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Richard Woolley, Carolina Cañibano, Jakob Tesch

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INGENIO [CSIC-UPV] Ciudad Politécnica de la Innovación | Edif 8E 4º | Camino de Vera s/n | 46022 Valencia
tel +34 963 877 048 | fax +34 963 877 991 | innco@ingenio.upv.es

A Functional Review of Literature on Research Careers

Richard Woolley[1,a], *Carolina Cañibano*[1,b], *Jakob Tesch*[2,c]

[1] INGENIO, CSIC-UPV (Valencia, Spain)

[2] DZHW – DZHW - Deutsches Zentrum für Hochschul und Wissenschaftsforschung GmbH

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[a] ricwoo@ingenio.upv.es
[b] ccanibano@ingenio.upv.es
[c] tesch@dzhw.eu

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1 Introduction – theoretical, analytical and empirical aspects of research careers

This working paper was developed as part of the Research Infrastructure for Science and Innovation Policy Studies (RISIS)[3]. In particular it comes from the work of WP24: 'Conceptual framework for the study of researchers' careers'.

This paper is designed to systematically reflect upon **available theories and empirical developments** leading to the proposal of a conceptual framework that will identify:

i) main career types of PhD holders;

ii) key milestones in career development of each type; and

iii) main factors affecting the career decision-making and development process, including personal, organizational, disciplinary, job market and systemic factors.

The starting point for this task is the conception of the career as an ***interactive decision-making process***, where career decisions are shaped and taken based on a set of framework conditions. The broad target population both for the conceptual and subsequent empirical exercises are PhD students and holders in all fields of knowledge.

The work will focus on providing the following main analytical tools:

1. A **typology of careers** for PhD students/holders, taking into account both disciplinary and cross-country diversity. Special attention will be devoted to assess the difference between conventional research careers, both in the public and private sector and more unconventional career types (Lee et al., 2010);
2. A **sequence of main career milestones** for each identified career type; and
3. A structured framework of **main factors shaping the career decision-making and development process**. A set of most relevant factors will be proposed, taking into account the above-mentioned factors as well as their mutual interaction. Special attention will be paid to cross-country and disciplinary diversity.

Whilst there is indeed a significant amount of literature that addresses aspects of science or research careers, one of the main objectives of this paper is to assess how well this literature facilitates the development of the analytical tools specified above. The

[3] http://risis.eu/

identification of gaps in this literature will be particularly important to clarify in terms of disciplinary and national differences.

2. Theoretical and empirical approaches to science and research careers & related literature

This section reviews the available theoretical approaches to science and research careers in the social sciences. Whilst there is a large body of academic work directed to theories of professional careers, the focus here is narrower. However, the extent to which theoretical approaches to research careers are built on elements draw from career theory then this lineage will be specified, in terms of citations and basic summaries of the approach being drawn on. This should provide an entry point into career theory for those readers wishing to explore the base on which conceptual understandings of research careers are built.

This section also contains comparisons between the available theories and their potential contributions to the main objective of building a conceptual framework for the study of research careers. It should be noted at this point that there is an important difference between **theories or conceptual frameworks of research careers** and **a unifying conceptual framework for studying research careers**.

A major difference is that the development of a conceptual framework for studying research careers should, from the start, pay specific attention to questions of potential data types, modes of data collection, the possibilities of indicator building and comparative monitoring across disciplines and national systems. In other words the framework for studying careers must be one that supports the possibility of comparative empirical investigation that can function to structure a kind of distributed observatory of research careers. The framework should background individual, specialised and often needs-driven investigations of aspects of research careers in such a way that these studies contribute also to the development of a coherent broader frame for understanding.

The current state of the art in relation to explicit theoretical approaches to careers and collaboration offers a contrast between a European neo-institutional approach (Gläser, 2001; Gläser and Laudel, 2007 & 2008; Laudel, 2001) and a U.S. human capital theory derived approach (Bozeman et al., 2001; Bozeman and Rogers, 2002; Dietz and Bozeman).

2.1. Evolving institutions, parallel career processes and the production of scientific knowledge (Laudel and Gläser)

Gläser and Laudel develop three analytical categories, cognitive careers, careers in research communities and organisational careers, which operate as parallel career processes (Gläser, 2001; Gläser and Laudel, 2007 & 2008; Laudel, 2001). Individual scientific activity and achievement involves a continuing development of scientific interests and problem choices and approaches. This cognitive career exists in a dynamic tension with institutional factors, including both transition through career stages within a scientific peer community and formal progression to higher level positions within research performing organisations. These parallel career processes do not necessarily develop in concert, for example, significant research achievements that attract peer acclaim are not necessarily accompanied by timely organisational promotion. Scientific research careers thus need to be understood in terms of their overall accommodation of the interactions and conflicts between these three parallel career processes as they unfold over time.

The research community features strongly in this approach, as an institutional context which links research, social and work roles and bureaucratic organizations hosting professional jobs. The **role of collaboration** as a social and professional mechanism is very significant in relation to the three parallel career processes and their interaction. Choice of collaborators is firstly important in terms of mobilizing the knowledge and/or skill required for research (Katz and Martin, 1997; Melin, 2000), particularly as most research is collective and cognitive resources are distributed across a research team (Beaver, 2001). Collaboration within a peer community is, in part, determined by the varying needs of members of that community, their relative standing and extent of common interests. Collaborators can be particularly important to facilitate moving into new areas of interest, for example. Collaboration choice is thus highly strategic in terms of advancing peer community careers (Merton, 1973).

Ultimately, collaborating with those colleagues whose positions allow them to determine the 'stakes of the game' (i.e. the defining research questions or problems) within a particular field or sub-field can be strategically the most rewarding, in that it leads to the greatest level of homology between individual interests and institutional arrangements (Bourdieu, 1975).

Gläser and Laudel (2007) show how transition from apprentice to colleague within the peer community involves the transformation of collaborative relationships (from mentoring to partnerships). Collaboration relationships and peer community career progression are thus mutually reinforcing. Finally, in terms of organisational careers, collaborators are important indicators of credibility and quality and can also provide important allies in terms of direct or indirect forms of support for advancement to higher level positions.

2.1.1 Building blocks

As a relatively comprehensive theory of research careers the approach is unique. It is also exceptional in being a theory that emerges from within social science approaches to the study of the field of science but which incorporates elements from other specialist literatures.

In Glaser 2001, research careers are described as theoretically important because they link individuals with institutions and social structures with knowledge production. Career are defined as overlapping social institutions within a neo-institutionalist approach that allows for more scope for individual autonomy that more determinist institutionalist approaches. These institutions prescribe sets of formal and informal social rules that shape individual actions.

