Technological Forecasting & Social Change 152 (2020) 119907

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

The value of PhD in the changing world of work: Traditional and alternative research careers

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ARTICLE INFO

Keywords:
Career
Research and development personal
Labor market
Career achievements

ABSTRACT

The paper considers career patterns of researchers and the ways to assess their career achievements on the academic and non-academic labor markets. Taking into account the approaches developed earlier in the framework of the sociology of science, as well as on the basis of recent empirical studies, the authors propose an original approach to the study of a research career, determine the integral indicator of career achievements and assess the research career rank by means of the transition probabilities. The study is based on the data obtained during a survey among Russian researchers involving 828 respondents employed by organizations in the main prospective science and technology areas (academic and non-academic sectors). We suggest the research career achievement (RCA) indicator as an analytical tool for managing highly qualified research personnel. The use of PageRank method enabled to discern an extremely uneven distribution of the research career achievement value in the surveyed sample of researchers. The analysis revealed the main factors determining academic and non-academic research career patterns. The findings attest that the factors affecting career patterns are closely linked with the recognition that the researcher obtains or expects at three levels: individual – professional community – society as a whole.

1. Introduction

Research career patterns are changing over time, reflecting tendencies in academic and non-academic national and global labor markets. The features of science and technology (S&T) systems change over time, and characteristics of the actors in these systems also change concomitantly (Santos and Horta, 2015). The low demand and the growing supply of PhD holders by academy, raise the question of the value of a scientific degree in the changing world of work. A traditional academic career as a goal of doing a PhD is becoming increasingly problematic. At the same time, a recent trend of an increasing demand for PhD holders from industry is noticeable, due to fast and radical technological changes. Many PhDs in the non-academic sector are engaged in research work, implementing projects related to research and development (R&D). The career of a researcher has become multi-faceted and has many indicators of its success.

The concept of "career", applied in academic literature, is constantly reviewed, acquiring new meanings and losing old ones. In the past, people believed they would always work for the same employer. Now they expect to change employers in the course of their career, getting as much as possible while they work for each of them. The accent is placed on "opportunities for self-realization", and "interesting and diverse work". The "boundaryless career" concept originally suggested by DeFillippi and Arthur (DeFillippi and Arthur, 1994) deserves particular attention. According to the authors, a boundaryless career implies disruption of the static, clearly delineated system of "career ladders", and the emergence of a more open and transparent environment for people's professional development. Alternative career options do not imply a strict hierarchy or a clear understanding of where the career path may be leading.

Previously (Hughes, 1958; Glaser and Strauss, 1971) it was believed that career amounted to moving up the career ladder from a lower position (which did not provide much professional freedom or responsibility) towards higher ones, associated with broader responsibilities, more opportunities to make decisions, and manage other workers. These days the concept of career is not interpreted in terms of hierarchical structures only. The concept of career includes opportunities to make choices, multiple development plans, and moving on between various positions which are not necessarily seen in terms of a hierarchical ladder. E.g. not too long ago, doctorate holders' careers were mainly developed in the academic labor market – working in the R&D and education sectors. However, now they can pursue successful careers in non-academic domains too.

Ambiguous interpretations of the career concept create problems

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https://doi.org/10.1016/j.techfore.2019.119907
Received 30 October 2018; Received in revised form 19 December 2019; Accepted 29 December 2019

with assessing career achievements. It may not be limited to an adequate remuneration or social recognition, or freedom to set one's own working hours (autonomous work), but also imply opportunities to change the content or place of work, take part in certain (breakthrough, large-scale) projects, meet particular needs or aspirations. Work provides the basis of the individual's identity, status, and access to social benefits. Work gives people goals, motives to compete, satisfaction – and, of course, material income. Hence, multiple criteria can be applied to measure career success.

PhD holders' career outside the academy is still considered an alternative. Many employers and policymakers continue to wonder why employees with advanced degrees are needed in industry or services, and whether this is a problem of over-qualification and a pure waste of money (Larson et al., 2014). But the simple conclusion that there are "too many PhDs" is disputable. According to Santos, Horta, and Heitor, (2016), who considered Portugal as a case of country developing their science, technology and higher education systems, there is a shortage of doctorate holders in many sectors of activity, and better monitoring of the changing nature of doctorate degrees is needed.

The article analyzes the approaches to the concept of a research career, as well as career patterns of doctorate holders. The purpose of this paper is to contribute for further development of the research career model, and to identify the main factors affecting academic or non-academic research career achievements. The study is based on the data obtained during a survey among Russian researchers carried out in 2016–2017. Being a part of the international project "Careers of Doctorate Holders" (CDH) (Auriol, 2010, 2012), the Russian dedicated panel survey aims at monitoring professional shifts and achievements of advanced degree holders.

The main research questions are:

- what factors affect successful career building in the academic and non-academic sector;
- what is the value of a PhD degree for a career outside the academy;
- how to assess the career achievements of the researcher given the variety of success factors;
- how are objective and subjective assessments of career success related?

2. Literature review

2.1. Traditional and alternative research careers

Most research career studies focus on analyzing the professional development paths of PhD holders. The authors are primarily interested in major labor market trends such as career choices of recent PhDs, barriers they encounter during and after their doctorate studies, and their distribution between various labor market segments. Secondly, such studies typically describe factors affecting the choice of a research career, e.g. publication activities during doctorate studies, or students' social capital. Thirdly, researchers analyze doctorate holders' career types and competences.

According to the approach suggested by Kaulisch and Enders (2005), three major aspects are important for understanding certain traditional features of academic careers: (1) academic careers' institutional embeddedness into the overall science system and their academic discipline, (2) national settings and cultural contexts, (3) apparent global trends towards marketization and managerialism on academic careers.

Despite the growing attention to the research career in the non-academic sector (industry, financial sector, knowledge intensive services organizations, etc.), a career outside the academy remains for many PhD holders the "second choice" and is considered as an "alternative". The trends that can be observed are quite contradictory.

On the one hand, an implicit assumption that the doctorate is preparation for an academic career often remains within universities (Neumann and Tan, 2011). Newest study done by Zimmermann (2018), examining biomedical PhD scientists in USA navigating career paths, reports that the stigma of non-academic careers is still noticeable and some trainees who went into their intended careers outside of academia were viewed as failures by faculty and funding programs. There also still exists a problem of career guidance, where supervisors do not provide proper career advice and guidance to PhD students and post-docs (Chen et al., 2015; Shibayama and Kobayashi, 2017). Many advisors do not discuss non-traditional career paths, and careers in industry are explicitly discouraged (Sauermann and Roach, 2012). Often the early-mid-PhDs wanting academic posts, imagined them in the abstract and have a rather naïve understanding of academic work. Their minimal experience of academic work likely contributed to the fact that the kinds of posts they imagined were unlikely to be achievable (McAlpine and Turner, 2012).

On the other hand, distance between academic and non-academic work is diminishing (Musselin, 2007). The academic labor market ceases to be an "ivory tower" when working in industry virtually eliminates obtaining an academic position in the future (Dietz and Bozeman, 2005). Herrera and Nieto (2015) note that doctorate holders are employed by firms not only for their ability to generate and absorb scientific knowledge. During their PhD studies and early research careers, doctorates develop a social capital that can be used by industrial enterprises to detect technological opportunities and resources outside of the company, and to manage strategic alliances with other researchers.

A non-academic career for PhD holders is becoming more attractive and common. For example, a survey of major US universities revealed that 50% of students specializing in life sciences and physics, saw a research career at university as an attractive prospect (Sauermann and Roach, 2012). Increasingly more doctorate holders specializing in chemistry, life sciences, or physics, opt for non-academic career choices. In Australia, more than half of doctoral graduates gain employment outside university settings, a proportion which has been increasing steadily since the early 1990s (Neumann et al., 2008). Germany belongs to those countries where the PhD has a relatively high value on the overall labor market for the highly qualified. Most indicators of career success, like access to high-level career positions and level of income, transition to employment and unemployment rates, job satisfaction and career satisfaction, indicate that PhD graduates have a significant career advantage. The overwhelming majority of German PhD graduates do not perceive their employment outside the research sector as a "career accident", but as a well-respected job with a reasonable return-on-investment (Enders, 2005).

