinants, besides income and social protection, which are identified as having a particularly significant effect on active aging (WHO, 2002, p. 30 ff.). To enjoy the opportunities for a dignified work is seen as an important aspect for aging people, to be able to participate in the workforce and for the benefit of the society as a whole. The increased need to support the active and productive contribution of elderly people in a formal and informal work situation or as a volunteer is recognized on a global level. Especially in the context of demographic change and the identified, related grand challenge 'aging societies' (Lund Declaration, 2009), an increased demand for new instruments and concepts was developed in politics, economy and science.

So, the interest of different stakeholder groups in the concept of active aging has increased in the last 15 years, among other things in the term 'aging workforce'. The proportion of older workers in the labor market will increase over the next 50 years all over the world. For example, the development of the German

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working population (from 20 to 64 years) is influenced by demographic trends as well as the German population in total. The working population will decrease from 50 million individuals in 2010 to 42 million individuals in 2030 and even further to an estimated 33 million individuals in 2060 (BMI, 2011, p. 36). Additionally, it is assumed, that elderly people will increasingly participate in the labor market which results in an increased average rate of the workforce age (Allmendinger and Ebner, 2006; Arlt et al., 2009). In the course of the demographic development in the form of a decreased population and an aging society the qualification patterns and the age structure among employed persons are subsequently changing. These observed societal changes lead to fundamental challenges for actors in policy, science and industry and to a necessary change in thinking regarding existing legal frameworks and policy instruments, theoretical concepts and research approaches as well as strategic and organizational management instruments.

Based on these insights, the future competitiveness of the German industry and scientific community depends on the ability to find tailor-made solutions in different key areas of an innovation system to deal with these challenges related to demographic change (Dosi et al., 1988; Lundvall, 1992; Kuhlmann and Arnold, 2001; Edquist, 2005). Here, only a systemic perspective enables to realize sustainable, innovative solutions for all involved stakeholders. Consequently, the present paper uses the innovation system approach as a conceptual framework to study the subject of 'active aging' and 'work environment' in the various sub-elements of the innovation system comprehensively. Following Edquist (2005, p. 152) an innovation system is defined and characterized by '[…] all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion and use of innovation'. The different key areas and their organizational actors as shown in Fig. 1 cover different perspectives of the demographic specific challenges and can operate with different instruments and measures to find sustainable ways (Edquist, 2005, p. 186). In general, for example, the involved scientific communities provide new knowledge and research findings about the influence of age on innovation attitude. These findings are normally transferred to the industry context, so that they are able to maintain their competitiveness and generate innovation and growth (Arundel, 2007, p. 50; Bescheikh et al., 2006, pp. 655f). The political system is mainly responsible for providing the institutional framework conditions (e.g. laws, norms, funding policy) in which innovation activities are embedded (Nelson and Rosenberg, 1993). The institutional structures, the incentive system, the skills and creativity of innovation actors and economic actors and the cultural peculiarities of a nation are the four main design elements which build innovation systems (Nelson, 1993, pp. 517–520; Patel and Pavitt, 1994).

The purpose of this paper is a stocktaking of how this challenge and related topics in the context of the work environment are addressed from the three different key areas: policy, science and industry. It is shown that in all areas the topic is highlighted and a number of activities have been conducted. Therefore, we analyze what kind of activities have taken place, which effects can be observed and what questions remain open, which have to be addressed in the future.

The paper will focus on the three main sub-elements by showing the following: First, an inventory of actions in the field of policy in Germany is composed. Here, the following questions are addressed: How extensive are innovation policy measures in the area of 'active aging'? Which measures have been initiated in the recent years at the national level? For the second key area, the field of science, especially, analyses of the relevant actors and research areas should give an overview of the scientific activities in the last two decades measured by scientific publications. The role of German scientific actors and their relationship to other national and international researchers or research groups is represented. Furthermore, the question regarding in how far possible concepts or solutions deal with the challenge we discussed earlier is addressed. For the third key sub-system of an innovation system, here industry, the stocktaking of activities is based on the results of a survey in the German manufacturing industry which was conducted by the Fraunhofer ISI. This analysis focuses on demographic specific personnel measures and asks questions such as: What concepts are already being used at the organizational level and to what extent are these concepts implemented? In addition, the impact of certain concepts on the innovation ability of enterprises is analyzed.

## 2. Aging society and the innovation system — the perspective of STI policy

The political and administrative systems as seen in Fig. 1 play an active role in shaping the whole innovation system, in making it coherent and in developing it further (Koschatzky 2012, p. 10). On this, one of the main objectives is to set the institutional framework for innovation activities. This includes legal rules, formal and informal standards, the promotion of innovation based on research and development funding and can be described by three framework measures (Reynolds et al., 2005; Djankov et al., 2002; Ahmad and Hoffmann, 2008) as reviewed in Ácsa et al. (2014). As one contribution, this paper will show how these thematic focuses are established or recognized in 'policy' and were adopted in policy instruments and research agendas. Especially, we will summarize the particular activities of the BMBF which promote the research and innovation activities related to 'active aging' in the context of work.

### 2.1. The policy perspective: aging research

Research on the topic of aging is conducted in different forms and on different levels in Germany. For example, the topic of aging research was already taken into account and mentioned as important in the year 2002 (Baltes, 2002). Age and aging are characterized as multi and transdisciplinary phenomena. Furthermore, the social importance of increasing age was stated and aging research was postulated as both promoting the economy and shaping the future. Therefore, a requirement for overall research funding was expressed.

On the national level, it was noticed that many existing funding programs, especially the BMBF's, dealt with sub-fields of aging research. For example, this includes funding for neurosciences, research into demographic change or skill networks in medicine or research into neurodegenerative diseases (Roloff and Beckert, 2006). So, for example, system biology has been supported by the BMBF with funding instruments for research and infrastructure since 2004. The BMBF initiative 'GerontoSys —

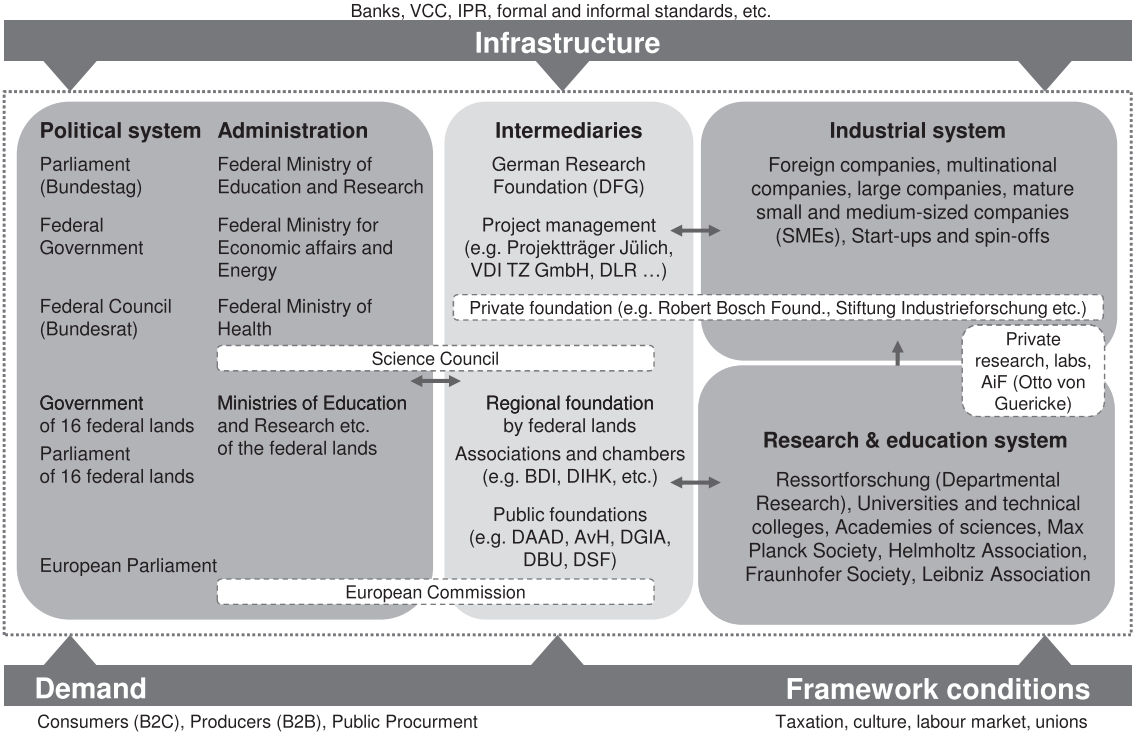


**Fig. 1.** Key actors of the German innovation system (Source: Frietsch and Kroll, 2010).

System biology of ageing' of 2008 focused exemplarily on the interdisciplinary research of aging processes. At the beginning, three projects with a total funding amount of 12 million euros were implemented. The second tendering round of the 'GerontoSys2' program was conducted in 2010.

Furthermore, as a consequence of the findings of the future project 'BMBF Foresight Process I' that was carried out by the Fraunhofer Institute for Systems and Innovation Research ISI together with Fraunhofer IAO, Technische Universität Berlin (TUB) and other partners in Germany, aging research was established as one political focus area for the next decade. Besides human-technology cooperation, sustainable living spaces, production consumption 2.0, trans-disciplinary models and multi scale simulation, time research and sustainable energy solutions, deciphering aging was one of seven new future fields (Cuhls et al., 2009b). As such, aging research was classified as one research field that expects to make outstanding, pioneering knowledge gains in science and technology as well as a considerable contribution to improving people's quality of life. The ways to understand different aging processes are recommended as one future field for potential focused research activities (Cuhls et al., 2009a, Vollmar et al., 2011). In the elaboration process for these upcoming fields it was suggested that the entire process of life and aging should be researched in the future field of »Aging Deciphering«, taking a multi-perspective and trans-disciplinary approach, focussing not exclusively on 'older people'. These findings lead to some additional structural changes as well as to new institutional arrangements. On this, the BMBF division for vocational training, retraining and livelong learning and the unit demographic change and human-technology interaction were reorganized and founded to process the activities.