The approach draws on the work of John Ziman (particularly Prometheus Bound (1994) and Knowing everything about nothing: specialization and change in scientific careers (1978), particularly in relation to the idea of an organisational career, individual cognitive careers as research trails, and the understanding that the overall conditions (expansion, stasis, expansion) in a particular system or part of a system, and the way these conditions are 'managed' will have repercussions for the career possibilities of researchers. Ziman argues that 'steady state science', in which the expansion of the science system ceases its continual expansion means there is now competitive pressure on scientists to perform, to be promoted and to earn income from external funding sources. The supply of PhD researchers outstrips available places, meaning the fixed-term contract and project funding becomes the new default career situation for many post-docs. Changes in the nature of research careers from an institutional perspective need to be understood as long run and evolutionary.

Glaser and Laudel take changes in authority relations (Whitley et al 2010) and tenure type into account, whilst still defining a research career in the same way as career theory as a sequence of jobs (2001, 701). The focus in their work is very much on academic careers. Nevertheless a tension is expressed between science careers, which seem to be largely constructed by organisational and societal factors and research careers shaped by the cognitive career and peer communities of disciplinary specialist.

Four career stages are described: **apprentice, mentor, colleague, sponsor**, and the transition from one of these stages to the next is described as a change in the dominant 'role set'. Ultimately it is the process of cognitive broadening, acquiring learning and other capabilities, which drives the transition from one role set to another – making the production of knowledge and the cognitive career the real trigger for career development (2001, 703).

The four stages of a research career are drawn from **career theory**, specifically the work of Dalton and colleagues (1977) on professional careers (section 4). Scientific careers are seen as sharing many characteristics with other professional occupations. However, it is the key impetus provided by the trajectory of the individual 'research trail' that makes scientific careers more problematic to understand. Advances in the cognitive career are adjudicated by the peer community and not by the organisation which pays for the researcher's time and provides a career ladder in terms of the potential for vertical mobility. Moving up in the organisation can mean moving out of research, but achieving recognition in the peer community for the contribution to knowledge production is a prerequisite for such an elevation in organisational status.

The separation of approval/credit and promotion leads to the fundamental tension between these parallel career processes. Taking on the role set of an autonomous research colleague depends on peer recognition, but this does not necessarily equate to the opening up of a promotion or permanent position within the research performing organisation – usually a university or institute. Much of the friction within the research and science systems can be attributed to the tension or conflict between different processes with an individual's career.

An escape valve for this systemic tension is the part-time contract, which allows for the temporary hiring of individuals who are not able to find permanent positions. This mechanism also facilitates the mobility between organisations and communities that is

fundamental to scientific innovation. On a positive note, such mobility can provide opportunities for additional learning that can advance the cognitive career and bring new knowledge to host organisations in exchange for a permanent job. On a negative note, individual careers can get trapped in a sequence of temporary contracts trading the researcher's long-term research horizons for a series of project-based results which may or may not provide access to longer-term funding or employment.

The concept of internal labour markets (ILM) is introduced from labour economics to frame markets for researchers around specific practices in scientific specialities. The peer community is once again the controlling social actor, with peer reputation and evaluation the basis for job selection decisions. The framing of an internal labour market within a scientific speciality overlaps with other interpretations such as Lam (2005) who looks firms' extended ILMs where they develop strategies to drawn on the human capital of university employees. (See also Stephan Economics of Science).

2.1.2 Career steps and stages

Laudel and Gläser (2008) investigates the transition from apprentice to colleague, in particular the **changing role set that defines these career stages** and how these may or not be aligned with the progress of the organisational career. Relevant definitions are streamlined and specified in this paper. The **cognitive career** is defined as an iterative process of proceeding from one project to the next in constructing a unique research trail (2008, 390). A **peer community career** is a sequence of role bundles within a specialty or discipline with four stages: **apprentice, colleague, master, elite** (390). The four stages that were adopted from Dalton et al (1977) in Gläser (2001) have been adapted somewhat, most likely to tailor them to the specific characteristics of scientific careers. An **organisational career** is defined as moving between jobs offered by research performing orgsanisations, linked to specific performance expectations and research opportunities.

The three career processes are linked together in a complex pattern of interactions that determine the trajectory of the career. However, variations in the trajectories produced by the three interacting process are also shaped by a number of independent variables including: **researcher's traits** (including capability, motivations); **field-specific characteristics** (including time and material resources, research objects, methods); **collaborators** (needed or not); and **mentors**.

In the empirical study of the transition from apprentice to colleague it is the expectations of more senior members of the peer community that define the role set that is expected of a colleague. The competences that define this role set are listed (2008, 391) and are focused exclusively on the capacity of the individual to undertake autonomous research based on a sound understanding of the state of the art, the research gaps and appropriate methods to answer outstanding questions. Progress in careers is driven by scientific achievement that conforms to the expectations of peers – but this is not the sum total of the career, or the processes given momentum to the career.

It is also important not to understand knowledge production within a peer community as an epiphenomenon of a structured organisational career. Rather distributed peer communities are the primary contexts for knowledge production and these communities are hosted (on varying terms) by organisations. The big difference between these communities and other professions is that scientific specialities are their own customers (2008, 390) and have relative autonomy to make their own hiring decisions.

Research career stages – evolving role sets

Apprentice	Colleague	Master	Elite
	– Selection of research topics: How did the research questions after the PhD emerge? - Does the ECR pursue long-term research interests? Is the topic self-selected or was it suggested by colleagues/ collaborators? – Publishing of the research following the PhD: Was it published at all? Where was it published? Does the ECR publish independently, i.e., without the former supervisor? – Perception by the Scientific Community: How is the research perceived by the national and international scientific community? – Competitive research funding: Funding agencies often have high expectations about the research concept outlined in the funding proposal; hence a successful grant application can be considered an indicator for achieving the 'colleague' stage.		

Source: Laudel and Gläser 2008

Researcher mobility is understood within an 'inter-organisational' frame, as the classic type of moves between research conducting organisations that take place through 'channels of excellence' as Mahroum (2001) describes. Mobility can be to change jobs, entailing a 'step' in the organisational career, or for visits or extended stays, which may not entail such a step. Research mobility also links the cognitive career to new contexts and learning possibilities. Whilst mobility can be used as a career strategy to get ahead in the sense of a promotion, or to enhance scientific opportunities, it remains unclear how often these things happen in concert with each other.

The significance of the parallel process theory and the transition between role sets is that it allows for an analytical distinction between the taking a 'step' and entering a new career stage. The role set that characterises a new job may replicate that in the job that has been left behind. A visiting position may require taking on new roles. A change in the organisational career (new job) AND a transition in role sets DOES NOT necessarily mean vertical mobility (promotion). These changes need to be investigated empirically – most likely through biographical interviews. A major strength of this theory is that it provides a life-course framework for scientific careers that is also an effective heuristic for interpreting the trajectory of individual careers in terms of both significant events and evolutionary transformations in work roles.