Contia and Visentin (2015) note that doctorate holders' choice in favor of a particular future career, is much more complex than the choice between academic or non-academic employment. The authors conclude that PhD students value positions at prestigious universities and prominent research organizations equally high, and prefer these two career options to everything else, i.e. non-prestigious universities, companies which do not conduct research, start-ups, or administrative positions.

Within an academic career, it is important to distinguish between research and teaching. PhD students in the USA, as pointed out by Fox and Stephan (2001), report their preferences for academic or non-academic research careers over teaching. Educational work is rarely rewarded, meanwhile publications and mobility are considered to be the key instruments to prevail in harsh competition for senior positions in academia (Müller, 2014). Much attention is paid to the tenure phenomenon, where "tenure lens" can be applied as one of the main measures of career success (Aanerud et al., 2007; Enders, 2015). In the USA, tenure is a system that largely determines the success of a PhD's career (Bozeman and Gaughan, 2011).

The desire to build an academic career is already evident in the early stages of academic life. Graduate students' publishing as an indicator of pre-doctoral research activity and future scholarly success

(Pinheiro et al., 2014). While writing a thesis, students who identify themselves as wanting an academic career, are more concerned what intellectual contribution they will make with their work, and networking is extremely important for them to position oneself within a community of future colleagues (McAlpine and Lucas, 2011). A "taste for science", and doctorate holders' personal preferences were analyzed in the study by Roach and Sauermann (2010). The authors pointed out that students who showed independence, a desire to publish as much as possible, and an interest in basic research, tended to opt for a career in science, while those who were interested primarily in material aspects (salary, access to resources), were more likely to choose a career in the entrepreneurial sector.

On the basis of data collected in the scope of the OECD project "Careers of Doctorate Holders" (Auriol et al., 2012), Balsmeier and Pellens (2014) made several conclusions regarding doctorate holders' motivation to keep their academic positions. Publication activity turned out to be an important factor: the more publications doctorate holders had, the more likely they were to carry on with their academic career. Each additional publication reduced the inclination to leave academia by about 6%. Another important conclusion regarding factors affecting their career development, concerns patenting of doctorate holders' inventions. Doctorate students who have submitted patent applications during their studies, even if they had numerous publications, were more likely to discontinue academic careers than students who have never submitted patent applications. The authors conclude that patenting increases the chances of opting for a non-academic career, because it shows doctorate holders' interest in commercializing their research results.

2.2. Impact of mobility on research career

Lee et al.(2010, 2012) presents an analysis of labor mobility conducted to study specific features of the labor market for PhD holders specializing in sciences and engineering. Labor mobility, and development of knowledge and skills, vary depending on career patterns. Three pattern types were identified. Those who work in the public sector and conduct academic research most fully use the knowledge and skills obtained during PhD programs and move quickly in their careers, but there is a sharp contrast between permanent and temporary employees. Many of the temporary employed researchers tend to leave the sector because they do not get promoted and offered the desired permanent contract. Another career pattern comprizes technical positions in the entrepreneurial sector, i.e. researchers and engineers employed by production companies. In this case, doctorate holders tend to develop their general skills and quickly move up the career ladder until they become managers of their organizations, or decide to change jobs. The third career pattern has "hybrid" characteristics: it implies having transferable knowledge and skills, i.e. along with the sector-specific knowledge, general skills are required. Representatives of this career pattern tend to move between different organizations, but they face different kinds of obstacles in transferring knowledge and skills obtained in PhD programs in natural and engineering sciences to other non-conventional spheres of employment.

International mobility is an influential factor affecting researchers' productivity and professional career. The experience of studying or working abroad enhances researchers' performance, increases their publication activity and involvement in knowledge and technology transfer (De Filippo et al., 2009; Edler et al., 2011; Scellato et al., 2017). Getting new knowledge abroad gives an employee an additional competitive advantage in the home country, which is an important factor in the development of a scientific career. According to Musselin (2004), in the 90 s - early 2000s, most post-docs in France, Germany, and the UK perceived their foreign experience as a personal strategy and aimed at improving their chances for recruitment in their own country. In Portugal, managing mobility at doctoral level is considered as one of the science policy instruments promoting brain gain (Heitor et al., 2014).

Mobility is common and brings advantages mostly at the beginning of a professional career (Deville et al., 2014). Early career stages were particularly important: they produced the so-called "memory effect" which affected the subsequent career path. E.g. if a scientists started their career at a less-than-prestigious research institution, the chances they would ascend to a high academic position are small.

It is worth noting that an "immobile career", in some cases, can lead to an earlier receipt of a permanent contract. The factor of a successful academic career in a particular organization can be not only high results, but also a degree of loyalty (Bozeman and Corley, 2004). According to the study of Kosmulski (2015), a typical young Polish scientist is an alumnus of doctoral studies at the same university and department where he/she completed his/her Master degree. The career is then continued by receiving a habilitation and later tenured position at the same university and department.

Researchers mostly tend to have traditional careers moving on from lower institutional positions to higher ones. Gargiulo and Carletti (2014) indicated that between 1955 and 2009, researchers (on average) changed institutions 2–4 times during their career, and 90% of them have never worked at more than 4 universities in 3 countries.

2.3. Recognition and scientific stratification

The science system and a career in it has its specific features, and a research career is a unique path connected with the research projects and, especially, creative abilities of individuals. According to the concept suggested by P. Bourdieu, scientific capital is a key aspect defining the success of a researcher's career. It comprizes characteristics interpreted as socially significant resources for scientific production, which regularly generate income for the agent defined in terms of stakes made in the course of this production (Bourdieu, 1984); note that such resources remain available for a long time. In other words, scientific capital defines the individual's chances to win academic recognition, and/or secure a high position. Under this approach, a research career should be seen as a sequential change of positions in the scientific field and as a "competitive struggle for the monopoly of scientific authority" (Bourdieu, 1975, p. 19).

In the concept of Merton (1973, 1988), the central object for studying scientific stratification is the system of rewards and its impact through social contexts of scientific practices. Rewards of different forms and sizes awarded for scientific achievements constitute social recognition (Cole and Cole, 1973; Allison and Stewart, 1974; Long, 1978; Allison et al., 1982; Gaston, 1978). Recognition, in its turn, is the central factor of the scientific employment system, and of scientists' individual perceptions. Recognition by competent colleagues is the main indicator of the researcher's contribution to advancing science, and accomplishing the goal of scientific learning (Merton, 1973, p. 293).

In academic networking, relationship with peers, achieving a certain position among them is extremely important, and in this system, recognition is the greatest reward. According to Kaulisch and Enders (2005), the most important rewards academics receive are not given by the organization, but by the colleagues within the overall science system.