In addition to the BMBF's funding and research program, other national ministries have addressed the topic of an aging society from different perspectives. For example, the Federal Ministry of Family Affairs, Senior Citizens, Women and Youth (BMFSFJ) conducted different programs for elderly people, like the program for action 'secure life in old age' from 2008 to 2012 (Görgen et al., 2012). The realization of senior-related policy actions with regard to crime and violence in the lives of older people was the overall objective. The focus lay, for instance, on the following topics: prevention measures for specific forms of fraud and other property-related offenses, measures for the prevention of violence in partnerships of older people, and measures for prevention and intervention with regard to the problem of abuse and neglect of older people in home care. In addition, research projects which dealt with the topic of dementia have been funded by the BMFSFJ since the late 1990s (BMFSFJ, 2006). Some intermediaries as shown in Fig. 1 like the Bertelsmann Stiftung or the Volkswagen Foundation deal with research initiatives related to the grand challenge of demographic change. For example, the Volkswagen Foundation had a research initiative on 'Individual and Societal Perspective on Aging' from 2008 to 2011. It was funded with approximately 3.6 million euros for twelve projects which involved researchers from 17 universities and research institutions.

At the end of 2011 the Federal Cabinet adopted the Federal Government's 'The new future of old age' research agenda for demographic change, which was proposed by the BMBF (2011). This agenda focuses on research programs on the challenges and opportunities of demographic change. Longer employability, mobility and communication, housing, health and care, as well as social and cultural inclusion are identified as action fields. The following focus areas for research funding

have been established: principal issues in a society of longer lives, benefiting from skills and experience of the elderly in economy and society, growing old in good health, social inclusion: staying mobile and in touch, living safely and independently, and good nursing care to boost the quality of life.

The research agenda for demographic change aims to conduct research that will encourage the development of new solutions, products, and services to improve the quality of life and social participation of older people (BMBF, 2011). It is seen as a milestone on the way to a comprehensive 'demographic strategy' in Germany (BMI, 2012). So, in 2012, the Federal Government introduced a 'demographic strategy — policy for all generations' in Germany ('Demografiestrategie: Politik für alle Generationen') (BMI, 2012). The aim of the strategy is to extend opportunities to everyone according to their living situation and age, opportunities to develop their potentials and capabilities and to realize their vision of life. The focus is on the areas of life in which people directly and most experience the effects of demographic change: in the family, at work, in old age or in the specific contexts of their rural or urban environment. For these major projects to manage the demographic change are currently under way, like the 'concept securing skilled labor' dated 22 June 2011, the plan of action for the sustainable design of public service tasks/welfare service developed jointly together with the East German federal states from 2011 or the research agenda 'The new future for old age' of November 2011 were established.

The government is aware, however, that managing demographic change can only succeed if at all levels of government, social actors and citizens participate locally and mutually agree to cooperate (BMI, 2012, p. 5). For this not only the divisional, but also in particular the cross-level cooperation between federal, state, local authorities, social partners and other design partners have to be expanded. Based on these activities, with respect to the innovation and technology policy as well as the research priorities and involved actors a change towards more overarching and integrated approaches is currently observed.

The topic of demographic change and its related developments is mentioned as one of the grand challenges and opportunities for the future by policy especially for the innovation and technology performance of Germany (BMI, 2011). But if we are looking at the total research funding by the BMBF between 2009 and 2012 it shows that the topic of 'demographic change' by itself is one of the funding priorities with the lowest budget (see Fig. 2). The total amount of funding for demographic change has increased over time, from 7.035 to 27.385 thousands of euros, but the share of the funding budget has been relatively constant at the low level of around 0.5% over the last three years. Research topics that are more technology oriented like 'health research and healthcare economy', 'dismantling of nuclear facilities', 'software systems and knowledge technologies', 'bio-economy', and 'optical technologies' received the highest amount of funding over the mentioned time period.

Regarding the recipients, a detailed look at the public funding expenditures on 'demographic change' shows that universities as well as non-university research institutions received approximately 26% of the total funding budget (BMBF, 2014b). However, industry gets more than 40% of the total funding budget in this research priority field. Because of the funding quota for industrial players, mostly between 40 and 60% of their investments, the participation in these research projects indicates that this topic is important especially for industrial players and their future interests. Nevertheless, the funding activities can also address appropriate demographic specific topics. So, for example, the research priority of 'health research and healthcare economy' could have a strong relationship to the aging society and the related health topics like chronic common diseases. This could be a starting point for further research related to assessing the importance of the grand challenge in the science, technology and innovation policy. A detailed analysis of current and completed projects funded by the national ministries can provide information about the direct and indirect investments in the management of demographic change and its related aspects. Regarding the observed change towards a more mission-orientated and overarching innovation and technology policy it remains to be seen whether the importance of the topic is also reflected in a changing funding budget in comparison to other research issues that are more technology-driven.

### 2.2. The policy perspective: aging research and work environment

Since the 1990s, the topic of 'demographic change and employment' has been one of the funding priorities of the BMBF (Pack et al., 2000; Zahn-Elliot, 2001). As such, the framework concept 'Innovative Arbeitsgestaltung — Zukunft der Arbeit' ('innovative work design — future of work') was established in 2001 to 2006 (BMBF, 2000, pp. 7–8). It focused on activities to develop and to maintain the decision-making and responsibility and employability, to design sustainable business development, to promote and develop unused potential of equal opportunities and to walk along new ways of implementation and transfer.

Since 2006, the BMBF has supported the R&D program 'Working–Learning–Developing skills, Innovation capability in a modern world of employment'. This program aims to help people to bring their knowledge, creativity and motivation into the working environment, to support firms to create the conditions for successful competence development and to establish networks or cooperation's that are able to generate market and employment opportunities (BMBF, 2007). Focal points within the framework program deal with topics like balance of flexibility and stability in a changing work environment, innovation capability in the context of demographic change or internal competence management and demographic change. Besides this, approaches for work design are funded in the lighthouse project 'integrated industry'. The importance of these focal points was also supported by the results of the Survey 'Vision of Germany — new paths in tomorrow's world' ('Vision Deutschland — neue Wege in die Welt von morgen') (Opaschowski, 2009). 85% of Germans requested new employment opportunities for older workers.

Also in the represented BMBF Foresight Process I research questions have been raised with regard to the focus of the paper 'active aging and work environment' (Cuhls et al., 2009a). Some of them were identified as being most important for the next years or centuries: 'What are the economic and social effects of longevity, especially if the life span and health is extended?', 'How will work processes and the image of aging change as a result of a longer life span and health (individually, in companies, socially)?', 'In what ways is the brain able to react

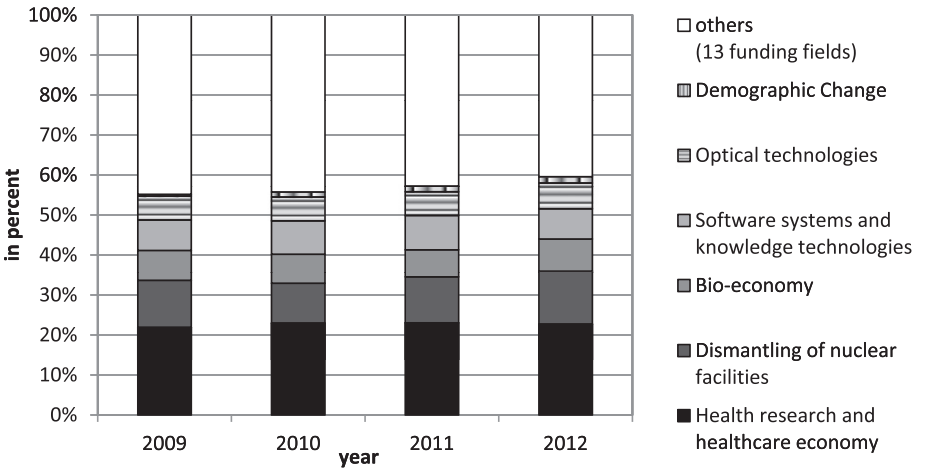


**Fig. 2.** BMBF project funding regarding funding priorities from 2009 to 2012 (BMBF, 2014a).

to changing conditions in different phases of life? How can lifelong learning be stimulated and what should successful learning settings 'look' like (e.g. to support learning in old age)?', 'How can learning be promoted in conditions of increasing pressure ('compression' of work processes, information overload)?'. The analyses of the funding portal (http://foerderportal.bund.de) show, that ongoing funded projects or projects that have just started are dealing with these research questions. For example, projects like 'InnoRix', 'DOMINNO' or 'INNOKAT' address the topic of innovation capability and creativity in the context of an elderly society and workforces. The innovative design of the work environment and organization, the demographic oriented concepts for the measurement and advancement of innovation potential as well as the role and potential of mixed age teams in medium-sized firms are captured in these projects. Here, the BMBF department for research related to production, services and work is the main 'customer' for the research findings. These research results could mainly provide information about the extent and the factors which characterize the innovation ability of the company or the age structure or age composition of its employees. In particular, these findings will be particularly important for topics such as the generation of ideas and strategic foresight in firms. But, foresight activities, such as technology roadmapping or scenario development within a company are not yet in the focus of research projects. So, it remains to be seen how far reaching the results from the ongoing projects will be.