The theory has been developed on the basis of working with scientists and researchers in public sector organisations, mainly universities and research institutes. Applying this framework to industrial research careers may also produce interesting information, but it seems likely that its explanatory power would be reduced. The empirical approach most suited to this theory is detailed qualitative investigation using mixed methods. These investigations are likely to require significant time and focus on small *n* comparative studies.

2.1.3 The transformation of PROs and universities

A different body of work focuses on the changes in authority relations, funding systems and evaluation processes in public science and the impact on universities (Whitley et al 2010; Whitley and Glaser 2014). This work charts the deeper structures of changes in the missions and cultures of the public sciences. The transformation in the governance of science in a range of different countries is described and its impacts discussed. Other author stress changes in universities 'task environment' due to globalized competition for

students, mass marketization of higher education and the need to be responsive to political and social changes (Howells et al. 2014). Universities have also taken on the 'third mission' of societal engagement to varying degrees (Barrioluengo-Sanchez 2014). National and European prioritising of research grand challenges has an impact on research topic choice, or at least how the topic is framed. Just as these authors highlight the impact of such changes in governance on innovation in scientific research it should also be taken into consideration that these are the conditions that are very likely shaping new occupations, work roles and research careers.

2.2. Scientific and technical human capital (Bozeman and colleagues)

Bozeman and colleagues (2001, 718) more abstract formulation of 'scientific and technical human capital' pairs an 'expanded notion of human capital' with a 'productive social capital network´. Or alternatively, 'the sum of researchers' professional network ties and their technical skills and resources' (Bozeman and Corley 2004, 599) They argue that educational qualifications should not be understood as either an indicator of homogeneous human capital or as an end point in human capital acquisition. Rather both training and experience are heterogeneous, and individual scientific careers are somewhat unique trajectories of ongoing human capital accumulation.

Scientists' technical human capital is defined by three dimensions:

- Cognitive skills – those cognitive abilities (maths reasoning, memory, ability to synthesize) that are largely independent of context or more likely interact but are not determined by context. Not only 'scientific' abilities (2001, 726)
- Substantive scientific and technical knowledge – formation and education, understanding or experimental and research findings (2001, 727)
- Context skills – knowledge accumulated by doing and creating and including tacit knowledge, craft skills, and knowledge specific to the design and implementation f specific research or experimentation plans (2001, 727) not directly applicable but provide heuristics and analogies for other contexts.

The extent to which an individual scientist has particular 'loadings' of these factors will shape their career path. Evolution in capacities of these dimensions over time also shapes the possibilities in terms of career trajectories. These dimensions overlap and are in part

co-constitutive of each other, but relative weightings determine to some degree the kinds of work roles within teams or other collectives that a scientist is most suited for (cf. habitus, Bourdieu).

However, human capital represents only half the resources available to scientists, the remainder being available through a researchers' accumulated social capital. Social capital is embodied in the sum of professional and personal interactions and relationships in which an individual is embedded and which increase the resources available to them.

Social capital is defined along two dimensions:

- The institutional setting of the network partner (firm, NGO, Govt institute, etc.)
- Role of the partner (entrepreneur, colleague, funding agency, etc.)

These dimensions combine into the social capital network. In terms of the formal analysis of a social capital network, insights from SNA (Burt, Granovetter) also show that the configuration of extended network roles in terms of centrality, density and brokerage can also affect the resources that are available to an individual. Positioning within networks thus has career implications as well.

The most important parts of the social capital network are the 'knowledge value collectives' in which a researcher is involved. Knowledge value collectives (KVCs) are a 'set of individuals connected by their uses of a body of scientific and technical knowledge' and are smaller and less durable than scientific disciplines (Bozeman and Rogers 2002, 777). The basis for choices of research questions or collaborators in the S&T human capital model may thus be somewhat different to that in a model of disciplinary peer communities.

Following from the work of Stephan and Levin (1997) to some extent, empirical studies utilising the S&T human capital approach have made a considerable contribution to understanding the role of research collaboration in research careers. For example, collaboration with industry has been shown to have beneficial effects on scientific productivity (Lee and Bozeman, 2005; Lin and Bozeman, 2006). Different collaboration strategies among researchers have been linked to different sets of motivational factors (Bozeman and Corley, 2004; Bozeman and Gaughan, 2011). While earlier studies (Bozeman and Corley, 2004; Lee and Bozeman, 2005) suggested men have greater numbers of collaborators than women, a more recent study found women and men to have similar levels of research collaboration – prompting suggestions that policies

promoting gender equity in U.S. university careers may be paying dividends (Bozeman and Gaughan, 2011, p.1399).

Dietz and Bozeman (2005) looks at the impact of time spent/jobs (*n*) in the private sector on scientific productivity measured exclusively as publications and patents. An index of career 'homogeny' is constructed to measure the extent to which an individual career conforms to a very standard or normal vision of an academic career (PhD, post doc, assistant Prof, tenured Prof). They found that among research centre based academics there is significantly more time being spent in the private sector (often through dual appointments) than life course productivity literature had shown in the past. This may be because the centre's in the study were mission centres funded by government and hence, perhaps more likely to be strongly engaged with industry issues and problems. Career diversity was found to create some productivity boosts around both sides of a 'job transition' – so-called because of dual and hybrid appointments (industry PhDs). The overall change in universities toward a more 'business' model was also seen as a potential explanator for some of the emergence of these different career structures (see Lam 2005). This problematic makes it seemingly important to better distinguish between career steps or job transformations (such as taking on a dual industry appointment or chairing a spin-off) and changes (moving from one University research, centre to another).

In the STHC model, the interaction between these elements and career stages is not explained. Rather the tenure track process is said to be under stress (see Ziman) from the proliferation of post-docs trapped in sequences of temporary positions. A much greater proportion of PhD graduates are doing post-docs reflecting institutional changes that are affecting careers (from 27% in 1973 to 63% in 1995). Problems include oversupply, 'steady state funding', cheap labour, discrimination against women, minorities and other relatively weak labour market actors, the most talented go straight to tenure-track leaving a pool of lesser lights to try an establish their credentials, whilst this may be a much bigger problem in some fields than others. For example, lack of research funding in some parts of SSH mean there are too few post doc opportunities.

In summary, whilst scientific and technical human capital is what scientists bring to their jobs or collaborations, these contexts are also sites for the continuous augmenting of capitals. The *scale of S&T human capital* is enhanced by increasing the volume of collaborations. The *scope of S&T human capital* is enhanced through the diversity of

collaborations, with different types of organisations or researchers from different disciplines, for example. The degree of social capital diversity will determine whether an individual engages in a relatively generalist or specialist career.

In this model, collaboration and networking simultaneously contributes to the advancement of individual careers and capabilities and the enhancing of systemic capacities. Jobs and collaborations also provide a context for further learning, knowledge transfer and skills development. They also facilitate the core network building and professional connections that will shape a professional career.