Within hierarchies of fields, positions and institutions, various ranking systems play an important role in organizing academic society. The prestige of a previous organization where a researcher has studied or worked, can strongly influence their future career path (Croxford and Raffe, 2015). Prestige hierarchies are also likely to influence faculty hiring across academe (Clauset et al., 2015). The school from which a researcher comes, can be a key evaluation criteria rather than achievement or merit (Arimoto, 1978). Status differences among academic departments are rooted in processes of social closure and the accumulation of social capital (Burris, 2004). But when different hierarchies intersect and interact, single criteria cannot be applied to measure career achievements. For example, when institutional differentiation interacts with disciplinary differentiation, a wide and complex system of differences between academics occurs (Clark, 1997). The lack

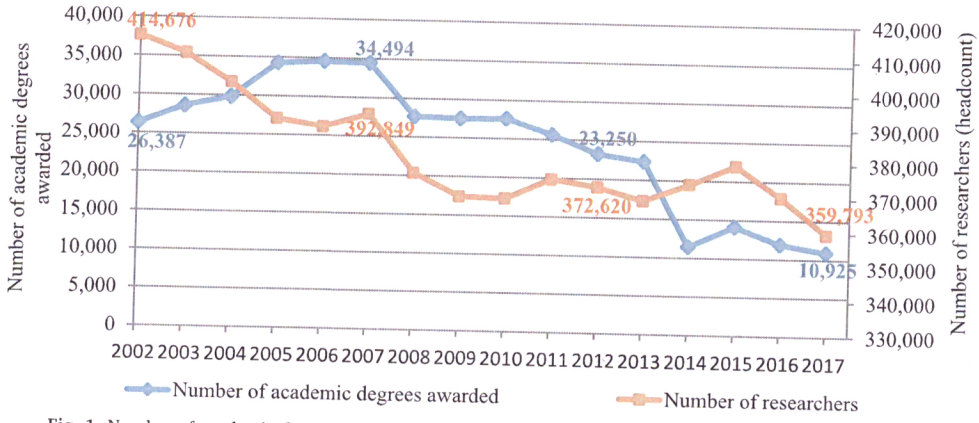

Fig. 1. Number of academic degrees awarded and number of researchers in Russia, 2002–2017 (headcount).

of a strict unidimensional hierarchy in the academic community makes it impossible to evaluate the research careers using single variables.

2.4. Research career in Russia

Prospects for scientific careers varied, reflecting economic and social constraints (Fox and Stephan, 2001). Research career patterns vary considerably between countries (Auriol, 2007, 2010; Musselin, 2005; Enders, 2015, Duarte, Mendonca, 2016). In absolute terms, Russia continues to occupy a leading position in the world after the US, Japan, and China, based on R&D personnel numbers. In the academic labor market we can find researchers both with and without advanced degrees. In 2016, among Russian researchers, only 29.3% had a doctorate degree, but it is worth noting that this share is tending to grow (for comparison: in 1995 their share was 22.4%; in 2000 – 24.9%; in 2010 – 28.5%) (Gorodnikova et al., 2018).

The current state of the corpus of Russian researchers (including their professional preferences) cannot be considered outside of its historical context. After a landslide decline in researcher numbers in the period 1990–2000 (the population of researchers reduced by 2.1 times), later, between 2000 and 2013, this process slowed, with a decline of 15.4% overall. It can be accounted for by the substantial growth in budgetary spending on R&D (since the mid-2000s), and a number of government measures to support research (Gokhberg et al., 2016).

The development trends of the doctorate education system and the changes of the academic labor market in Russia, do not always go in the same direction (Fig. 1). In 2002–2007, despite the sharp decrease in researcher's employment, the number of doctorate awarded, on the contrary, increased. The number of researchers decreased by 5.3% in 5 years, while the number of academic degrees awarded each year, increased by 30.7% and began to decline much later. Russia is a case of a country where doctorate training is not consistent with the dynamics of employment in the academic sector, and the academic degree can be also considered as a tool for building a non-academic career.

In Russia the share of researchers engaged in the business sector is less than half (47.1% in 2017), compared with 58.8% in Germany, 71.1% in the USA, and 73.4% in Japan (Gokhberg et al., 2019). Unemployment among the doctorate holders is rather an exceptional situation (unemployment rate in 2017 is just about 1%). Most researchers are employed on a full-time basis: 90.1% of the Russian doctorate holders worked full-time in 2017 (in the USA – 87.3, in Germany – 82.4).[1]

Professional mobility of Russian researchers is quite low: almost 70% of Russian doctorate holders have not changed jobs over the past 10 years (Shmatko and Katchanov, 2016). In addition, a research career in the higher education sector in Russia is characterized by the high rates of academic inbreeding (Horta and Yudkevich, 2016). Under these conditions, international mobility and participation in international projects are becoming a valuable career development resource in both the academic and non-academic sectors (Shmatko et al., 2016).

Mobility between the academic and non-academic sectors is not a common practice among Russian researchers (Shmatko and Volkova, 2017a). Data on internal mobility is shown in Fig. 2 (for those who changed principal job over the last 10 years; for each sector the share of researchers that changed their type of organization and that remained in their sector equals 100%). University staff mostly (56.6%) simply changed the university and only 11.6% moved to industrial and service sector companies. 59.3% of researchers in the non-academic sector just changed one industrial and service sector company to another, without moving to academia. The largest outflow is observed from research institutes, and such researchers are twice as likely to go to universities than to non-academic organizations.

3. Methodology

The choice of traditional or alternative career options that do not imply a strict academic hierarchy and an unambiguous interpretation of success or professional recognition is considered. A critical analysis of existing approaches enabled us to establish key variables, which measure researchers' career success in quantitative and qualitative terms (Appendix 1). This essential features describe the research career as a system of relational social positions of researchers (Bourdieu, 1984; Lebaron, 2009). The list of variables combines "objective career" indicators (the sequence of statuses the researcher obtains over their career paths) with "subjective career" ones, such as the researcher's assessment of their abilities and opportunities, personal prospects, and work-related achievements. Hughes suggested (Hughes, 1971, 1994] a social mechanism which explains how and when subjective careers change: a system of turning points matching the objective career. In the course of life and career development not only the objective status changes, but also individuals' subjective perception of themselves – i.e. a two-way adjustment occurs, which helps to avoid an internal conflict (Glaser and Strauss, 1971). Indicators such as scope for self-realization and personal development, being able to pursue personal interests other than research-related ones, and meeting personal needs and goals at work are subjective assessments, and reflect specific researchers' perceptions of their career position.

The authors offer an original approach to the study of career in the academic and non-academic sector. The concept "research career" is operationalized using PageRank. Career is understood as a set of achievements of various kinds, which can be reduced to an integral indicator – Research Career Achievement (hereafter, abbreviated as RCA). The proposed approach makes it possible to formulate a

[1] OECD (2019).Careers of doctorate holders (CDH) light 2017 data collection.

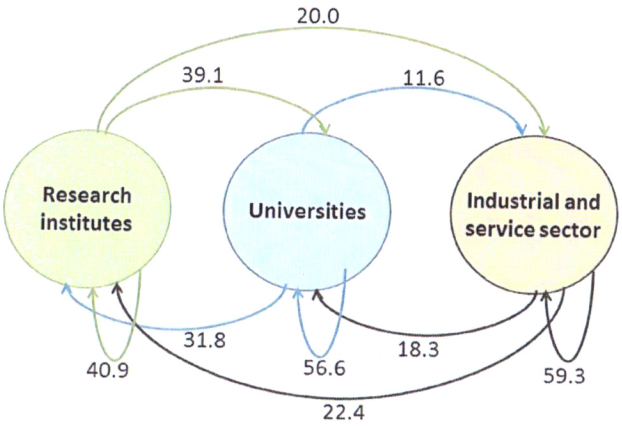

Fig. 2. Outgoing mobility of Russian researchers, 2016 (%).

hypothesis I about the uneven distribution of the value of career achievement in the surveyed sample of researchers. A significant part of the respondents will show a low level of professional achievement, while several leaders will be characterized by successful careers. High values of RCA are more characteristic of the academic sector of the labor market of researchers.

Hypothesis II of the study is that the main factor affecting the research career assessment, is the recognition that is either achieved or expected on three levels (ranging from individual to global): (1) specific individual (self-recognition); (2) professional community (recognition by peers); (3) whole society (nationally and internationally). The endeavor for recognition is manifested in the fact that researchers mostly follow an altruistic strategy; they prefer the values of creativity, knowledge, and self-realization to all others. These values are considered as the key to further recognition of the scientist. This strategy of delayed success is widespread in the scientific field. One of the initial assumptions is that "subjective" careers are no less important to researchers than "objective" ones, and self-realization, combined with the belief in the prospects for further professional development are more important to them than their actual position in the office hierarchy.