Besides the BMBF, the Ministry for family, seniors, women and youth (BMFSFJ) has also conducted a study regarding the experience and competences of elderly people in the work environment. The study noted that due to their specific strengths older workers can contribute to the firm's success (BMFSFJ, 2008). The consistent implementation of demographic-specific measures is valuable for firms across all industries. The results of the study showed that aging workforces do not have to be a risk for firms, but rather the view of their competences illustrates the little perceived opportunities posed by demographic change for the economy. Currently, the federal ministry focuses, among other things, on issues like sharing the experience-based knowledge of elderly people with other generations and measures for further education in the second half of life. Also, the Federal Ministry of Labour and Social Affairs (BMAS) funded projects that deal with the topic of demographic change. For example, in the project 'KrIDe — Kreativität und Innovation im Demografischen Wandel' (Creativity and Innovation in Demographic Change) practical concepts and tools have been developed to promote innovation under the consideration of demographic change which were tested and implemented in the user companies.

Furthermore, intermediaries have also picked up the topic of 'active aging' and 'work environment'. For example, motivated by the '2012 European Year of active Aging and Solidarity among the Generations' the Bertelsmann Stiftung and the European Policy Centre (EPC) conducted a joint project on 'Second Career Labour Markets. Towards more Employment Opportunities for Older Workers' (Bertelsmann, 2013). The aim of the project was to stimulate the debate on 'active aging at work'. The identification, analyses and comparison of innovative solutions that can assist the relevant stakeholder's government, social partners, business and individuals with creating reform initiatives in that area were the main focus of this project.

Actually, the topic of an aging society related to the work environment is addressed in the second aspect of the aforementioned research agenda for demographic change 'benefiting from skills and experience of the elderly in economy and society'. Research and development measures that aim at better utilizing the knowledge of seniors and increasing their participation in the labor market, in order to ensure that specific potentials can be of even greater benefit, whether it is professional, private or in voluntary work (BMI, 2011). Ultimately, these measures should help to maintain and expand the capacity for innovation, competitiveness and progress in a society in which people live for longer. This focus was continued with the science year 'The Demographic Opportunity' in 2013. Under the slogan of 'We are living longer, we are becoming fewer, and we are becoming more diverse' the three fields of action in which tackling the challenge were addressed.[2] The focus of the discussion was how politics,

[2] http://www.demografische-chance.de/index.php?id=252.

industry and society can face up to the changes and use them to their advantage.

It turns out that only recently the subject of demographic change has been comprehensively addressed with a general strategy. On this, first projects will be funded to meet the challenges at the corporate level. The previous examples for funding research and infrastructure show the diversity of these topics. This variety is also represented in the national innovation policy; different ministries and other funding sponsors have dealt with specific topics, like health research, life sciences, effects of crime and violence or ergonomics and work studies. Only in the last two years the need for a broader, integrated and holistic approach has been recognized. This is particularly evident in the research agenda for demographic change (BMBF, 2011) and the formulated demographic strategy for Germany (BMI, 2012). So, a normative turn in innovation policy can be observed, the mission orientation that creates an arena for more participatory and multidisciplinary activities. Because of the new cross-departmental and interdisciplinary orientation on the policy level, the lack of cooperation and possible synergies that were identified earlier are addressed. It has to be shown in the future, whether this claim can be implemented in existing and planned research projects. Furthermore, it remains to be seen how new legal frameworks that enable lowering the retirement age to 63 in Germany, summon changes and also become influential on the level of innovation policy.

## 3. Aging society and the innovation system — the perspective of science

Aging research connects different scientific fields, for example sociology, philosophy, economics, sport sciences, medicine, cognitive sciences, chemistry, and ethics (Cuhls, 2009a, p. 38ff.; Gruss, 2007; Lehr, 2003). The following analysis will focus on activities in the scientific community in the form of scientific publications on aging research and related aspects and concepts for dealing with the challenge of an aging workforce. With respect to the innovation system approach, scientific publications are sources of information for codified knowledge of science and economy. They are used as indicators for measuring and illustrating the change of technological and non-technological research issues (Grupp and Schmoch, 1991; Grupp, 1997). Publications reflect a relevant part of the fundamental research and describe the processes, dynamics and results of research activities from individuals, institutions or countries and scientific fields by themselves (e.g. Moed et al., 1985; Nederhof and van Raan, 1993). Publication analyses indicate developments in the scientific system and cover technological aspects which are tangible as well as conceptual, like underlying management concepts, at an early stage of the discussion (Lichtenthaler, 2002). On this, bibliometrics is a method to statistically and mathematically analyze scientific publications and is often used in research areas like information retrieval, research evaluation and science research (Havemann, 2009). In the context of foresight, this kind of publication analysis supports the scanning and scouting processes and can offer the opportunity to identify early signals.

So, the publication analysis provided (quantitative) information on relevant research topics related to 'aging research' in general and 'active aging and work environment' in particular. For the analysis data from publication databases (ISI Web of Knowledge) is used to gain thematic insights and their dynamics, scientific networks and the involved researchers as well as organizations. The analysis of scientific activities by publications recorded in the SCI and SSCI in ISI Web of Science™ has become a broadly accepted standard and many authors have dealt with the methodological issues linked to this database (van Raan, 2004; Moed, 2005; Schmoch, 2007). The simple analysis in this paper shows the number of publications (articles and proceeding papers), the growth rates in topics, as well as the share of the nations within the topics and clusters in the time frame 2000–2013. Furthermore, relevant key players, organizations and their interconnections are analyzed based on a network analysis with regard to joint publications.

### 3.1. Aging research in the scientific discussion

As mentioned earlier, aging research was classified as a research field that expects outstanding, pioneering knowledge gains in science and technology as well as a considerable contribution to improving people's quality of life in the BMBF Foresight Process I. In the elaboration process it was suggested that the entire process of life and aging should be researched in the future field of »Aging Deciphering«, taking a multi-perspective and trans-disciplinary approach, focussing on the development process from young to old. The following figures present the overall results of a bibliometric analysis for 'aging research', as it is defined in the BMBF Foresight Process I. The focus of this investigation was on biological aging processes, the effects of aging processes in all phases of life and the potential for innovation that could be derived from developments in this area, including topics like age-related diseases, anti-aging measures, measuring age, demographic change, developmental biology, geriatrics, gerontology, regenerative medicine, and silver markets. On this, a comprehensive search strategy for title, keywords and abstracts was elaborated to find relevant publications. To show the overall dynamic in the field of 'aging research' the number of scientific publications over time is shown in Fig. 3. Here, the publications worldwide are compared to the scientific publications in which at least one German author was involved.

Aging research compared to other topics is relatively dynamic. The increased number of publications over around 10 years is due to the most developed topic of 'geriatrics'. All other aspects, like 'gerontology', 'anti-ageing measures' or 'society & ageing' are relatively similar to the initial situation. Many fundamental research questions have not yet been answered, especially the question of how aging processes actually occur, one of the focuses of (bio-)gerontology. This could be an interesting connecting point for further research funding. Similar results are observed regarding publications with at least one German author (fig. 4). The dynamics of the different fields is compared to the dynamics of publications worldwide. With a closer look at the different actors behind these publications, it can be stated, that most of the publications in the field of aging research are coming from organizations in the USA (>40% of publications worldwide) followed by the United Kingdom of Great Britain (~9%), Germany (~7%) and Japan (6%). The scientific institutes, which are frequently involved, are: Harvard University (~24%), University of California Los Angeles (~13%) and University of California San

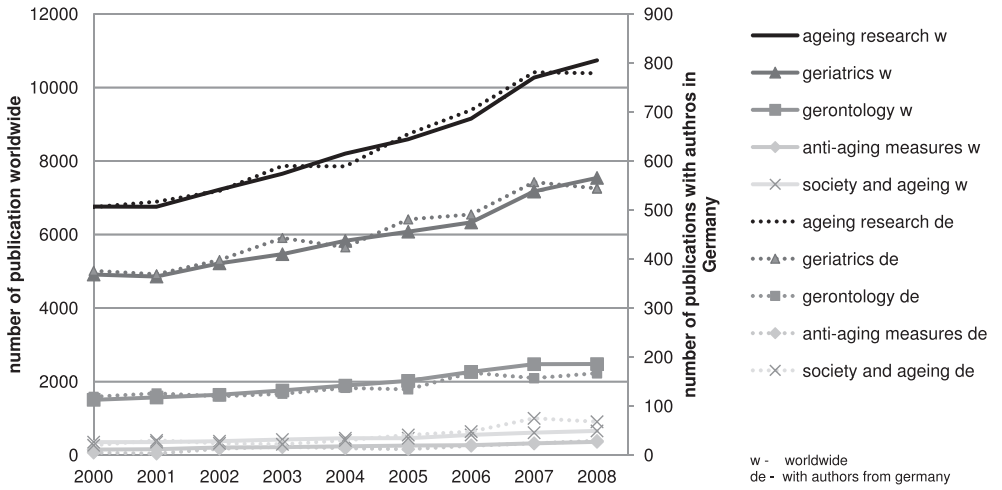


**Fig. 3.** Comparison of the total number of scientific publications in aging research worldwide and with German authors, time horizon 2000–2008 (Source: web of Science, own calculation).

Francisco (~12%). From the German perspective, institutions like the University of Munich (~8%), the University of Heidelberg (~6%) and the University of Bonn (~4%) are mostly listed. A further actor's analysis based on co-publication analysis of scientific publications points out clusters of researcher and the development of networks. For example, based on the scientific publication output of German research institutes the Universities of Florence, Amsterdam or Helsinki are partners in most cooperation's. But the share of co-published scientific articles is very low, not more than 12%.