From a theoretical perspective, human and social capital are regarded as indivisible, and their 'interplay' as 'so fundamental, intimate, and dynamic that neither concept is fully meaningful by itself' (Bozeman et al., 2001, p.723). Scientific careers can thus be understood in this model as a function of the acquisition and interplay of complements of S&T capitals and how this impacts on the evolution of research capacities and performances over time.

An advantage of the STHC approach is that its concepts are applicable across a fuller range of institutional settings. The framework enables the exploration of hybrid careers in EILMs (Lam 2005) and careers that move back and forth between industry and universities or other public sector research organisations. Empirical analyses can be conducted on a large scale, including through the use of surveys and CV coding, to draw out patterns that can help identify different types of 'standard' careers and the impact of independent variables on career trajectories.

2.3. Comparison of the two relatively comprehensive approaches

The two theoretical models of careers are distinct and offer different perspectives for interpretation and understanding of research careers. Table 2.1 compares the two models on a variety of dimensions.

	Gläser & Laudel	**Bozeman and colleagues**
Research career	Sequence of jobs	Job transformations
Career Stages	Defined by continuous evolution of role sets	Labour market defined
Context	Academic scientific careers	Science and R&D careers
Theoretical approach	Neo-institutionalist/sociological	Human & social capital/public administration

Individual	Motivated by cognitive questions	Motivated by rewards/augmenting STHC
Collective	Disciplinary speciality	Knowledge value alliance/social capital network
Causality	Insitutional conditions frame the capacity of researchers to makes decisions about research questions and approaches	Endowments of STHC structure the possible technical and social contexts in which a researcher can apply their capacities
Research assessment	Contributions to new knowledge	Productivity over the life course
Career authority	Specialist community	Faculty/firm HRM
Labour market	Internal labour market of disciplinary specialty	Competitive labour market of research performing organisations
Researcher mobility	Channels of excellence linked to cognitive questions	Learning and productivity contexts matching STHC endowments

2.4. Related literature

2.4.1. The role of collaboration

The **role of collaboration** in constructing research careers is described in a range of empirical literature. Collaboration has variously been shown to provide access to skills, tacit knowledge, funding or research infrastructure (Katz and Martin, 1997; Melin, 2000; Beaver, 2001) and to be motivated by the desire to mentor junior researchers (Bozeman and Gaughan, 2011; Melin, 2000; Beaver, 2001) and to acquire prestige by association (Crane 1972; Katz and Martin, 1997). However, a theoretical understanding of careers and collaboration remain relatively implicit in most such studies, with notable exceptions (Merton, 1973).

2.4.2. Gender

The principle of equality of opportunities for men and women is enshrined in the European Treaty of Amsterdam (Articles 2, 3). The 'mainstreaming' of gender equality of opportunity into all policy areas has been subsequently pursued. In 1999, the European Commission communication on 'Women and science: Mobilising women to enrich European research' recommended several measures to mainstream gender equality for integration into the Fifth Framework Programme. The European Council Resolution of 20 May 1999 on women and science welcomed these recommendations and encouraged

their adoption by Member States. The recommended strategies and measures included 40% participation rate of women, on average, throughout the 5th Framework Programme, in Marie Curie scholarships, advisory groups and assessment panels. In November 1999, the Commission established the Helsinki Group on 'Women and Science', as a space for dialogue on local, regional, national and European policies, experiences and best practices for promoting gender equality and the participation of women in scientific fields. In its Resolution of 26 June 2001 the Council urged the Commission to reach its target of a 40 % participation of women at all levels in implementing and managing research programmes, while continuing to bear in mind the need to ensure scientific and technological excellence. The Council invited Member States to collect gender-disaggregated statistics in human resources in science and technology and to develop indicators in order to monitor progress towards equality of opportunity and equity of outcomes for men and women in European research. The Council also invited Member States and the Commission to continue support for the ongoing work of the Helsinki Group.

Career development strategies recognise the importance of the objectives of equality of opportunity and gender mainstreaming in European science and research. Overall, quantitative indicators suggest that whilst progress has made toward gender balance in European science, "[w]omen in scientific research remain a minority, accounting for 30% of researchers in the EU in 2006" (European Commission 2009: 7). Participation of women and men remains uneven, by field. In the EU-27 in 2006, women made up 52% of PhD graduates in Humanities and Arts and 46% of PhD graduates in Social Sciences, Business and Law. In contrast, 41% and 25% of PhD graduates in Science, Maths and Computing and Engineering, Manufacturing and Construction, respectively, were women. Data also shows the careers pipeline remains leaky for women scientists with under-representation of women at higher levels/ranks. For example, women made up 36% of PhD graduates in science and engineering in the EU-27 in 2006, but just 22% of researchers at Level B (mid-level research positions) and 11% of Level A (top level research positions) within professional science (European Commission 2009: 74). Gender balance in the science careers pipeline is thus an issue with important implications for gender representation within high profile support mechanisms such as the ERC Starting, Consolidator and Advanced Grant Programmes for example.

Zuckerman (1991) reviewed the state of the art in US research explaining differences in productivity between women's and men's research careers. The differences were explained by social selection (discrimination, differences in role performance and the distribution of rewards), self-selection (family choices, career commitment) and cumulative advantage. Women tended to have lower expectations about what it was possible for them to achieve and to be less vocal, or take less ownership, of their achievements. Zuckerman noted the interplay of these various factors, with cumulative advantage amplified by women's lower expectations and disadvantage due to career breaks. Small differences could become more significant gaps over the duration of the career, particularly as women scientists tended to prefer working with others to make a contribution to the pursuit of rewards and recognition.

Ackers and colleagues in Europe emphasises the importance of gender and life course in the migration decision-making processes of male and female scientists. Partnering, particularly in the context of dual science careers, constitutes a serious challenge to migrant scientists, as does parenting and the need to support family members in other countries (Ackers, 1999, 2001, 2005). Dual or same career partnering has a particularly significant effect (Ackers, 2010; Cox, 2008). Female researchers also display reduced fertility in comparison with their male peers (Buber et al. 2011) and have a marked tendency to delay motherhood. The presence of children has a complex effect, generally contributing to a degree of 'stickiness' reducing longer term forms of mobility and also increasing the resistance to precarious forms of employment (Ackers and Oliver, 2008). The increasing use of inappropriate indicators in the assessment of research performance may exacerbate the leakage of women (Ackers, 2008).

In US research universities, academic women have been found to have lower marriage and partnering rates compared to me (Fox 2005; Probert, 2005). In partnerships of two academics who have children at home, women tend to have greater child rearing responsibilities (Hamovitch & Morgenstern, 1977); women more often the 'trailing spouse' (Bailey & Cooke, 1998; Shauman & Noonan, 2007). Women in academic science report higher work-family conflict than do men; gender difference is greater for conflict of family with work than for work with family (Fox et al. 2011).