The research career model is based on the principles developed in the scope of sociology of science (Bourdieu, 1984), and the approach adopted by the Careers of Doctorate Holders (CDH) project (implemented under the auspices of the OECD, the UNESCO Institute of Statistics, and Eurostat) (Auriol et al., 2012). This project offers the most complete and structured data about the motives for choosing a career in science, researchers' employment, specialization areas, and mobility. The objective is to identify the patterns and human resources' development trends in the science and technology sphere. The main data collection method is questionnaire-based surveys of doctorate holders; all participating countries use the agreed toolset including the questionnaire structure. Data on researchers' careers is collected at their current and previous (if any) employer(s). The methodology is based on the "career path job" concept.[2] It is assumed that researchers may have various kinds of work experience (especially in the early stages of their career), but then choose the career path job for full professional self-realization.

The data about Russian researchers was collected in 2016–2017[3] during a dedicated survey by questionnaire. The respondents comprized researchers employed at R&D divisions of universities, research institutes, engineering services providers, industrial companies, medical centres, and clinics. The survey was conducted in all Russian federal districts in large cities with research institutes and major universities, and in "naukograd" (science cities). The surveyed researchers were specializing in science and technology (S&T) areas with the best prospects in Russia, in particular information and communication technologies, new materials and nanotechnology, the agricultural sector, life sciences and medicine, biotechnology, rational use of natural resources, energy efficiency, and transport and space systems. Data about Russian doctorate holders was collected through a sampled survey using a multistage stratified sample, with respondent quotas established for age groups, gender, specialization areas, employment sectors, and territories of residence (federal districts); the sample is representative for the population of the Russian doctorate holders employed in most perspective S&T areas. The main characteristics of the obtained sample are summarized in Table 1.

The subsample comprizing 828 respondents aged 30–49 years (59.1% of them male) was built in order to test our research hypotheses. Age restrictions were introduced to pick out the researchers in the active phase of career building, and to exclude the direct influence of the age factor on the analyzed variables describing careers. Distribution of the respondents by employment sectors and positions was as follows: 71.8% were employed in the academic sector (out of them, 34.6% worked at research institutes and 37.2% – at universities); 28.2% were primarily employed by industrial and service sector companies. 25.8% of the respondents worked in management positions; out of them 2.7% were CEOs and deputy CEOs of their organizations, and 23.1% managed various research units and faculty departments.

4. Results and discussion

4.1. Academic and non-academic careers of Russian researchers

One of the central questions while analyzing a career, is how free and conscious is the choice of career path. Among the reasons for choosing a career in R&D, respondents were offered the option "there was no other job", which should indicate forced choice. According to the survey results, less than 3% of those employed in Russian research institutes or universities, and about 8% of those employed in industrial and service organizations noted this reason. This means that the situation when a research career is a hopeless or forced choice is relatively rare. In most cases, researchers consciously make such a professional choice, preferring it to other alternatives.

For doctorate holders, career-affecting professional experience primarily implies the research-related component of their work. The amount of time they spend on research (as the share of total working time) and the length of time working in a research position, are the indicators which by themselves define the current position in the professional community and their further career prospects. A key professional experience indicator is research productivity, in particular publication and patenting activity, practical application and commercialization of research results. Another important indicator is international mobility, which measures the researcher's willingness to participate in global research cooperation.

At the time of the survey 85.7% of research institute and university staff had more than 10 academic publications to their credit. As for industrial and service sector companies' employees, the relevant figure was just 16.5%. Within the academic sector, research institute staff typically publish more often than their university colleagues, including foreign language publications: on average, during the previous 5 years, a research institute member had approximately 6 such publications, while a university employee had less than 4. Patenting is not generally common for Russian researchers: most of them did not patent any inventions during the previous 10 years. However, researchers employed in the academic sector tend to be somewhat ahead of their industrial and service sector colleagues in terms of patenting activity.

[2] A "career path" job is a job that will help further your career plans or is a job in a field where you want to make your career (Auriol et al., 2012, p. 58).

[3] The research project "Monitoring survey of Highly Qualified R&D Personnel" is realized in the framework of Basic Research Program Higher School of Economics (NRU HSE) in 2010-2018. This article is an output of a research project implemented within NRU HSE's Annual Thematic Plan for Basic and Applied Research. Any opinions or claims contained in this article do not necessarily reflect the views of HSE.

Table 1
Main characteristics of surveyed Russian doctorate holders,% (N = 1880).

Sex	
Male	59.5
Female	40.5
Age group	
Younger than 29 years old	16.7
30–49 years	44.5
50–70 years	38.7
Type of organization (by current main job)	
Research institutes	34.6
Universities	36.9
Industrial and service sector companies	28.4
S&T specialization (by current main job)	
Information and communication technologies, cybersecurity	13.1
New materials and nanotechnology	24.5
The agricultural sector, food supply security	4.7
Life sciences and medicine	11.6
Biotechnology	4.1
Rational use of natural resources	15.1
Energy efficiency	10.3
Transport and space systems	16.5

The higher education sector has the biggest share of staff who have received awards for their academic and professional achievements (Fig. 3). Membership in expert councils and professional associations is also more common for researchers who have chosen academic careers.

The data collected during the survey confirms that Russian researchers do not change jobs frequently: most of them did not change jobs during the previous 10 years (68.7% of the sample), and had no plans to do so in the future (71.6%). Respondents from the non-academic sector were more mobile, with a much bigger share of those who changed jobs two or three times during the previous 10 years (27.8% in industrial and service sector companies, but only 12.2% in research institutes and 11.8% in universities). As to mobility potential, researchers employed by organizations other than research institutes and universities, consider changing their principal job more often too.

As for international academic cooperation, the share of internationally mobile researchers (i.e. those who have studied or worked abroad for three months or more) outside the academic sector is just 6.2%, while for research institute staff it is 16.3%, and for university employees – 11%. In terms of short-term trips abroad for professional purposes, research institute and university staff display more or less equal activity (68.9% and 75.2% of the respondents took part in some form of international cooperation in 2013–2015, respectively). University staff more often go to deliver lectures or attend training programmes at foreign organizations, while members of research institutes more frequently participate in international projects, or publish jointly with foreign co-authors.

Researchers who have opted for a non-academic career, frequently tend to be "excluded" from the academic environment: they publish less often, patent less frequently, and less actively participate in international academic cooperation. However, in terms of other professional development criteria, a career outside research institutes and universities provides certain advantages. First of all, it is a higher rate of pay, stability, reliable prospects, and involvement in accomplishing important practical objectives. Industrial and service sector companies' employees participate in the practical application of research results no less often than their academic sector colleagues do. Researchers' subjective assessments of how their work contributes to accomplishing major important objectives and applying their ideas in practice, are also quite similar for both types of organizations.

4.2. Recognition by peers and by institutions in Russian scientific system

Despite significantly different values of numerous variables describing researchers' employment and productivity, people who have opted for different career paths assess their chances to win recognition more or less similarly (Fig. 4.). Regardless of the organization type, most researchers are quite satisfied with an opportunity to win recognition and achieve decent social status for their professional performance.

It means that researchers interpret the concept of "recognition" differently, and apply different criteria to assess their career prospects. Success of a research career cannot be measured using a single variable, because the relationship between different parameters describing a research career is not straightforward. This implies the need to choose specific parameters of research career success, and take into account not just isolated variables distribution, but their interactions.

Empirically, we can determine the position of a researcher only by comparing and matching it with the positions of other researchers. Obviously, the career of a researcher also has a relational nature. The value of the research career of the respondent is the resultant juxtaposition and comparison of the essential characteristics of his position with the characteristics of other respondents' positions. Roughly speaking, the values of the research career may be thought as network nodes of relations between the positions of the whole sample of respondents.