### 3.2. Aging society and work environment in scientific discussion

To supplement these previous findings we performed a deeper analysis of scientific literature covering specific topics that are related to the aging society and work environment. For this, the following research topics with related aspects were analyzed by using the following listed key words for compiling a search strategy also for title, keywords and abstracts:

- *age related work time model*: aspects like work time models for aging workforces; work time models flexible working arrangements, part-time, and flexible working hours
- *age-related employee loyalty*: aspects like prolonged working life, working past retirement age, anti-retirement, incentives for young professionals, retention of young talent, loyalty and long-term commitment, binding of employees, organizational identification, employee retention, and securing competence
- *age-related training and knowledge transfer*: aspects like aging, learning and working, lifelong learning, specific training opportunities, advanced age-related training offers, increased training and education of junior employee

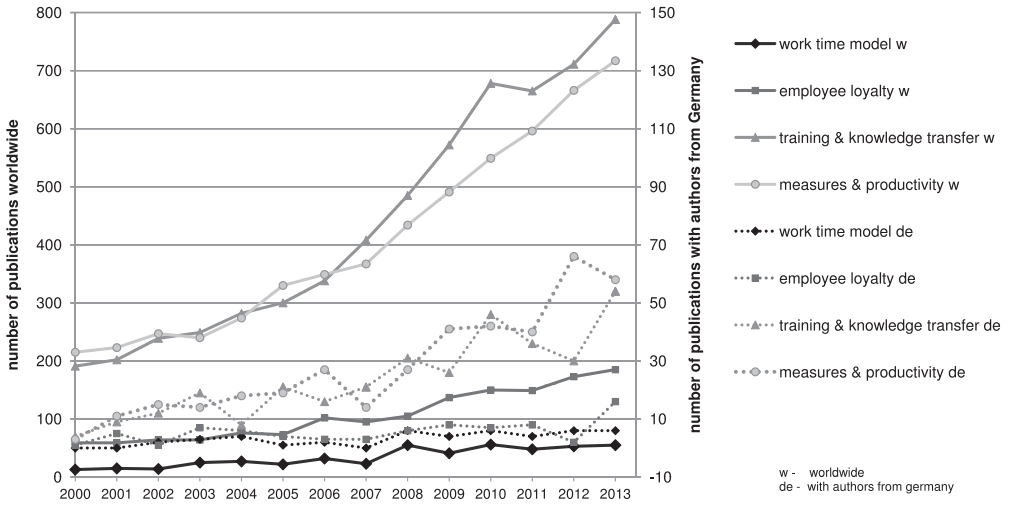


**Fig. 4.** Comparison of the number of scientific publications worldwide and with at least one author in Germany regarding 'aging and work environment', time horizon 2000–2013 (Source: Web of Science, own calculation).

- *age-related measures and productivity*: active aging and productivity; special age-related performance factors, performance appraisal, operation attendance and resource availability information, age-adaptation, and demographic oriented personnel measures.

The number of publications differs significantly between these topics considering the time span 2000 to 2013 (see Fig. 5; with total amount of 9957 publications).[3] Especially, the analyzed field of 'work time model' compared to the other topics like 'training and knowledge transfer', 'measure and productivity' and 'employee loyalty' is underrepresented in the amount of publications. The first two topics are characterized by a relative dynamic, but publications that investigated work–time models and aspects like 'part-time' or 'flexible working-hours models' are constantly on a lower level. A relatively low dynamic can also be observed in the case of 'employee loyalty'. Concepts for binding employees or organizational identification from the perspective of employees are rarely discussed in scientific publications worldwide.

If we are looking at different characteristics of the publications in the field, we see that most of them are written by authors with the following residences: the USA (~40%), followed by the United Kingdom of Great Britain (~12%), Canada (8%), Australia (~7%) and Germany (~6%). From the content perspective it shows that most publications are related to the overall science categories (a classification of journals related to the addressed topics) of 'Neuroscience', 'Education & Educational Research', 'Public Environmental Occupational Health', 'Psychiatry', 'Surgery' and 'Management'. This result is really surprising due to the orientation of the analyzed topics, which address more economical or management issues. Especially, in the field of 'age-related training and knowledge transfer' it can be observed, that most publications are related to the overall subject category of 'Psychology' followed by 'Education & Educational Research', 'Neuroscience' and 'Business & Economics'. This tendency is due to the aspect, that most of the papers are published in journals with a medical or psychological background, like PLOS ONE (open-access, online-publication), Behavioral Brain Research, Academic Medicine or Medical Education. The International Journal of Human Resource Management and the Journal of Knowledge Management are two named journals which obviously deal with management related aspects.

The number of publications with at least one German author is relatively low in the four fields which have been analyzed in detail (see Fig. 5, with total amount of 861 publications). The topic 'training and knowledge transfer' is the only topic that has been relatively positively developed over time. This might be explained by the issue of knowledge management and the related aspects like knowledge sharing and storage, which have been really prominent in the business management community in Germany over the last two decades. Otherwise, in the overall sample, research topics with regard to strategic and innovation activities, technology forecast and foresight activities are hardly mentioned.

The following research institutes are frequently named in the articles: Max Planck Institutes, the Entrepreneurial University Munich, University of Göttingen, University of Heidelberg, and Ruhr University of Bochum. Fig. 5 shows the results of the actors' analysis using co-publication analysis. The co-publication networks on author affiliations were calculated, showing the total degree in a Fruchterman–Reingold network calculated on a co-occurrence matrix. Here the bibliometric information was extracted using a visual basic tool in Excel and Gephi to visualize the network. Besides the involved organizations this analysis also points out clusters of researchers and the development of these networks can be observed.

The analyzed publications addressed different research areas as seen in Table 1. The most addressed areas are 'Psychology', 'Neuroscience Neurology' and 'Business & Economics' the same areas are compared to the analysis of publications worldwide. So, the focus on medical and psychological related journals is also observed in the publications with at least one German author. Furthermore, scientific networks measured by co-publications exist with institutes from the USA, the United Kingdom of Great Britain, the Netherlands, Switzerland, France and Italy. The analysis of the cooperation activities based on the institutional level points out of the following partner research institutions: University of California, Harvard University, Catholic University Leuven, and University of Melbourne.

The analysis of publications elaborated the most important research experts and their scientific networks in the field of aging society and work environment. Furthermore, the main relevant research areas as well as the scientific journals which are used by the researcher were analyzed. It is shown that the selected research fields are represented differently in the scientific community and especially the topic of knowledge management and training is well established. As presented in the next chapter, necessary future cooperation and the transfer of research results between the science and industry were noted, due to the underrepresented personnel measures in this specific topic.

## 4. Aging society and the innovation system — the industry perspective

With regard to the diffusion and practical application of new organizational concepts and HR practices, industry firms are one of the most important actors within the national innovation system. From the theoretical perspective, the industrial innovation sub-system is influenced by the demand system, which it influences at the same time, the framework conditions and the existing infrastructure system and is shaped by the political system (Koschatzky, 2012, p. 9). This chapter discusses the general challenges for manufacturing enterprises regarding the aging workforce by presenting empirical evidence from the German manufacturing industry with respect to their ongoing activities in the field of demographic-oriented personnel measures.

### *4.1. Aging society and aging workforce*

To maintain their competitive advantage, firms are increasingly facing the need to innovate and to implement their novelties successfully according to their specific internal and external framework conditions. To achieve this goal, the human resource base of the firm and its incorporated stock of

[3] A comparative bibliometric analysis in Scopus shows very similar findings regarding the development and dynamics of the four research topics.