Research collaboration is an important area in which differences appear to exist based on gender. Women tend to have a higher percentage of female collaborators than do men (Bozeman and Corley 2004), with untenured women scientists' collaborators are likely to

be other women (84%). Tenured women tend to have gender collaboration patterns similar to tenured men (around 35% female collaborators). Men seem to experience gains in the number of collaborators via three collaboration strategies: instrumental, experience and mentoring, whilst women's mentoring strategies are the only ones that predict the number of research collaborators (Bozeman & Gaughan 2011). A recent paper (Bozeman & Gaughan 2011b) found no effect of either marriage or dependent children on collaboration, suggesting decades long policy focus on reducing family-related barriers to women's participation in scientific work may be paying off (Bozeman & Gaughan 2011), at least in the US. Studies of the structural context of female and male scientists' work focus on scientific productivity or collaboration (Fox, 1991, 2010; Xie & Shauman, 1998), finding that if one compares men and women working within similar structures and hierarchies differences in productivity or collaboration are reduced or vanish.

A large and growing body of research highlights the impacts of the **underrepresentation** of women in science, technology, engineering and mathematics (STEM) fields (Fox 2010; Fox and Stephan 2004; Gaughan and Corley 2010). The organizations conducting and administering scientific research are largely of the hierarchical and bureaucratically organized type in which, according to Acker (1990, 146), "men are almost always in the highest positions of organizational power". The organizational and institutional contexts of STEM are thus systemically gendered (Acker 1990), which has significant and pervasive effects on the social processes of working in STEM – leading to differential outcomes in careers. The degree of women's underrepresentation increases with the level of occupational hierarchy in STEM, with statistical data showing women clustered in low-ranking positions in both the U.S.A. (NSF 2012) and Europe (EC 2013). The underrepresentation of women in STEM peer communities means that women have less same-sex peers than men, which can impact women's access to strategic scientific information (Villaneuva et al. 2015). According to this literature, careers of scientific researchers in 'gendered organisations' (Acker 1990) will be differently structured according to whether they are women or men.

[It should be noted the Gender is one of the dimension of Responsible Research and Innovation being mainstreamed in Europe. A series of H2020 funding calls are focused on helping organisations improve gender practices and processes.]

2.4.3. Mobility

"Scientific mobility" is defined by Mahroum (2000, p. 367) as "cross-border physical and geographic movement that comprises a stay in another country of no less than one year." Mahroum argues that such scientific mobility "goes through channels of institutions that enjoy a high reputation for excellence and expertise" (2000, p. 367). The universities, research institutes, and laboratories that are the principal sites of research degrees and post-doctoral positions (Melin, 2004), along with the government-funding programs underpinning these arrangements, provide the organizational and institutional contexts for these movements. The movement of scientists to foreign institutions for postgraduate research degrees and/or early-career postdoctoral positions sits within this definition of "scientific mobility through channels of institutions. In terms of the STHC framework (above) mobility can be seen as another career dimension contributing to scientists' "sustained ability to contribute and enhance their capabilities" (Bozeman et al., 2001, p. 718). In terms of the institutional framework (above) mobility provides access to researchers, teams and infrastructure necessary for pursuing cognitive questions and facilitated by organisational support mechanisms or job changes.

Literature on the mobility of scientists focuses on how scientific mobility contributes to the development of aspects a professional research career. Researchers who are mobile can build trans-national networks that sustain productive international collaborations (Woolley et al 2008) and can gain access to key postdoctoral labour market entry points (Melin, 2004; Lancio-Morandat & Nohara, 2002; Marceau & Preston, 1997; Stephan 2012), among other benefits.

According to some studies there is also a productivity return to mobility. Franzoni and colleagues (2013) found that migrant scientists who had been mobile for work or study outperformed their domestic colleagues, who had not been mobile, on the basis of the impact factor of focal publications. However, the study does not calculate whether any career benefits can be associated with such superior performance.

However, another study of researcher mobility, productivity and tenure in Spain found there was not return to careers – in terms of earlier time to tenure – from mobility (Cruz-Castro and Sanz-Menendez 2010). In fact, due to the institutional conditions under which employment in research organisations (CSIC and national institutes) and universities occurs, those who remain within their department of PhD graduation may have an advantage in terms of productivity (through shared papers) and lower transaction costs

associated with attempting to gain employment. Productivity is more likely to be linked to staying within an academic department and 'queueing' for permanency. This paper contains a very good description of the institutional and organisational conditions of of research careers in Spain. It is clear that mobility should not be considered unproblematically as beneficial to scientific careers. (See also Sanz-Menendez et al 2013, mobility associated with longer time to tenure). (There may be some connection here with the mixed outcomes of highly skilled migration (HSM)).

One additional factor perhaps worth considering in the Spanish context is the emergence of regional research systems that do not conform to the traditional Spanish model in terms of employment and, in all likelihood, potential career patterns. The regional systems in Catalonia (ICREA) and the Basque Country (Ikerbasque) are funded with regional government money and have different recruitment and hiring profiles than the public sector *funcionario* model that characterises the Spanish state. A potentially important research question is whether such regional models, and the alternate career paths they offer, can be found in other European Member States (MS)?

A group of quite different studies (Stephan (2008), Fitzenberger (2102, 2013), Lissoni (2011), Cruz-Castro (2010)) provide good overviews of academic labour market processes, hiring and career development across France, Germany, Italy and Spain among MS. These studies can be useful in developing the comparative analysis of institutional conditions in WP24.

Stephan and colleagues (2014) examine the factors contributing to decisions to do postgraduate studies abroad. The most highly rated factors are scientific factors (benefit career, faculty, prestige, networks, infrastructure and funds), whilst non-scientific factors (lifestyle, life quality, family, fringe benefits) are less highly rated. The decision to do PhDs and Postdocs abroad are often linked to a desire to establish a career in the destination country subsequent to training. The study compares ratings for the US against the UK, France, Canada, Australia, Switzerland and Germany. These comparisons show that different countries are competitive in the global market for talent according to different baskets of perceived qualities.

2.4.4. Industry careers

One of the more difficult aspects of studying research careers is to understand careers in industry R&D. Dietz and Bozeman (2005, 350-1) review the state of the art in the US:

> studies of industrial scientific and technical careers have their historic roots in the discipline of management and the management of innovation. They tend to focus on engineers (Goldberg and Shenhav, 1984; Allen and Katz, 1992), on the dual career ladder (Shepard, 1958; Allen and Katz, 1986; Gunz, 1980, 1989), on gatekeeping behavior (Turpin and Deville, 1995), innovation (Fusfeld, 1986; Burns, 1994; Rosenberg and Nelson, 1994; Mowery, 1998), technological obsolescence (Dalton and Thompson, 1971; Pazy, 1990; Bartel and Sicherman, 1993; McCormick, 1995), and the management of technical personnel (e.g., Turpin and Deville, 1995; Debackere et al., 1997; Bowden, 1997).