We suggest the research career achievement (RCA) as an analytical tool for managing highly qualified research personnel. Herewith, the totality of researchers is viewed as a network. This concept can be used mainly in the context of science policy and management. We determine the RCA using the PageRank algorithm, because this algorithm is well-known and its application in the HR practice does not present much difficulty.

The initial data for the RCA is constituted by differences and similarities between researchers. Naturally, these differences and similarities are calculated on the base of variables included in the study. However, the variables themselves are not so important than the

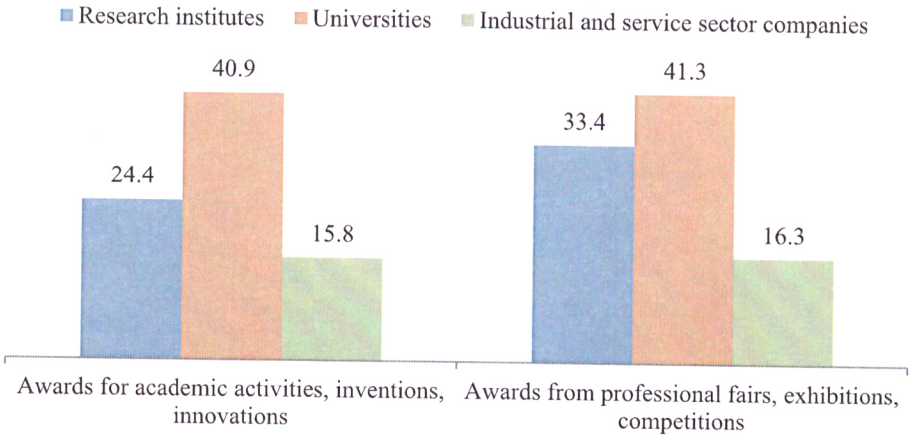

Fig. 3. Researchers who reported having awards, by organization type (%).

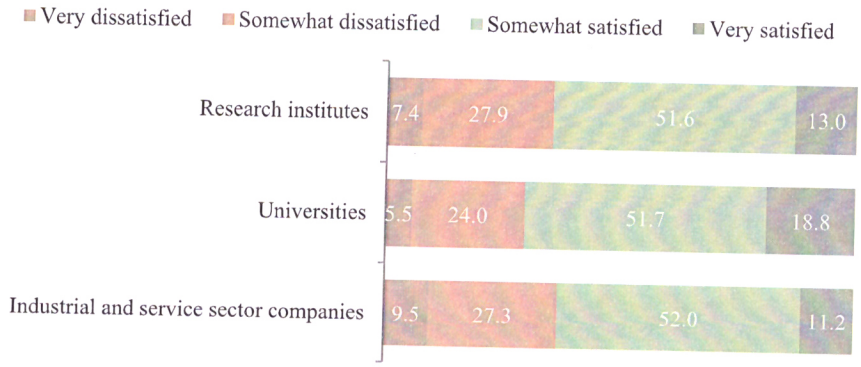

Fig. 4. Degree of satisfaction by opportunities to win a social recognition and achieve a decent status within the principal job, by organization type (%).

distinctions between researchers.

In 1960th, it has been found that the concept of Markov chains provides a rich mathematical framework for analysis of social mobility (Singer and Spilerman, 1976; Rosenbaum, 1979). Thus, the PageRank algorithm proposed by Brin and Page in 1998 (Franceschet, 2011) to measure the impact of webpages, and based on the Markov chains theory, can be used to measure the distinctions between social positions. In our case, the PageRank algorithm simulates the careers' dynamics of researchers changing their positions. The analogy is that one may consider a researcher as a random walker and the positions as the states of the irreducible Markov chain. Every PhD holder, independent of one another, is assumed to start his/her career from a recent position and to subsequently follow a chain of positions until finished.

Since we are concerned with the results of measurements, it is not surprising that the mathematics required to describe these results should be the mathematics of vectors. All information on a research career of a respondent i is determined by specifying the vector V_i with components $v_i^1, v_i^2, \ldots, v_i^{18}$, i.e., the results of a sociological measurement of a career i are conveniently identified with the numbers $v_i^1, v_i^2, \ldots, v_i^{18}$, and with each respondent from the underlying sample S we associate a unique vector V_i. Furthermore, the sample of the 828 respondents can be treated as a system S with the 828 possible states, indexed by the set {1,2, …,828}. In other words, a vector V_i can be interpreted as a state i of the system S.

We say that the transition probability p_{ij} is the probability of transitioning from a state i to a state j. Here, we can estimate the relations between the positions (i.e., between the careers) in S by means of the transition probabilities. The transition probabilities p_{ij} form the 828-square transition matrix $P = (p_{ij})$ with the properties: $p_{ij} \geq 0, \sum_j p_{ij} = 1$. The transition matrix P is said to be stochastic, and P interpreted as the transition probability matrix of a Markov chain of a random walk. In terms of vectors V_i, we assume that the probability of transitioning from a state i to a state j can be expressed in the following form:

$$P_{ij} = (cos\theta)^2 = \left(\sum_{k=1}^{18} v_i^k v_j^k\right)^2 / \sum_{k=1}^{18} (v_i^k)^2 \sum_{k=1}^{18} (v_j^k)^2$$

where θ is the angle between vectors V_i and V_j (cf. (Gentle, 2007)).

In this paper, we apply the PageRank algorithm to the matrix P with the purpose of measuring RCA. In the framework of the Markov chain theory, the matrix P completely describes the law of change of the state of the system S. The PageRank algorithm is based on the idea of computing the steady-state probability distribution $\{\pi_1, \pi_2, \ldots, \pi_{828}\}$, of a random walk on the sample S (for computational details and discussion, see, e.g., Langville and Meyer (2011)). The series of values $\{\pi_i\}$ is the solution of the system

$$\pi_i = \sum_{j=1}^{828} \pi_j P_{ij} \quad , \quad \sum_{i=1}^{828} \pi_i = 1$$

Here π_i is the proportion of time that the random walker spends visiting the state i. The larger the value of π_i is, the more significant the career i will be. Thus, the RCA of respondent i is then defined as the probability π_i. Our analysis is conducted with the R package 'igraph'.

To summarize these reasoning, we may say that we operationalized research career achievement (*RCA*) as PageRank. The numbers RCA_i are essentially the probabilities that the corresponding respondents have reached certain career achievements relative to other respondents in the sample. In this case, the higher the value of RCA_i, the more successful the career of the i^{th} respondent. Thus, we operationalized a research career as the rank of the respondent in the sample. As part of our approach to the respondent's career, it is likely that his achievements are greater than those of all other respondents in the sample.

The histogram in the Fig. 5 shows that the value of research career integral indicator is distributed extremely unevenly. The largest share of the sample (about 34%) has *RCA* values that do not exceed 0.00045. At the same time, the maximum *RCA* value is 0.00175, that is, the gap between the leaders and the main part of the group is almost 250%. This means that many respondents either do not want to make an academic research career, or do not have such an opportunity.

We can assess the quality of the proposed operationalization of a research career by examining the correlations of the *RCA* with 20 variables describing the career positions of the respondents (Table 2). The Spearman's rank correlation values in this table (given in descending order), indicate that the greatest contribution to the career is made by variables that characterize involvement in academic activities, namely, advanced degrees and scientific productivity, as well as international mobility and international cooperation. To a lesser extent, a research career is determined by variables describing social capital, and financial status. Finally, the variables affecting mobility and the intention to change jobs had the least impact on a research career. It should be emphasized that the results of this study revealed a significant statistical relationship between a research career and its relevance to personal needs and goals.