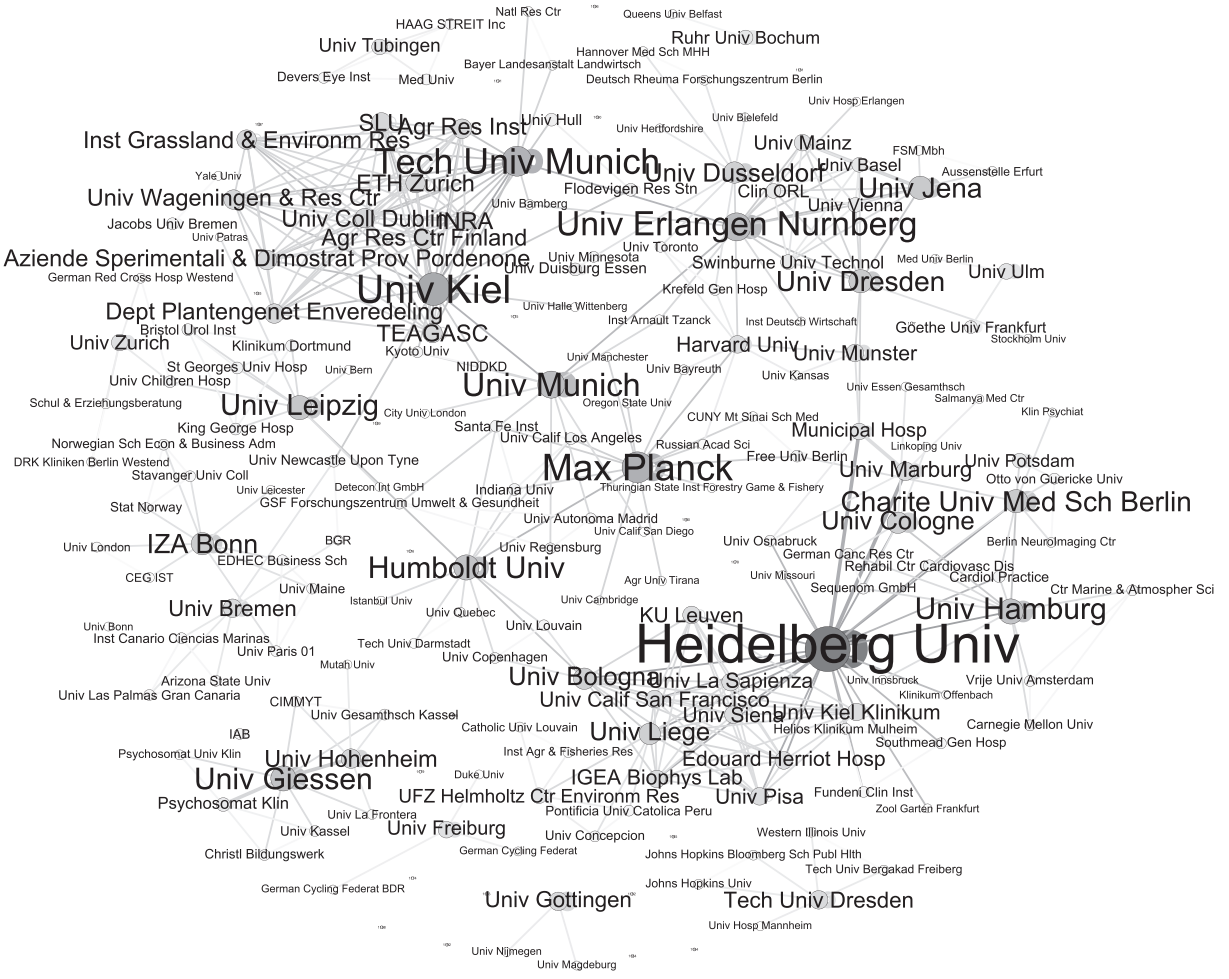


**Fig. 5.** Research network on the topic 'aging and work environment' in total based on co-publication, time horizon 2000–2013 (Source: Web of Science, own calculation).

innovation knowledge and competencies is one of the most important prerequisites (Wernerfelt, 1984; Barney, 1991; Foss, 1996; Grant, 1996). Against this backdrop, enterprises are increasingly confronted with the grand challenge of demographic change and their related developments 'decreased population' and 'aging population' today (under the ceteris paribus conditions of birth rate, migration pattern and life expectancy). The demographic change is accompanied by both external (market or demand) and internal (personnel resources, knowledge) consequences for enterprises. Firstly, from the external perspective, the average age of their customers is constantly increasing and the number of young costumers is decreasing. Moreover, the distribution of purchasing power will very much shift towards older consumers in the future. Simultaneously, the demands and needs of older consumers are changing according to their living situations. Thus, firms are increasingly facing the challenge to adapt their products and services accordingly. Secondly, the internal consequences of demographic change become especially visible by the increased average age of employees, the labor shortage in particular disciplines, problems in recruiting junior staff/junior employees and increased retirement of experienced staff. Consequently, enterprises have to deal with the changing conditions regarding their human resources and have to develop and implement appropriate concepts and approaches to deal with this situation.

Asking about the main obstacles which stop older people from working, the Eurobarometer 2012 survey on active aging showed that the lack of opportunities available to reduce working hours gradually, the exclusion from vocational training as well as the fact that older employees are not viewed positively by employers are regarded as the most severe

**Table 1**
Characteristics of publications with at least one German author, time horizon: 2000–2013.
(Source: Web of Science, own calculation)

| Research area | Share of % | Co-publication — country | Share of% |
|---|---|---|---|
| Psychology | 16% | USA | 12% |
| Neurosciences neurology | 16% | England | 9% |
| Business economics | 12% | Netherlands | 6% |
| Environmental sciences ecology | 6% | Switzerland | 6% |
| Psychiatry | 5% | France | 5% |
| Geriatrics gerontology | 4% | Italy | 4% |

barriers by about 70% of European citizens (EC, 2012, pp. 47). Additionally, the lack of skills for the modern workplace (62%) and the insufficient adaption of the workplaces to the needs of older employees (57%) are named as further important obstacles for working at an advanced age. With respect to the foreseen development of the German working society, the working population in Germany will shrink from 50 million individuals in 2010 to just 33 million individuals in 2060 ( BMI, 2011, p. 36). This underlines the sobriety of the demographic shift in the workforce as one of the major challenges for the German industry. It will be a decisive factor whether and how German industrial firms are able to deal with this trend, for instance by finding and implementing new solutions both on the organizational level as well as on the technological level.

Due to the identified obstacles, the changing age structure and the associated lack of skilled professionals, managers need to adapt their human resource strategy to these developments. Elaborated sustainable concepts for personnel binding, training and further education, workplace design, personnel planning, health management etc. are necessary to handle these challenges (Brooke and Taylor, 2005; Naegele and Walker, 2006; Zaeh and Prasch, 2007; Streb et al., 2009; Ilmarinen, 2012). Demographic-oriented personnel measures are aimed at a long-term improvement of the personnel structure and securing the supply of skilled labor. This long-term character carries the risk that it falls victim to short-term optimizations. Based on firm-level data of the German manufacturing industry conducted by the Fraunhofer ISI, this section provides an overview of the degree by which such organizational measures addressing the aging workforce are already deployed today on the industrial level in Germany.

### 4.2. Aging workforce and demographic-oriented personnel measures

#### 4.2.1. The database: German Manufacturing Survey

The findings presented in this section are based on a secondary analysis of 2009 data from the *German Manufacturing Survey* that has been regularly conducted by the Fraunhofer Institute for Systems and Innovation Research (ISI) since 1993. The objective of this questionnaire-based postal survey conducted in Germany is to systematically monitor innovation and modernization processes in manufacturing industries. Besides others, the survey mainly addresses the following topics: implementation of innovative manufacturing technologies, new organizational concepts in the fields of work organization and HR management, cooperation activities, outsourcing and globalization of production, performance indicators as well as product-related services. In the 2009 survey one of the focus was on the realization of innovative organizational concepts like strategic personnel measures in the form of demographic-oriented HR management. The survey includes firms with 20 or more employees from the manufacturing sectors, like the NACE 15–37. In 2009, 15,576 firms in manufacturing industries in Germany were invited to participate, 1484 of which returned usable replies, a response rate of 10%, based on the adjusted net sample. The dataset represents a valid cross-section of the manufacturing sectors (e.g. manufactures of metal products (28) 17%, mechanical engineering (29) 19%, manufacture of rubber and plastic goods (25) 9%, chemical industry (24) 5%, paper industry (21) 2%) and the realized sample differs only insignificantly in its branch distribution from the population.

#### 4.2.2. Strategic personnel measures to counter demographic change

Basically, there are two main levels on which the management of firms can address different measures: personnel recruitment and knowledge transfer & sharing. First, the reduced number of qualified junior staff aggravates the recruitment of sufficient and well-qualified workers. Second, the increasing retirement of older workers connects with the issue of securing and sharing their huge practical knowledge and experiences. So, fewer junior employees and less experience-based knowledge could lead to the limited capability to develop new products and services and ultimately to endanger commercial success and workplaces in the long term.

The following empirical analysis focuses on the implementation of strategic demographic-oriented personnel measures and their relationship to the innovation performance of firms. Against this background, the following question arises: to which extent have HR measures and concepts which address demographic change have been diffused today in German industry? To what degree does the use and implementation of such HR concepts affect the innovation ability of manufacturing firms? According to the available concepts in the EMS data, the following measures and concepts were included in the analysis:

- increased training for junior employees
- incentives for binding junior employees
- instruments for storing the knowledge of older employees
- specific working time models for older employees
- particular health management programs for older employees
- specific personnel resource planning for older employees
- specific performance factors for older employees
- specific further training offers for older employees.

First of all, the findings underline the high relevance of the demographic issue. About 75% of the surveyed companies have already introduced at least one of the eight included demographic-oriented personnel actions. One-third of the enterprises have even established three or more of these measures in parallel. The comparison of the distribution of demographic-oriented personnel measures shows that increased training of junior employees and new incentives to bind qualified junior employees (e.g. premiums or family-friendly working hours) are most widespread concepts (see Fig. 6).

Additional education and additional incentives for retaining junior staff are implemented more frequently than personnel actions that deal with measures for older workers. Therefore, the demographic-oriented personnel measures in the interviewed manufacturing firms address more the restricted number of junior employees than the larger number of elderly workers. One reason for this could be that personnel measures for young employees are more standardized because of the greater similarity of this group with regard to general personnel management in terms of qualification, health condition, vocational career, and motivational structure. However, older employees are more distinguishable in these characteristics from each other. So, measures for elderly people are often individually negotiated and are not recognized as personnel measures in the firm. This would mean that the different

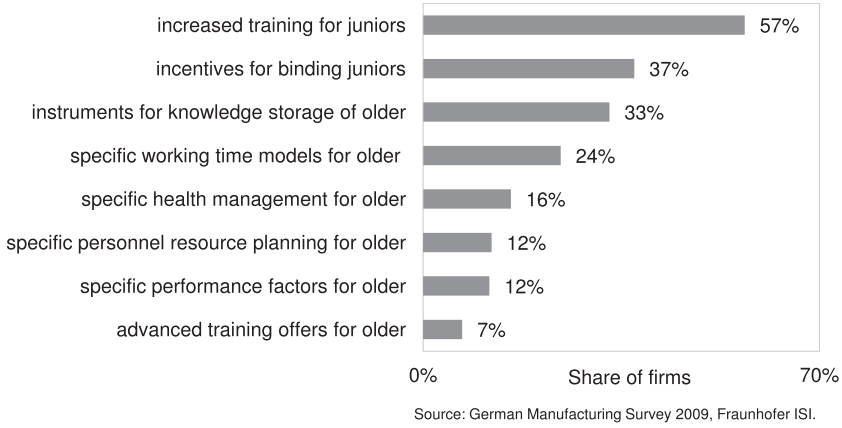


**Fig. 6.** Dissemination of demographic-oriented personnel measures (Source: *German Manufacturing Survey* 2009, Fraunhofer ISI).

demographic-oriented or specific concepts are not integrated in an overarching and sustainable concept which deals with the challenge of demographic change as part of the human resource management.