However, these studies usually only look obliquely at careers in industry, or focus on particular aspects. Some of these studies may also be out of date in relation to current industrial R&D contexts of research careers.

Other studies of large institutional programmes have looked at Cooperative Research Centres in the US (Boardman et al 2013), Australia (Turpin et al 2011), Ireland (Ryan 2011) and Spain (Ramos-Vielba and Fernandez-Esquinas 2012). These programmes are designed to bring universities and industry research organisations into a sustained alliance or cooperative embrace, in the interests of increasing the chances of producing outputs that can be commercialized or can address societal problems. However, researchers involved in these cooperative ventures can suffer career risk due to stepping outside the university HRM structure, becoming too focused on applied questions or being unable to renew a fixed term employment contracts due to the cessation of a CRCs term or emerging role conflict (Coberly and Gray 2013; Garret-Jones et al 2013; Gray 2011).

Sauermann and Roach (2012) look at whether there is a mismatch between the supply of scientists and their desired careers and the opportunities available to them (1). In particular they identify a gap in the information provided by PhD supervisors about career alternatives outside the academy. This is despite the supply of PhDs who want to work in the academy exceeding the positions available in life sciences, chemistry and physics. In fact, PhDs feel academic research careers are what they are encouraged to aim for. However, over the course of the PhD there is a drop off of enthusiasm for academic research and a corresponding rise in interest in alternatives. This is taken to mean that it is the information gap regarding non-academic careers is limiting a better allocation of PhDs in the market. It is suggested that potential PhDs should be informed

about career realities before commencing doctoral study to allow for a more accurate assessment of the cost-benefit of pursuing a PhD (6).

Sauermann and Stephan (2013) develop a multi-dimensional comparison of industrial and academic science. The authors seem to be arguing that there are not divergent 'insitutional logics' that characterise private and public section science, although their results do not offer much support for this claim (academics publish more and industry scientists publish more, for example). Their 'conceptual framework' is comprised of the nature of work, workplace characteristics, worker characteristics and disclosure of results. They argue that workers with a strong desire for freedom are more likely to self-select into academia while those with a stronger desire for money will self-select into industry (893). An interesting finding is that **the industry-academy gap is less for the life sciences than the physical sciences**. They also find that autonomy in the highly competitive life sciences is directed toward running a large and well-resourced lab (898). No difference is found between salaries for researchers doing applied or basic research in the life sciences. Given these distinguishing characteristics and the increasingly heavy concentration of research funding into life sciences this could have significant consequences for how we understand science careers overall, but perhaps more importantly suggests that a 'life sciences career' may be emerging that has significant points of departure from other fields.

In the UK, an interesting study by Lam (2005) compares the career structures of researchers under three different models of organising private sector R&D.

> Technology push model, firms had their own internal R&D capability and were organised as a hierarchical structured unit much like a university department. Dual track careers combining with, or moving into, management were a feature. Reward systems were often financial or other material incentives substituting for prestige associated with publishing new results.
>
> Market pull model, a project-based and matrix-competences type model used to break down old closed R&D units and disciplinary specialisations within private sector organisations. The emergence of mixed techno-commercial roles lead to hybrid and ambiguous careers.
>
> Network model, responds to new knowledge production and organizational contexts and policy incentives that drive collaboration, triple helix and co-

> creation of knowledge. Scientists are expected to access new and sticky tacit knowledge through networked interactions (with university labs). There is an emergence of new career structures to support boundary crossing knowledge networks (247)

The changing organization of R&D and knowledge production thus transforms many science careers. The various careers associated with the firms in the study are understood as an epiphenomenon of the models of organizing R&D and knowledge production, from technology-push to market-pull to networked models. Move from mode 1 to Mode 2 (Gibbons et al) has ramifications for the types of career paths of scientists, PhD graduates and Post docs. Tensions exist between scientific and business goals for networked scientists- Those R&D staff in network firms are expected to have a scientific profile and disciplinary network with scientific excellence being important for careers- However, the breadth of these roles also makes maintaining core expertise difficult. Under the network model researchers are expected to interact externally and be bottom up idea generators filling the role of 'boundary riders' (Turpin et al 1996).

Lam develops the concept of the extended internal labour market (EILM) of firms, where they seek alliance, sponsorship and collaborations with university based researchers to satisfy their HRST needs. These EILMs use the university career structure as the foundation of the individual scientist's organizational career in the main (avoiding some of the problems of CRCs). Additional exchanges and jobs occur at the PhD and post-doc levels. These human resource linkages and career structures are designed to break down the cognitive and institutional barriers between industry and academy (270). There is thus a critical role for careers and mobility in sharing knowledge across organizational boundaries (270)

EILMs provide career structures and incentives to ensure that academic scientists are willing to engage in short-duration industrial projects while maintaining their positions at universities and remaining integrated into the academic scientific community (271). Large firms don't abandon ILM but transform itby making use of the career systems provided by universities (271). However, there is tension and enormous challenge stemming from the expectation to be a private researcher and a public scientist (272).

There are specific institutional forms used to develop these EILMs:

- Strategic partnerships for personnel and knowledge flows;

- Hybrid organizations between universities and firms to provide pool of professionals with industry and academic competences (includes joint appointments, postdocs and PhDs working on projects jointly supervised);
- Linked scientists and network nodes, hybrid career experiences and mobility between the two sectors are key mechanisms supporting three types of personnel - entrepreneurial professors or focal links, jointly appointed postdocs; and industry funded PhDs who may be recruited by firm (268-9)

Owen-Smith and Powell (2001) also look at how transformation in the way technological innovation is organised impacts on academic work and careers. They generate a typology of career responses in life sciences, as academic and commercial worlds come closer together. The typology includes Professor Old-School who views academia and industry as distinct and feels threatened by commercialisation pressures, Professor New-School who is the opposite. Reluctant Entrepreneurs are those who believe academia and industry do overlap, but feels threatened by commercialisation, whilst Engaged Traditionalists are also 'hybrid' professionals who despite not being committed to the overlap of academia and industry are prepared to pursue commercial success. What this paper convincingly shows is the way academic researchers' engagement with university missions as 'economic engines' can have a fundamental influence on their values and beliefs. They suggest there are increasing 'fault-lines' between faculty – which translates into greater heterogeneity in the types of activities university researchers undertake and the types of rewards on offer. The paper establishes a basis for the emergence of 'hybrid careers' among academics who confront simultaneously scientific and commercial goals. What the paper does not do is investigate the use of multiple organisational or institutional structures by academics in the pursuit of these dual goals.

Developing models of typical industry R&D science careers, or industry linked hybrid academic careers, is complicated. Looking at the type of industry and types of organisations involved can provide basic dimensions. The model of R&D may be an additional dimension in that it helps to contrast **different sets of expectations of industrial scientists and industry-engaged academic scientists** with tradition academic expectations. If the sets of expectations that PhD graduates or post docs hold about industry careers are also accessible, then any **information gap** between these two sets of expectations could potentially be mapped. To some extent this is what Fitzenberger (2012, 2013) does (see Section 3.1) however this study only includes social sciences.