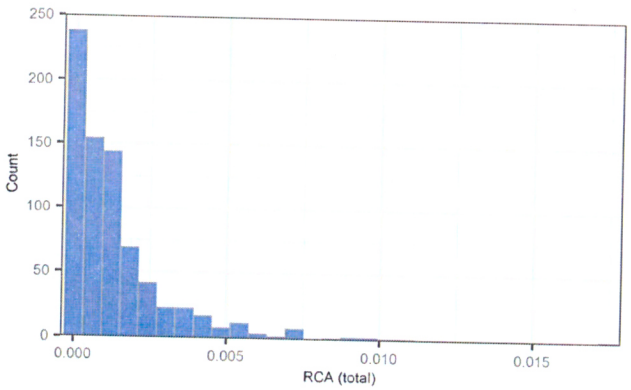

Fig. 5. Distribution of the value of RCA.

Table 2
Correlations of the RCA with variables describing the career positions.

Variables included in the RCA	Spearman's rank correlation
1. Number of papers published throughout the career	0.990
2. Advanced degrees	0.803
3. Participation in international cooperation (during the previous 3 years)	0.673
4. Number of papers published in foreign languages during the previous 5 years	0.661
5. Occupation (including team and project management responsibilities)	0.630
6. Academic supervision experience (master / PhD thesis, etc.)	0.624
7. Academic / non-academic sector of job	−0.617
8. Opportunity to realize professional potential (knowledge, experience, abilities)	0.611
9. Experience of managing research / education projects, practical implementation of results	0.595
10. Training experience at foreign organizations (leading R&D and S&T centers)	0.549
11. Patent activity (for the previous 10 years)	0.515
12. Membership in professional associations and expert councils	0.512
13. Honorary titles (awarded for professional or S&T achievements, inventions, innovations)	−0.491
14. Opportunity to pursue and develop own ideas for the sake of extending knowledge	0.488
15. Awards from professional exhibitions, competitions, etc.	−0.413
16. International mobility experience (working or studying abroad for three months or more)	0.378
17. Creativity and innovativeness of work	0.377
18. Training experience at Russian organizations (leading R&D and S&T centers)	0.305
19. Average monthly salary at the principal job (including all bonuses and benefits)	0.281
20. Principal job changing	−0.255
21. Experience of practical application of innovative solutions and research results	0.242

For the examined subsample, the RCA distributions for researchers in academic and non-academic sectors are significantly different (see corresponding histograms A and B in Fig. 6.). To statistically prove this statement, we applied the two-sample Kolmogorov-Smirnov test for subsamples of researchers with academic and non-academic careers. The value of the Kolmogorov-Smirnov statistic $z = 8.661$ exceeds the critical value. This means that the two underlying probability distributions of RCA are different. A comparison of histograms in Fig. 6 clearly demonstrates that RCA for academic careers are systematically higher than RCA for non-academic careers. In addition, RCA is more unevenly distributed among non-academic researchers than among academic.

Similarly, to prove hypothesis II, we used two samples of the Kolmogorov-Smirnov test to examine the assumption that the RCA significantly depends on the motivation of choosing a research career. For that we divided the sample into two parts three times, selecting subsamples of respondents who differ in their answers to questions about the importance of creativity and innovativeness of work (yes/no), opportunity to realize professional potential (important/unimportant) and the opportunity to pursue and develop own ideas for the sake of extending knowledge (important/unimportant). In all three tests, the statistical hypothesis that the two RCA probability distributions are similar was rejected (the values of the two-sample Kolmogorov–Smirnov statistic are equal to 3.600, 2.578, and 2.119 respectively).

4.3. Factors affecting academic and non-academic career patterns

In order to identify the most important factors affecting academic and non-academic career patterns, an exploratory factor analysis was conducted. The components were selected using the Kaiser criterion; the Varimax rotation method was used to calculate the inverted coefficient matrix; coefficients above 0.4 were selected. Based on the factor analysis results (Table 3), 5 main components for academic and 6 main components for non-academic research career were identified (the factor loads matrixes after rotation are presented in Appendix 2.1 and Appendix 2.2).

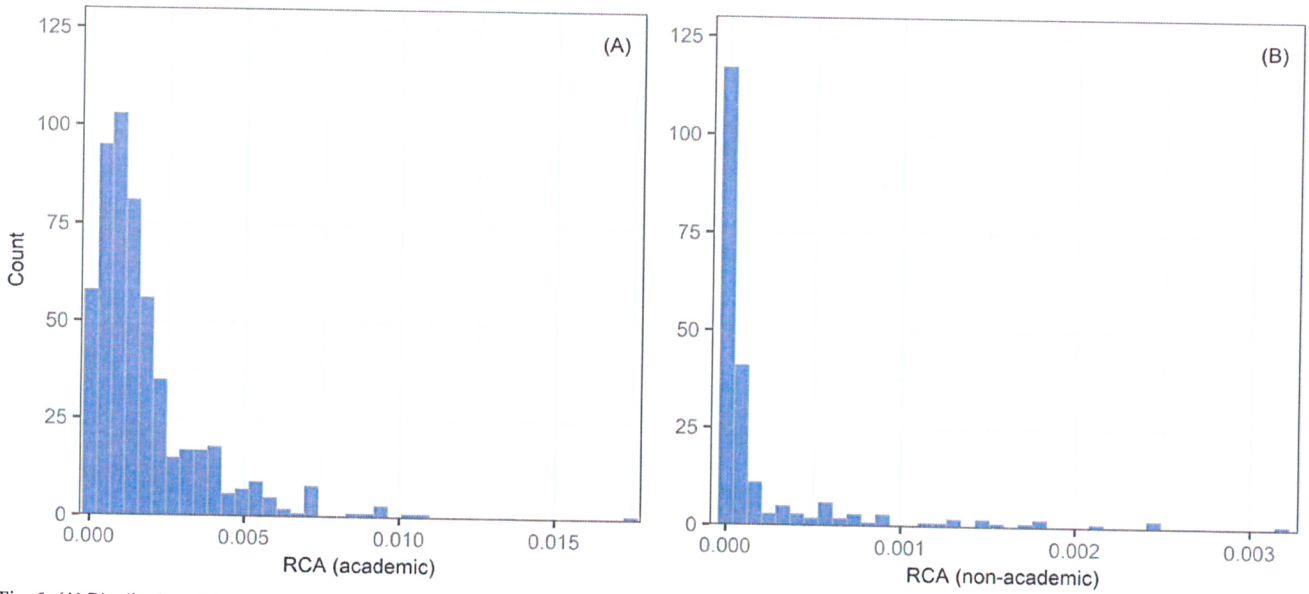

Fig. 6. (A) Distribution of the value of RCA for researchers employed in academic organizations (research institutes and universities); (B) Distribution of the value of RCA for researchers employed in non-academic organizations.

Table 3
Main components for academic and non-academic research career.

Academic research career *(Total Variance Explained = 49.4%)*	Non-academic research career *(Total Variance Explained = 54.8%)*
Factor 1 – Recognition by professional community (22.4%)	Factor 1 – Innovative and creative involvement (18.3%)
Factor 2 – Practical application of innovative solutions and research results (7.6%)	Factor 2 – Recognition of scientific achievements (8.3%)
Factor 3 – Pursuing personal research interests (self-recognition) (6.9%)	Factor 3 – Recognition of practical achievements (8.2%)
Factor 4 – Formal criteria of successful employment (salary, position level) (6.4%)	Factor 4 – Pursuing personal research interests (self-recognition) (7.7%)
Factor 5 – Mobility (including international one) (6.1%)	Factor 5 – Patent activity (6.6%)
	Factor 6 – International mobility (5.8%)

Variables representing the components are listed according to their factor loads (in descending order), on the basis of them the meaningful interpretation of each component was made.

4.3.1. Academic research career

Factor 1

Recognition by professional community
- number of papers published throughout the career;
- advanced degrees;
- number of papers published in foreign languages during the previous 5 years;
- academic supervision experience (master / PhD thesis, etc.);
- participation in international scientific cooperation;
- membership in professional associations and expert councils;
- experience of managing research / education projects, practical implementation of results.