With regard to firm size (Fig. 7), it can be expected, that larger firms (LE) with more than 250 employees have a higher demand of demographic-specific measures due to the larger number and diversity of employees alone (see Schat and Jäger, 2010 pp. 4). But, specific further education concepts for older employees are the least frequently measure in both groups, large enterprises and SMEs (medium sized enterprises). However, the share of large enterprises that offer specific health management programs is with 40% considerably higher than the share of SMEs (11%). The findings with regard to the specific working time models for elderly people are similar. 44% of the large enterprise and 21% of SMEs offer these kinds of measures to their employees. Only approximately 55% of SMEs have focused on the increased training of young professionals, however, more than two thirds of larger firms are active in this field. In fact, it is surprising; due to the under-representation of SMEs on the labor market and their image, that medium-sized firms are dependent on specific measures for the recruitment of qualified young professionals in order to deal with the future challenge of skill shortages.

On the one hand, these findings once again stress the relevance of demographics for both groups of firms. The

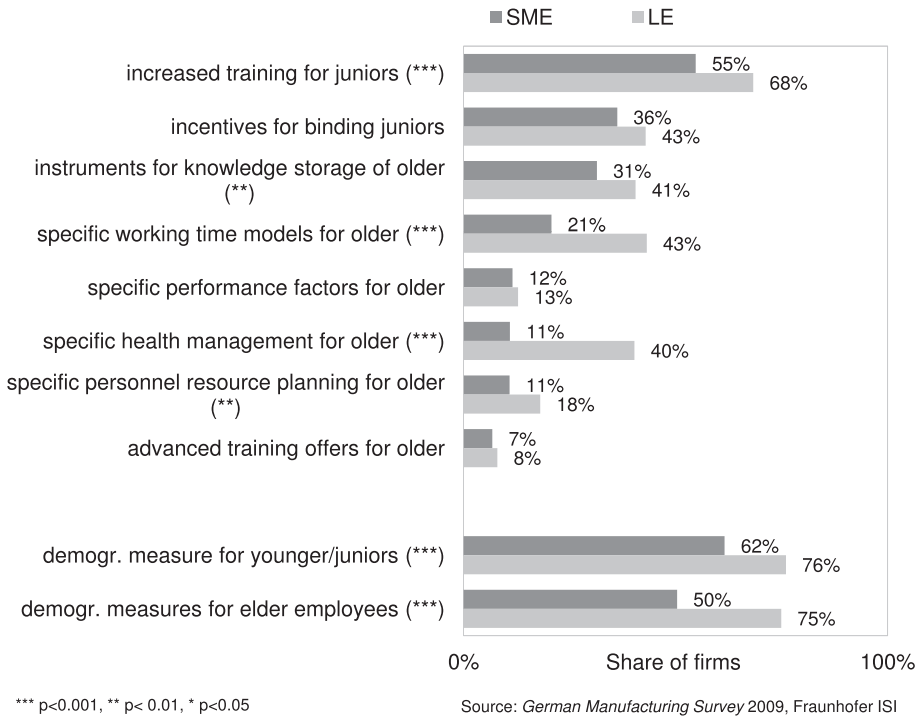


**Fig. 7.** Use of demographic-oriented HR measures by firm size (Source: *German Manufacturing Survey* 2009, Fraunhofer ISI)[4]. [4]Significance of differences between SME and LE has been tested by t-tests.

majority, half of SMEs and LEs respectively, report that they are using one or more of these HR measures to address demographic change. On the other hand, however, it seems that SMEs face more difficulties in implementing such HR measures. Unfortunately, the survey did not ask about the relevance or concernment to implement such measures for the different groups of firms. Then it would have been possible to crosstab the relevance and the realized implementation which would have provided an additional insight with regard to the existence of the prevalence of possible barriers. But it can be reasonably assumed that SMEs are even more strongly affected by demographic dynamics as they (due to their limited resource endowment) are not able to compete with larger firms in attracting the scarcer group of high-skilled employees in the future. Thus, future studies should investigate the reasons why SMEs today seem to be less able to implement such demographic-oriented HR concepts.

Following the resource-based line of argumentation, the securing of the valuable knowledge resources of older employees is supposed to play an important role in maintaining the innovativeness and competitiveness of firms. Thus, the following analysis sheds some light on this aspect. As can be seen from Fig. 8 there is a positive correlation between the implementation of demographic-oriented personnel measures and the firms' innovation successes measured by the successful introduction of a new or significantly improved product within the past three years.

Most prominently, there is a positive correlation between the use of demographic-oriented personnel measures both for younger and older employees and product innovation for the group of non-R&D performing firms. Interestingly, this positive effect vanishes as soon as the firm performs R&D, regardless of the intensity of R&D activities. There might be several reasons to explain this. Firstly, the innovation ability of non-R&D performing firms relies much more on exactly the kind of knowledge that is mainly represented by older employees: practical and experience-based stocks of innovation knowledge (Bender, 2006; Som et al., 2010; Som, 2012). Knowledge management approaches, for example, storing and sharing knowledge and experiences are important for the diffusion and market placement of new products. Secondly, as soon as R&D as an institutionalized process of formal knowledge creation comes into play, practical and experience-based knowledge might be internally fed into these R&D processes. In this case, the positive relationship between demographic-oriented HR measures and product innovation might be more of an indirect nature. This has to be further investigated by future research. Interestingly, HR measures aiming at younger employees show the same pattern. While there is a direct and positive relationship in non-R&D performing firms, no significant differences can be found for R&D performing firms using or not using such measures. Again, this could be due to the changing nature of the relationship from a direct effect to an indirect effect that is blurred or moderated either by internal R&D or – as R&D performers can be more frequently found among larger enterprises – other existing HR measures such as training and education programs.

To summarize this brief overview, companies are challenged by the reduced population of workers as well as by their aging workforces in the future. As mentioned before, the conducted analyses provide information about the implementation of specific measures related to the demographic challenge as well as how they might be related to operational framework conditions and innovation performance in the German manufacturing industry. The analysis shows that most of the companies are more focused on the challenge of the lack of young professionals than on the problem of increased older qualified personnel. The findings are comparable with existing studies (see e.g. Bellmann and Leber, 2008). It has been shown that firms offer limited specific personnel measures for older employees, at the same time it indicates that measures for older employees are significantly positively related to the firm's innovation ability regarding new products, especially for firms without R&D activities. From the HR management perspective, the prevailing focus on younger employees can be questioned in the future. Instead, it would be more promising to extend existing HR measures to all groups of employees and their specific needs along their individual life and working situation. As some authors argue, HR management should become more

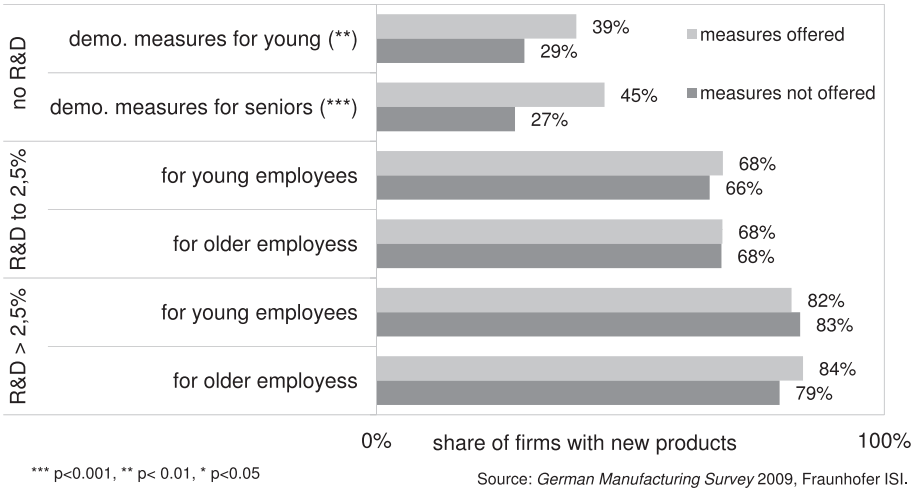


**Fig. 8.** Demographic-oriented HR measures and product innovation (Source: *German Manufacturing Survey* 2009, Fraunhofer ISI)[5]. [5]The statistical significance of the differences between the different groups of R&D-intensity has been tested by t-tests.

holistic, intergenerational and life-phase oriented to cover future oriented approaches like job design, enabling people of different ages to work, age-diverse work teams and active recruitment (Muller-Camen et al., 2011; Streb et al., 2009; Armstrong-Strassen, 2008). Nevertheless, this chapter can only provide a first insight into the diffusion and effects of demographic-oriented HR measures. Future research is needed to deepen our understanding of the determinants, mechanisms and barriers of both the use and the effects of such HR measures in firms.

## 5. Discussion and summary

The overall objective of this paper was to give an overview of the issue of active aging and the special aspect of the work environment. The conceptual framework of the innovation system approach was used focussing on the three main subsystems: policy, science, and industry. For this, an inventory with regard to the main sub-elements has been carried out. It may be noted that in each of the three areas varied priorities for action are given on the subject of an aging society.

In more detail, the policy perspective was characterized as being responsible for institutional settings in different forms, e.g. laws, standards, and initiatives. Here, the detailed analysis focuses on the research and innovation activities in Germany. It could be determined that a multitude of research agendas, funding activities and initiatives, conducted in the last 15 years were related to the topic of demographic change and aging society. Especially the BMBF as well as the BMFSFJ were instrumental for these measures. Only since 2012 a comprehensive 'demographic strategy' in Germany is proposed. But, a normative turn in innovation policy that created a demand for different types of innovation patterns as well as for further development of policy instruments could be observed. 'Aging society' identified as one of the 'grand challenges of our time' could be one important starting point for the necessary changes in research, technology and innovation policy.