2.4.5. Other studies of scientific careers

A very comprehensive and original study of the careers of physics faculty in the US is conducted by Hermanowicz (2003, 2007, 2009). Hermanowicz develops seven dimensions of careers: career focus; professional aspirations; recognition sought; orientation to work; work/family focus; attribution of place, and overall satisfaction. He traces the way these dimensions change over the course of three career transitions: early to mid-career, mid to late career; and late to post career. He does this for three different cohorts of physicists: elites (star researchers); pluralists (mixing research and teaching); and communitarians (largely teaching academics but with interest in research). He finds that some dimensions remain very stable (eg. Elites are focused research throughout their careers) but other dimensions evolve considerably, and do so differently for the different cohorts.

Hermanowicz also finds that the reference group by which different cohorts value their contribution and experience can vary, both between the cohorts and over the career. Unlike in the Mertonian formulation, reference-group selection depends not only on professional recognition from peers but also on the organisational reward system and to some extent on internal satisfaction (in particular for those whose career fades away from research activity over time). It is also noticeable that elites believe the rewards system of science to be fair throughout their careers, whereas pluralists start out thinking it is unfair but later are persuaded of its fairness. On the other hand communitarians believe the reward system to be unfair throught their careers.

Scientists can tend to become anomic or disenfranchised over time. In part, Hermanowicz argues this is because scientists have high expectations of their careers. He suggests this is because, first, they have come through a long selection process, second, science is a profession and people who enter professions tend to be achievement oriented and third, science has a star system (261).

Hermanowicz's conceptualisation of early, mid, late and post career phases depends largely on the age and time since PhD of the individual. These stages are mapped onto the seven dimensions as a structure to trace evolution in individual scientist's self-perceptions regarding their careers. It is a very detailed and rich study that reminds us that even within a single discipline within a single national research system, careers carried out in largely the same type of organisation (research universities) can still vary markedly and need to be tracked with sensitivity to work task distribution and

contextualised markers of what constitutes success and/or satisfaction in a scientific careers.

2.4.6. Linking PhD training, labour markets, innovation policy and research careers

Lee and colleagues (2010) compare the demand for different types of competences acquired in science and engineering (S&E) PhDs across three different career types. Research careers are classified according to sector and occupation:

- Careers in academia/public research: S&E occupations in academia and public sector
- Technical positions in manufacturing: S&E occupations in manufacturing
- Employment outside the conventional technical occupations: non S&E occupations in all sectors.

The results are from a survey of S&E graduates from one university in the UK between 1998 and 2001. The largest group of the PhD respondents are in employment outside conventional technical occupations, many in management roles, business services or consultancy. Those who pursue careers in academia typically struggle for a continuing appointment. The study shows that the competences that PhDs find important in their careers varies according to career type:

- knowledge directly tied tosubject areas is regarded as more valuable in academia/ public research
- both general knowledge directly tied to subject areas and general and transferable skills are regarded as valuable in technical positions in manufacturing
- general and transferable skills are regarded as more valuable in employment outside the conventional technical occupations
- general analytical skills and problem solving capability acquiredfrom doctoral education are perceived as valuable in all three career types.

Overall, this study suggests that S&E PhD careers can flourish in different sectors and occupations thanks to a diversity of competences acquired in doctoral training. It confirms that *careers of PhD holders are often not research careers*, particularly in the industrial context.

Jürgen Enders and colleagues (2004a, 2004b, 2006, various) argue that academic careers, including those which have as a main activity research, are being reconfigured by transformation in the overlapping institutions of science and society. Higher education policy has gradually enlarged the frame of its interest and impact to include the area of PhD research training. The belief exists that while traditional science training is still vital, the one size fits all model of PhD training has outlived its usefulness. A key driver of this has been the search for PhDs equipped for a fuller array of careers as required by societal actors engaged in knowledge focused activities. The job market for PhDs has become diversified (Dany and Mangematin 2004). Changing forms of knowledge production (referring to arguments about Mode-2, post-industrial science, etc.) have also been coupled with new forms of inter-organizational alliances, creating new contexts for PhD trained workers – but also potentially enlarging the scope of sites for training. At the same time there has been focus on more geographical and organisational mobility, transdisciplinary approaches to societal challenges and translational research. All this means that scientists need to be prepared to deal with **hybrid institutional contexts and less predictable career structures**.

PhD research training thus functions not just to reproduce the academic workforce but to diffuse knowledge across commercial and other sectors, provide knowledge focussed competences in non-academic organisations and institutionalizing a culture of innovation throughout society. Increasingly decisions about taking PhD training will not be about decisions to join the academy – presenting challenges to make doctoral training attractive in some contexts. Whilst an overall shortage of PhDs may not be expected, careers in some fields of study may become less attractive. The rise of the postdoctoral researcher, as a liminal position between career stages and often between adopting a particular organisational or institutional career path also presents some challenges to the training-career nexus – not least due to the low wages of many postdoc positions.

Moving away from a predominantly full-time academic career path into more fluid and hybridized career thus appears to be becoming more common – including amongst those working in the university sector (Enders and de Weert 2004b). Whilst academic researchers largely retain control over how-to-do research they are increasingly relinquishing control over what-to-do to societal actors including governments and firms. This also links to external partnerships and opportunities to train, work and learn in a variety of different research environments and to acquire the employability skills that can

make transitions between contexts relatively seamless. There is a feedback loop at work also here – the university becomes a more adaptable and open organization as such inter-organizational training and collaboration links intensify (Enders and de Weert 2004b).

Christine Musselin and colleagues (various) identify specific mechanisms that have facilitated the transformation in academic labour markets and careers in the kind of context described by Enders. In particular, the shift towards these more hybrid institutional contexts has been accompanied by an increase of casual and contract positions and consulting roles, with recruitment practices also evolving as the 'secondary labour market' of postdocs, part-time, assistant and adjunct jobs expands. The traditional function of the secondary labour market as a gateway to the primary market is declining. At the same time more formalized processes characteristic of professional organizations have started are re-shaping recruitment processes toward **broader sets of competences** (Barrier and Musselin nd: 10). 'Inbreeding', or the practice of being hired in the department of PhD training has declined as a consequence of such an evolution in many European countries.

2.5. Contribution to developing analytical tools

The three analytical tools to be developed are: a) a typology of research careers, b) a summary of career stages; and c) the main factors shaping the career decision-making and development process.