Factor 1 describes the status in the academic environment, or in the close-knit professional community; the accumulated social capital as recognition by colleagues; the position in the academic social environment. This component includes parameters specific to the R&D sphere, which are primarily important to people directly involved in research work. Having a doctorate degree, publications, experience of academic supervision, cooperating with researchers from other countries – these success criteria are particularly important in the narrow professional community.

Factor 2

Practical application of innovative solutions and research results
- awards from professional exhibitions, competitions, etc.;
- training experience at Russian organizations (leading R&D and S&T centres);
- experience of practical application of innovative solutions and research results;
- patent activity;
- honorary titles (awarded for professional or S&T achievements, inventions, innovations, etc.).

Factor 2 comprizes indicators describing practical applicability of results obtained by researchers (in various spheres and areas), and social recognition of their scientific work's usefulness. In this case, research results *per se* are not as important as the potential for their practical application by organizations, for patenting and commercialization. Here the environment where the career success is measured includes the wide range of organizations interested in applying relevant innovations.

Factor 3

Pursuing personal research interests (self-recognition)
- opportunity to realize professional potential (knowledge, experience, abilities);
- opportunity to pursue and develop own ideas for the sake of extending knowledge;
- creativity and innovativeness of work.

Factor 3 describes how much the current job allows the researcher to realize their potential, and how well it matches their specific research interests and priorities. A number of studies (Lam, 2011; Boosten et al., 2014; Ryan, 2014; Shmatko, Volkova, 2017b) show that researchers, being highly skilled knowledge workers, tend to have high personal motivation related to their personal research interests, and aspirations to participate in accomplishing innovative objectives.

Factor 4

Formal criteria of successful employment (salary, position)
- occupation (including team and project management responsibilities);
- average monthly salary at the principal job (including all bonuses and benefits).

Factor 4 comprizes general formalized career success indicators applicable to any professional activity, such as salary size and level of position (in terms of management responsibilities). These indicators are used to assess employment and career not just in the R&D sphere, but in the whole society. It is the formal criteria which determine the social status and its stability, and serve as evidence of a successful career for a wide range of people.

Factor 5

Mobility (including international one)
- training experience at foreign organizations (leading R&D and S&T centres);
- international mobility experience (working or studying abroad for three months or more);
- principal job changing.

Factor 5 describes the scope and prospects of researchers' mobility, demand for their potential and achievements in other cities and countries. Opportunity to take part in international mobility not just in the format of short-term events, but also through long-term studies or work abroad is one of the criteria which determine the quality of R&D workers' careers, and importance of their professional achievements. Here the global academic community as a whole becomes the environment where results achieved by researchers are benchmarked.

It should be noted that the third principle component (pursuing personal research interests) comprizes only variables which are based on researchers' subjective assessments. It can be argued that assessment of research careers' success in this case is based on the level of "personal recognition", or "self-recognition".

4.3.2. Non- academic research career

For the non-academic research career, the differentiation between 3 recognition levels (personal, professional community, and international) is also relevant. However, the factors determining career patterns have their own specifics.

A key feature is that factor "Recognition by professional community", which is fundamental for an academic career, is divided separately into recognition of academic merit and of practical results (factors 2 and 3 in the non-academic sector). The main factor is the opportunity to participate in innovative and commercially perspective projects, to apply knowledge in practice, while receiving high income.

Factor 1

Innovative and creative involvement
- average monthly salary at the principal job (including all bonuses and benefits);
- experience of practical application of innovative solutions and research results;
- experience of managing research / education projects, practical implementation of results;
- creativity and innovativeness of work.

For a non-academic career, professional success is primarily associated with well-paid employment within a company that is actively engaged in innovation activity. The variable with biggest factor load within the Factor 1 is average monthly salary. However, career in the non-academic sector does not mean that a researcher sacrifices the innovativeness and creativity of work in order to get more. On the contrary, professional realization includes the opportunity to manage innovative projects and apply innovative solutions.

Factor 2

Recognition of scientific achievements	- number of papers published throughout the career; - advanced degrees; - number of papers published in foreign languages during the previous 5 years.

For researchers employed in the non-academic sector, indicators of "academic" performance, such as publications and doctorate degree, remains an important criterion for a successful career. But recognition of academic merit is separated from recognition that can be received for practical implementation of research results.

Factor 3

Recognition of practical achievements	- awards from professional exhibitions, competitions, etc.; - honorary titles (awarded for professional or S&T achievements, inventions, innovations, etc.); - principal job changing; - membership in professional associations and expert councils; - training experience at Russian organizations (leading R&D and S&T centres).

Factor 3 reflects recognition among colleagues who are primarily engaged in the practical implementation of innovations. Career success is associated first of all with awards for professional, scientific and technical activity, for invention and innovation.

Factor 4

Pursuing personal research interests (self-recognition)	- opportunity to realize professional potential (knowledge, experience, abilities); - opportunity to pursue and develop own ideas for the sake of extending knowledge.

Both for academic and alternative research career, important factor is "self-recognition" of own results, subjective assessment of own professional realization and growth. Professional realization is associated with the opportunity to follow personal research interests, to use own knowledge and experience during current work tasks.

Factor 5

Patent activity	- patent activity; - occupation (including team and project management responsibilities); - participation in international scientific cooperation.

Patent activity is a separate factor determining research career pattern. Russian specific is that patenting is common mostly for those who occupy high positions and have wide range of professional contacts, including with foreign colleagues.

Factor 6

International mobility	- training experience at foreign organizations (leading R&D and S&T centres); - international mobility experience (working or studying abroad for three months or more).

The ability to achieve recognition not only in own country, but also by international professional community is a separate indicator of career success. The most relevant is not the experience of international mobility by itself, but the possibility of implementing and improving own practical skills during a training at one of the leading foreign organizations.

As for mobility in general, researchers with academic career are more often focused on the international labor market, and in the non-academic sector mobility is mostly associated with the professional community within the domestic country. For academic research career the desire to change principal job is in one aggregated factor with international mobility, for alternative research career - with recognition of practical results, primarily within the local professional community. Researchers from industrial and service sector companies, who have been recognized as experts and highly skilled professionals, can consider job changing as tool of career improvement.

5. Conclusions

A high supply combined with a low demand is the main trend in the academic labor market in many countries around the world. This is one of the reasons why about fifty percent of recent doctorate holders, especially those specialising in natural and engineering sciences, choose not to continue their academic career and move on to other areas. When they do opt for academic employment, they have to accept short-term employment contracts at early career stages, which do not provide the full range of benefits and social insurance. They will get a chance to secure a permanent academic position only after several years. Despite the fact that about half of doctorate students leave academia, universities keep training PhD students for an academic career. Many studies of doctorate holders' careers (Neumann and Tan, 2011; Sauermann and Roach, 2012; Gokhberg et al., 2016; Zimmermann, 2018) attest that a non-academic career is still stigmatized as an alternative to traditional academic, and seen as a failure.

The survey of Russian doctorate holders has largely confirmed the conclusions made in other countries regarding factors affecting the choice of an academic or a non-academic career, and influencing the success of a research career (Bozeman and Gaughan, 2011; Auriol et al., 2012; Contia and Visentin, 2015; Enders, 2015). Characteristics of researchers' employment obtained from the survey were quite different for academic and non-academic careers, while, within the academic sector, significant differences were revealed between research institutes and universities. Depending on the type of the organization, researchers have different salaries, demonstrate different publication and patent results, a different level of participation in international academic cooperation, and a different likelihood of receiving awards.

However, despite these differences, all researchers estimate their chances to win recognition for their professional achievements at about the same level. It can be concluded that researchers use different variables to measure "recognition", and no single parameter or universal criterion can be adopted to measure research career success. Career success frequently depends not just on objective achievements, but also on the subjective perception of one's success – i.e. how the "subjective career" develops in the academic and non-academic sectors.