The analyses of scientific publications give an overview of the scientific communities which are involved in aging research as a whole and especially in research activities that deal with topics of aging society and work environment. Knowledge management activities as well as training and education concepts were relatively frequently discussed in scientific articles compared to aspects like organization of working time. It appears that the science community has not attributed to a central contribution to deal with the challenge of an aging society respectively aging workforces in the corporate context. But, if we remember the results of the survey Eurobarometer 2012, precisely those kinds of obstacles were named that discourage older employees from staying in their working environment. To enhance the employability of elderly people will be one important future research topic. Furthermore, creative as well as foresight activities in firms, like environmental scenarios, technology and product roadmapping or technology scanning or scouting processes, were hardly mentioned in the publication. Hence, there could be a point for further research activities in the future, that deals with the influence of older workforces on foresight related actions in the firm's environment.

Based on the *German Manufacturing Survey* 2009 it has been shown, that many firms have implemented demographic specific measures despite the economic crisis. When analyzing eight selected concepts it became clear that additional training and incentives for binding young professionals are implemented in many firms. However, it can be seen that firms are still a bit reluctant in terms of personnel measures for older employees. Especially, in the field of age-specific training and further education it can be observed that firms are not yet able to assess the potential of these measures for their sustainable success. On that basis, future scientific research activities could arise which deal with the question, whether and under what conditions age-specific training or age-mixed training teams are purposeful and learning success can be achieved. Furthermore, it has also been shown that the firm's intensity of research and development activities has mainly an impact on the development of personnel measures specifically for older employees. A high intensity of research activity of an industry goes hand in hand with more binding and training for the older workforces. On the other hand, there is a positive relationship between the successful development of product innovation and the use of demographic-specific measures in firms without research and development activities. But exactly for this reason, non-research intensive firms could stand out clearly with regard to the product innovation ability from the competition with such kinds of personnel concepts.

The innovation system is characterized as a social process of negotiation which is only successful by a sustained interaction of the sub-elements. In the synopsis of the above-mentioned results it should be noted, that the weakness of the innovation system is more likely in a diffusion problem from science to industry and in an adaption problem from the industry. As mentioned before the scientific community has enhanced discussion of different concepts and approaches related to aging workforces. However, the industry is mainly focusing on concepts for binding young professionals. The demographic change and active aging aspects are fully underrepresented compare to the technological funding programs. Consequently, scientific findings diffuse insufficiently into the enterprises or the awareness regarding the grand challenges and solutions is not adequately pronounced. Therefore, it should be noted that the political design possibilities are not adequately exploited. Connecting factors for the knowledge transfer of existing concepts and approaches in the industrial application could be changing incentive scheme in the research programs and funding activities. So, the topic of active aging or demographic specific aspects could attach more importance within the mentioned technology funding priorities. They could be an integrated part of the technological orientated future projects, so that technical and non-technical aspects especially demographic aspects are considered from the beginning. Furthermore, direct measures like collaborative projects which are enable to develop tailor-made solutions for the industrial project partners are promising approaches. Here the first initial steps can be stated, but the comprehensive integration of this topic in the science, technology and research policy is limited.

## 6. Limitations and future research

The inventory of the three main elements in an innovation system could only focus on selected aspects in the different fields. The effects of the different mechanisms of development and interactions between these elements are not discussed in detail. So, the comparison of funded

projects and their research results as well as their scientific publications and implementation in a firm's environment could be a starting point for further research. The qualitative analysis of the policy perspective has focused on the funding activities, especially by the BMBF, over the last decades. It can be stated that various activities have taken place, but a statement regarding the delivery in a quantitative way has not been made. A detailed analysis of the funding programs by different ministries and with different research priorities can provide further information about the visibility and importance of the issue 'demographic change'. The industry perspective was presented through research results from the *German Manufacturing Survey* 2009: An analysis of the importance of demographic specific measures as well as their interrelation to the innovation capability of a firm was conducted. Based on this, further analysis would be possibly related to different types of innovation, like service, marketing or process innovation, which have to be considered in the discussion about the innovation performance of a firm. As mentioned before, future research is needed to deepen the understanding about the determinants, mechanisms and barriers of both the use and the effects of such HR measures in firms. Furthermore, the survey of panel data could be helpful for the analysis of the development of corresponding concepts over time and their dynamics. In addition, from the content perspective, the topic of organization of working time could be stated as one important starting-point for further research activities, which address both the demand of citizens and the needs for those concepts in the industry. As mentioned before, aspects like foresight and aging society are barely mentioned both in the scientific community and on the innovation policy level. To accomplish the demographic change and its effects, all key actors of the innovation system should contribute to the grand challenge of 'aging societies' in a comprehensive and appropriate way. Consequently, to reach this goal, information exchange and detailed discussions between the different actors are important for future activities about their concerns, needs and essential framework conditions are necessary and its implementation is just at the beginning.

## References


Ácsa, Z.J., Autiob, E., Szerb, L., 2014. National systems of entrepreneurship: measurement issues and policy implications. Res. Policy 43, 476–494.

Ahmad, N., Hoffmann, A., 2008. A Framework for Addressing and Measuring Entrepreneurship. SSRN eLibrary.

Allmendinger, J., Ebner, C., 2006. Arbeitsmarkt und demografischer Wandel. Z. Arbeitsmarkt Organ. Psychol. A&O 50 (4), 227–239.

Arlt, A., Dietz, M., Walwei, U., 2009. Besserung für Ältere am Arbeitsmarkt — Nicht alles ist Konjunktur. Institut für Arbeitsmarkt- und Berufsforschung, IAB Kurzbericht 16.

Armstrong-Strassen, M., 2008. Organisational practices and the post-retirement employment experience of older workers. Hum. Resour. Manag. J. 18 (1), 36–53.

Arundel, A., 2007. Innovation Survey Indicators: What Impact on Innovation Policy? In: OECD (Ed.), OECD publishing, Paris, pp. 49–64.

Baltes, P.B., 2002. Stellungnahme für den Deutschen Bundestag: Ausschuss für Bildung, Forschung und Technologiefolgenabschätzung: Thema: Alternsforschung.

Barney, J., 1991. Firm resources and sustained competitive advantage. J. Manag. 17 (1), 99–120.

Bellmann, L., Leber, U., 2008. Weiterbildung für Ältere in KMU. Sozialer Fortschr. 57 (2), 43–48.

Bender, G., 2006. Peculiarities and relevance of non-research-intensive industries in the knowledge-based economy. Final Report of the Project 'Policy and Innovation in Low-Tech – Knowledge Formation, Employment & Growth Contributions of the 'Old Economy' Industries in Europe – PILOT'. Technische Universität Dortmund.

Bertelsmann, Stiftung, 2013. European policy center. Second Career Labour Markets Assessing Challenges — Advancing Policies. Gütersloh, Brussels (http://www.bertelsmann-stiftung.de/cps/rde/xbcr/SID-7D0BEEBD-E364F1BC/bst_engl/xcms_bst_dms_38023_38024_2.pdf, accessed May 30, 2014).

Bescheikh, N., Landry, R., Nabil, A., 2006. Lessons from innovation empirical studies in the manufacturing sector: a systemic review of the literature from 1993–2003. Technovation 26, 644–664.

Brooke, L., Taylor, P., 2005. Older workers and employment: managing age relations. Ageing Soc. 25 (3), 415–429.

Bundesministerium des Innern — BMI, 2011. Demografiebericht. Bericht der Bundesregierung zur demografischen Lage und künftigen Entwicklung des Landes, (Berlin).

Bundesministerium des Innern — BMI, 2012. Jedes Alter zählt. Demografiestrategie der Bundesregierung. (Berlin, http://www.bundesregierung.de/Webs/Breg/DE/Themen/Demografiestrategie/Basis-Artikel/2012-04-18-artikel-top-basis.html, accessed May 19, 2014).

Bundesministerium für Bildung und Forschung — BMBF, 2000. Rahmenkonzept. Innovative Arbeitsgestaltung — Zukunft der Arbeit. (Berlin, http://pt-ad.pt-dlr.de/de/502.php, accessed May 19, 2014).

Bundesministerium für Bildung und Forschung — BMBF, 2007. Arbeiten – Lernen – Kompetenzen entwickeln. Innovationsfähigkeit in einer modernen Arbeitswelt: BMBF Forschungs- und Entwicklungsprogramm. (Berlin, http://www.pt-ad.pt-dlr.de/_media/Broschuere_Arbeiten-Lernen-Kompetenzen-entwickeln.pdf, accessed May 19, 2014).

Bundesministerium für Bildung und Forschung – BMBF, 2011. The New Future of Old Age. The Federal Government´s Research Agenda for Demographic Change. , (Berlin/ Bonn, http://www.das-alter-hat-zukunft.de/en/alter_hat_zukunft_en.pdf, accessed May 23, 2014).

Bundesministerium für Bildung und Forschung — BMBF, 2014a. Projektförderung des BMBF nach Ländern und Förderschwerpunkten. Statistiken des BMBF. (Berlin, http://foerderportal.bund.de/foekat/jsp/StatistikAction.do?actionMode=renderPDF&type=pdirfoe&ressort=BMBF, accessed May 23, 2014).

Bundesministerium für Bildung und Forschung — BMBF, 2014b. Bundes Mittel des BMBF nach Förderbereichen/Förderschwerpunkten und Empfängergruppen, Einzelplan 30. Zuordnung der Empfängergruppen über die Ausführenden Stellen. Statistiken des BMBF, Berlin (http://foerderportal.bund.de/foekat/jsp/StatistikAction.do?actionMode=renderPDF&type=foegeswz&ressort=BMBF, accessed May 23, 2014).

Bundesministerium für Familie, Senioren, Frauen und Jugend — BMFSFJ, 2006. Aktuelle Forschung und Projekt zum Thema Demenz. http://www.bmfsfj.de/BMFSFJ/aeltere-menschen,did=126706.html (Berlin, accessed May 19, 2014).

Bundesministerium für Familie, Senioren, Frauen und Jugend — BMFSFJ, 2008. Studie — Erfahrung rechnet sich. Aus Kompetenzen Älterer Erfolgsgrundlagen schaffen. , (Berlin).

Cuhls, K., Bayer-Kutzner, A., Ganz, W., Warnke, P., 2009a. The methodology combination of national foresight process in Germany. Technol. Forecast. Soc. Chang. 76, 1187–1197.

Cuhls, K., Ganz, W., Warnke, P. (Eds.), 2009b. Foresight Process – On Behalf of the German Federal Ministry of Education and Research – New Future Fields (Karlsruhe).

Djankov, S., La Porta, R., Lopez-de-Silanes, F., Shleifer, A., 2002. The regulation of entry. Q. J. Econ. 117, 453–517.

Dosi, G., Freeman, C., Nelson, R., Silverberg, G., Soete, L. (Eds.), 1988. Technological Change and Economic Theory. Pinter Publishers, London.

EC — European Commission, 2012. Active ageing. Report, Special Eurobarometer 378 (http://ec.europa.eu/public_opinion/archives/ebs/ebs_378_en.pdf, accessed May 20, 2014).

Edquist, C., 2005. Systems of innovation: perspectives and challenges. In: Fagerberg, J., Mowery, David C., Nelson, Richard R. (Eds.), *The Oxford handbook of innovation* Oxford. Oxford University Press, New York.

Frietsch, R., Kroll, H., 2010. 'Recent trends in Innovation Policy in Germany. In: Frietsch, R., Schüller, M. (Eds.), Competing for Global Innovation Leadership: Innovation Systems and Policies in the USA. Europe and Asia. Fraunhofer Verlag, Stuttgart, pp. 73–92.

Foss, N.J., 1996. Knowledge-based approaches to the theory of the firm: some critical comments. Organ. Sci. 7 (5), 470–476.

Görgen, T., Nägele, B., Kotlenga, S., Fisch, S., Kraus, B., Rauchert, K., 2012. Sicher leben im Alter – Ein Aktionsprogramm zur Prävention von Kriminalität und Gewalt gegenüber alten und pflegebedürftigen Menschen. Bericht an das BMFSFJ. http://www.dhpol.de/de/hochschule/Fachgebiete/silia_abschluss.php (accessed May 19, 2014).

Grant, R.M., 1996. Toward a knowledge-based theory of the firm. Strateg. Manag. J. 17, 109–122.

Grupp, H., 1997. Messung und Erklärung des Technischen Wandels: Grundzüge einer empirischen Innovationsökonomik. Springer-Lehrbuch, Berlin, Heidelberg.
Grupp, H., Schmoch, U., 1991. Technologieindikatoren — Aussagekraft, Verwendungsmöglichkeiten, Erhebungsverfahren. In: Bullinger, H.-J., Fähnrich, K.-P. (Eds.), Handbuch des Informationsmanagements im Unternehmen. Bd.II : Technik, Organisation, Recht, Perspektiven. Beck, München, pp. 1571–1615.
Gruss, P., 2007. Die Zukunft des Alterns: Die Antwort der Wissenschaft; [ein Report der Max-Planck-Gesellschaft]. Beck, München.
Havemann, F., 2009. Einführung in die Bibliometrie. 1. Aufl.: Ges. für Wiss.-Forschung c/o Inst. für Bibliotheks- und Informationswiss, Berlin.
Ilmarinen, J., 2012. Promoting Active Ageing in the Workplace. European Agency for Safety and Health at Work, (https://osha.europa.eu/en/publications/articles/promoting-active-ageing-in-the-workplace/view, accessed May 30, 2014).
Kalache, A., Kickbusch, I., 1997. A global strategy for healthy ageing. World Health 50 (4), 4–5.
Koschatzky, K., 2012. Fraunhofer ISI'S systemic research perspective in the context of innovation systems. Innovation System Revisited — Experiences from 40 years of Fraunhofer ISI Research. Fraunhofer Verlag, Stuttgart, pp. 1–24.
Kuhlmann, S., Arnold, E., 2001. RCN in the Norwegian Research and Innovation System: Background Report No. 12 in the Evaluation of the Research Council Norway. Fraunhofer ISI, Karlsruhe/Brighton.
Lehr, U., 2003. Psychologie des Alterns. Quelle & Meyer, Wiebelsheim.
Lichtenthaler, E.R.V., 2002. Organisation der Technology intelligence: Eine empirische Untersuchung der Technologiefrühaufklärung in technologieintensiven Grossunternehmen. Technology, innovation and management Bd. 5. Verlag Industrielle Organisation, Zürich.
Lund Declaration, 2009. Europe Must Focus on the Grand Challenges of our Time. http://www.kooperation-international.de/detail/info/the-lund-declaration.html (Lund, accessed May 22, 2014).
Lundvall, B.A., 1992. National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning. Printer Publisher, London.
Moed, H.F., 2005. Citation analysis in research evaluation. Information Science and Knowledge Management vol. 9. Springer, Dordrecht.
Moed, H.F., Burger, W.J.M., Frankfort, J.G., Van Raan, A.F.J., 1985. The use of bibliometric data for the measurement of university research performance. Res. Policy 14 (3).
Muller-Camen, M., Croucher, R., Flynn, M., Schröder, H., 2011. National institutions and employers' age management practices in Britain and Germany: 'path dependence' and option exploration. Hum. Relat. 64 (4), 507–530.
Naegele, G., Walker, A., 2006. A Guide to Good Practice in Age Management. European Foundation, Dublin.
Nederhof, A.J., van Raan, A.F.J., 1993. A bibliometric analysis of six economics research groups: a comparison with peer review. Res. Policy 22 (4), 353–368.
Nelson, R.R., 1993. A retrospective. In: Nelson, R.R. (Ed.), A Comparative Analysis. Oxford University Press, New York, pp. 505–523.
Nelson, R.R., Rosenberg, N., 1993. Technical innovation and national systems. In: Nelson, R.R. (Ed.), National Innovation Systems. A Comparative Analysis. Oxford University Press, New York, pp. 3–21.
Opaschowski, H.W., 2009. Vision Deutschland. Neue Wege in die Welt von morgen. Forsch. Aktuell 30 (215), 1–7.
Pack, J., Buck, H., Kistler, E., Mendius, H.G., Morschhäuser, M., Wolff, H., 2000. Zukunftsreport demographischer Wandel. Innovationsfähigkeit in einer alternden Gesellschaft, Bonn.
Patel, P., Pavitt, K., 1994. The nature and economic impact of national innovation systems. STI Rev. 9–32.
Reynolds, P.D., Bosma, N., Autio, E., 2005. Global entrepreneurship monitor: data collection design and implementation 1998–2003. Small Bus. Econ. 24, 205–231.
Roloff, N., Beckert, B., 2006. Staatliche Förderstrategien für die Neurowissenschaften: Programme und Projekte im internationalen Vergleich. Hintergrundpapier/TAB 15. Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag, Berlin.
Schat, H.D., Jäger, A., 2010. Einfluss demografischer Entwicklungen in Betrieben auf deren Innovationsfähigkeit. Mitteilung aus der ISI Erhebung 58. Fraunhofer ISI.
Schmoch, U., 2007. Double-boom cycles and the comeback of science-push and market-pull. Res. Policy 36 (7), 1000–1015.
Som, O., 2012. Innovation without R&D — Heterogeneous Innovation Patterns of Non-R&D-Performing Firms in the German Manufacturing Industry. Springer, Gabler, Wiesbaden.
Som, O., Kinkel, S., Kirner, E., Buschak, D., Frietsch, R., Jäger, A., Neuhäusler, P., Nusser, M., Wydra, S., 2010. Zukunftspotenziale und Strategien von nichtforschungsintensiven Industrien in Deutschland – Auswirkungen auf Wettbewerbsfähigkeit und Beschäftigung. Innovationsreport Nr. 140, Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag, Berlin.
Streb, C., Voelpel, S., Leibold, M., 2009. Ageing workforce management in the automobile industry: defining the concept and its constituting elements. Z. Pers. 23 (1), 8–27.
Van Raan, A.F.J., 2004. Capita selecta of current main issues. In: Moed, H.F., Glänzel, W., Schmoch, U. (Eds.), Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems. Kluwer, Dordrecht, Boston/London, pp. 19–55.
Vollmar, H.C., Georgieff, P., Cuhls, K., 2011. 'Das Altern entschlüsseln – Ausschnitte des BMBF-Foresight Prozesses'. Zeitschrift für Gerontologie und Geriatrie 44, 66–70.
Walker, A., 2006. Active ageing in employment: its meaning and potential. Asia Pac. Rev. 13 (1), 78–93.
Wernerfelt, B., 1984. A resource-based view of the firm. Strateg. Manag. J. 5 (2), 171–180.
WHO — World Health Organisation, 2002. Active Ageing. A Political Framework. http://whqlibdoc.who.int/hq/2002/who_nmh_nph_02.8.pdf (Geneva, accessed May 20, 2014).
Zaeh, M.F., Prasch, M., 2007. Systematic workplace and assembly redesign for ageing workforces. *Production engineering*. Res. Dev. 1 (1), 57–64.
Zahn-Elliot, U., 2001. Demographischer Wandel und Erwerbsarbeit. In: Bullinger, H.J. (Ed.), Zukunft der Arbeit in einer alternden Gesellschaft. Fraunhofer IRB Verlag, Stuttgart, pp. 7–10.

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