Given the variety of success factors in order to assess the career achievements of the researchers, the integral indicator RCA was introduced and the PageRank was used as the measurement tool. By PageRanking the respondents, we solve the task of evaluation of a research career in the interests of the science, technology and innovation policy. We suggest the Page Rank as a new tool for the assessment of academic and non-academic career achievements. The quantity of RCA_i in the sample of respondents is an additional sociological object that endows it with some additional social meaning. Our sociological intuition clearly indicates that a totality of research careers must display some organizing principle, which should be encoded in their ranking. The results of the analysis of data collected in the scope of the "Monitoring survey of Highly Qualified R&D Personnel" project (in 2010–2017), supported hypothesis I. Despite the fact that there are many different indicators of achievement in a research career, analysis using the PageRank method showed an extremely uneven distribution of the quantity of the RCA in the surveyed sample of researchers. This feature is as relevant for the whole sample as for academic and non-academic sectors separately. A significant proportion of respondents demonstrated a low level of professional achievements, and only a small proportion accumulated high results in many aspects at the same time. High values of career achievements are more characteristic of the

academic sector in the labor market of researchers. All the top positions in our ranking were taken by researchers from the academic sector. The work at the academy and the large number of publications contributed the most to their quantity of RCA_i.

Opting for a non-academic career, does not imply discontinuing R&D activities. However, if this happens, the main reasons include vague career prospects. Employees of industrial and service sector companies abandon research work, not because they are no longer interested in it, but because they believe carrying on would not advance their career.

The factor analysis of the empirical data confirmed hypothesis II. Parameters describing R&D careers can be grouped in line with the principle of extending the scope of professional realization and recognition: from the work matching the researcher's personal interests, via recognition by the narrow professional community to a high status in the overall society (including in other subject areas and countries). Indicators applicable in any activity area, such as formal position and salary size, comprize a particular component, quite separate from the variables which primarily describe research activities properly.

The key feature of a non-academic career is that recognition by the professional community can be divided into two separate components: recognition for the previous scientific achievements (publications), and the recognition for the practical implementation of the R&D results. These findings demonstrate the growing value of a PhD for a career in industry and outside of academia in general.

Orientation towards mobility makes another important factor affecting the success of research careers. Note that aspirations to change jobs inside the country, turn out to be closely linked with the participation in international mobility, and in academic cooperation. Frequently, researchers find the scale for evaluating their career achievements not in the national, but in the broad international professional community. Thus, assessing the success of their careers, researchers position themselves, not only in relation to their direct colleagues, but also with respect to the international academic network.

CRediT authorship contribution statement

Natalia Shmatko: Conceptualization, Investigation, Writing - original draft, Supervision. **Yurij Katchanov:** Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Galina Volkova:** Conceptualization, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization.

Acknowledgement

The article was prepared within the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE) and supported within the framework of a subsidy by the Russian Academic Excellence Project '5-100'.

Appendix 1. List of variables to analyze research career

Variable	Min	Max	Mean	St. dev.
1. Advanced degrees	0	2	0.73	0.58
2. Principal job changing	0	1	0.71	0.45
3. Occupation (including team and project management responsibilities)	1	4	2.82	0.64
4. Average monthly salary at the principal job (including all bonuses and benefits) (range from 1 to 5)	1	5	3.00	0.94
5. Number of papers published throughout the career	0	500	36.24	48.70
6. Number of papers published in foreign languages during the previous 5 years	0	63	3.68	7.94
7. Academic supervision experience (master / PhD thesis, etc.)	0	1	0.51	0.50
8. Membership in professional associations and expert councils	0	1	0.32	0.47
9. Experience of managing research / education projects, practical implementation of results	0	1	0.47	0.50
10. Experience of practical application of innovative solutions and research results	1	2	1.64	0.48
11. Patent activity (for the previous 10 years)	0	32	0.96	2.47
12. Awards from professional exhibitions, competitions, etc.	1	2	1.65	0.48
13. Honorary titles (awarded for professional or S&T achievements, inventions, innovations, etc.)	1	2	1.79	0.41
14. Creativity and innovativeness of work	0	1	0.62	0.49
15. Opportunity to realize professional potential (knowledge, experience, abilities)	1	4	3.63	0.53
16. Opportunity to pursue and develop own ideas for the sake of extending knowledge	1	4	3.22	0.69
17. Training experience at Russian organizations (leading R&D and S&T centers)	1	4	1.48	0.84
18. Training experience at foreign organizations (leading R&D and S&T centers)	1	4	1.26	0.66
19. International mobility experience (working or studying abroad for three months or more)	1	2	1.88	0.32
20. Participation in international cooperation	0	1	0.61	0.49

Appendix 2.1. Factor loads matrix for academic research career

Rotated component matrix	Component				
	1	2	3	4	5
Advanced degrees	0.808				
Principal job changing					0.537
Occupation (including team and project management responsibilities)				−0.655	
Average monthly salary at the principal job (including all bonuses and benefits)				0.769	
Number of papers published throughout the career	0.812				
Number of papers published in foreign languages during the previous 5 years	0.681				
Academic supervision experience (master / PhD thesis, etc.)	0.630				
Membership in professional associations and expert councils	0.544				
Experience of managing research / education projects, practical implementation of results	0.448				
Experience of practical application of innovative solutions and research results		−0.456			
Patent activity (for the previous 10 years)		0.452			
Awards from professional exhibitions, competitions, etc.		−0.668			
Honorary titles (awarded for professional or S&T achievements, inventions, innovations, etc.)		−0.431			
Creativity and innovativeness of work			0.475		
Opportunity to realize professional potential (knowledge, experience, abilities)			0.785		

Opportunity to pursue and develop own ideas for the sake of extending knowledge			0.741			
Training experience at Russian organizations (leading R&D and S&T centers)		0.611				
Training experience at foreign organizations (leading R&D and S&T centers)						−0.635
International mobility experience (working or studying abroad for three months or more)						0.706
Participation in international cooperation (during the previous 3 years)	0.569					

Factor identification method: principle components analysis.
Rotation method: Varimax with Kaiser normalization.
a. Rotation converged in 6 iterations.

Appendix 2.2. Factor loads matrix for non-academic research career

The variable "Academic supervision experience (master / PhD thesis, etc.)" was excluded from the analysis as the factor mostly common for career in academia and that is not inherent for non-academic research career.

Rotated component matrix

	Component					
	1	2	3	4	5	6
Advanced degrees		0.732				
Principal job changing			0.500			
Occupation (including team and project management responsibilities)					−0.618	
Average monthly salary at the principal job (including all bonuses and benefits)	0.697					
Number of papers published throughout the career		0.797				
Number of papers published in foreign languages during the previous 5 years		0.583				
Membership in professional associations and expert councils			−0.495			
Experience of managing research / education projects, practical implementation of results	0.559					
Experience of practical application of innovative solutions and research results	−0.570					
Patent activity (for the previous 10 years)					0.708	
Awards from professional exhibitions, competitions, etc.			0.653			
Honorary titles (awarded for professional or S&T achievements, inventions, innovations, etc.)			0.578			
Creativity and innovativeness of work	0.539					
Opportunity to realize professional potential (knowledge, experience, abilities)				0.830		
Opportunity to pursue and develop own ideas for the sake of extending knowledge				0.754		
Training experience at Russian organizations (leading R&D and S&T centers)			−0.461			
Training experience at foreign organizations (leading R&D and S&T centers)						0.825
International mobility experience (working or studying abroad for three months or more)						0.569
Participation in international cooperation (during the previous 3 years)					0.440	

Factor identification method: principle components analysis.
Rotation method: Varimax with Kaiser normalization.
a. Rotation converged in 9 iterations.

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