2.5.1. A typology of research careers

Gläser and Laudel (2001, 2007, 2008)	Focus on academic careers. Careers characterized by three parallel career processes that are linked in a complex pattern of interactions: Cognitive career Career in peer communities Organisational career
Bozeman and colleagues	- Standard vision of an academic career: PhD, post-doc, assistant Prof, tenured Prof; versus hybrid careers with dual appointments: Industry & academia - Generalist versus specialised career

Hermanovicz, 2003, 2007, 2009	Typology of researchers with implications for types of careers - Elites - Pluralists - Communitarians
Sauermann and Stephan, 2013	*Careers in industry* Characterized by el weaker desire for freedom and a stronger desire for money
Lam, 2005	*Careers in industry* Traditional structure: firms with own internal R&D capability organized hierarchically versus emergence of new career structures to support boundary crossing knowledge networks including hybrid careers
Owen-Smith and Powell 2001	*Careers in industry,* a basis for the emergence of hybrid careers - Professor Old-School - Professor New-School - Reluctant Entrepreneurs Types defined in terms of attitudes towards commercialisation and overlap of academic and industrial research activities.

2.5.2. A summary of career stages

Gläser and Laudel (2001, 2007, 2008)	Stages in careers in peer communities. Stages defined in terms of role sets. - Apprentice - Colleague - Master - Elite
Hermanovicz, 2003, 2007, 2009	- Early to mid-career - Mid to late career - Late to post career

2.5.3. Main factors shaping the career decision-making and development process

Gläser and Laudel (2001, 2007, 2008)	Independent variables affecting career processes: researchers' traits (including capability and motivations); field-specific characteristics (including time and material resources, research objects, methods); collaborators and mentors From apprentice to colleague: Scientific achievement that conforms to the expectation of peers Mobility
Whitley and colleagues Howels et al. 2014 Sanchez Barrioluengo 2014	- Transformation in the governance of science - Changing roles of universities
Bozeman and colleagues	- Scientific and technical human capital: researchers' capacities (addressed from a three-dimensional approach) shape the frame and possibilities for career trajectories - Research collaboration and networking - Inter-sectoral mobility - Institutional changes affecting careers: oversupply, funding issues, gender discrimination…
Ackers and colleagues Fox and colleagues Gaughan Zuckerman Cox other	Factors linked to the *gendered dimension of careers* - Parenting and other family choices - Dual careers (same career partnering)
Woolley et al. Melin Stephan et al. Cruz-Castro & Sanz-Menéndez others	Factors linked to *geographical mobility* and its impact on careers - Mobility and networks - Mobility and access to labour markets - Mobility and publication productivity - Mobility and career risk taking Mobility is viewed as positive for cognitive careers, but in some institutional contexts it can be negative for organisational careers

3. Economics and economics of science

This section reviews work on science and research careers in the field of economics and the sub-field of the economics of science. There has been a wave of publishing in the new economics of science, however research careers have not been a focus of this work.

3.1. Economics of science and research careers

The 'old economics of science' (Nelson 1959; Arrow 1962) view science as a market phenomenon and scientific knowledge as a public good, which allowed economists to use conventional neoclassical welfare economics (Samuelson 1954, 1958) to address the phenomena of knowledge production and allocation. Similarly, from an old economics of science perspective, issues regarding the functioning of the scientific labour force and research careers have been interpreted through the lens of neoclassical labour economics and human capital theory (Sent 1999). Human capital theory (Becker 1964) leads to an understanding of careers as sequences of job matches driven by market conditions and to scientific human capital formation as a process of knowledge accumulation through investments in training and through experience over time. The work by Biddle and Roberts (1994) for instance applies an equilibrium job-matching model to explain switches in careers of scientists and engineers working in the private sector and moving from technical to managerial occupations, where scientists make their decisions based on current and predicted earnings on the basis of their productivity in different tasks. Scientists are therefore assumed to be income maximizing agents in this context and to be capable to accumulate human capital and learn while on the job.

The cumulative or aggregative approach to scientific human capital is also associated with an understanding of scientific mobility as a zero-sum or drain-gain game since human resources can only be located at one spatial point at a time (Cañibano and Woolley 2015). A direct and explicit challenge to this vision available in the literature is the concept of scientific and technical human capital (STHC) (Bozeman et al. 2001) (see Section 2.2).

The more recent developments from the so-called 'new economics of science' (Dasgupta and David 1994) are rooted in the need 'for an enhanced understanding of the social structures of scientific research to carry out an informed discussion of critical issues regarding economics' (Sent 1999: 103). Sent points out how these 'new' contributions

show less interest in applying mainstream labour and individualistic economics (102) while scientific labour markets remain of central importance to understanding the economic aspects of science. She underlies the fact that career patterns of scientists may reflect economic circumstances more than intellectual trajectories. Emerging economic and social changes (i.e. increased global competition, environmental challenges, public health needs) 'bring new opportunities for varied careers in science and technology (110).

3.2. The work of Paula Stephan and colleagues

One of the most prominent scholars of the economics of science is Paula Stephan. A significant part of her work has considered the impact of changing 'market' conditions on scientific careers. However, she has also collaborated extensively with sociological researchers in developing a broad-based definition of what are considered 'market factors', including family and gender dimensions. This was due to her recognition that neo-classical human capital theory (Becker) was not adequate for dealing with the complexity of the production of scientific model, in which the virtually all production is the result of intensive collaboration and collective validation and relatively open dissemination practices.

Stephan uses a human capital framework expanded to include research productivity alongside income as incentives for scientific careers, due to the fact that publishing earns prestige and recognition which is regarded as a form of capital that can be accrued and, in turn, capitalised upon (following Merton and the Matthew effect). In addition, solving puzzles is regarded as an intrinsic reward from research.

In a number of studies, research productivity is studied over the life cycle (Levin & Stephan 1991; Stephan 1996 for a review; Stephan & Levin 1997). Overall, productivity either declines with age or increases initially with age before declining – with the differences apparently due to scientific field specific conditions (Levin & Stephan 1991; Stephan & Levin 1997).

Stephan sees two main factors that impact on the career prospects of young researchers. First is the growing prevalence of 'soft-money' positions where researchers secure external funding to pay for the cost of their own position within a research university (or some part of the cost). This has an impact on the time horizon of research, research topics and the dissemination or results. Second, the postdoctoral transition to a tenured or

tenure-track position fails in a large proportion of cases, with extended postdocs characterised by substituting research by competing for research funding become an increasingly common career type (Stephan and Levin 1997). As postdoc work is often directed or designed by PIs this career trap becomes increasingly difficult to break out of, as the key to success is to become an autonomous PhD directing a lab – and the criteria for accessing this level is demonstrating autonomous contributions to research.

Fox and Stephan (2001) found that young researchers have a relatively negative view of their career prospects. Expectations of PhDs about their career prospects tends to vary between fields, and also to some extent does the mismatch between these expectations and the 'reality' of the careers in these fields in the academy and industry (as far as these can be objectively known). Women tend to have greater preference toward careers in teaching universities than do men, with the authors speculating this is likely to be due to lower expectations about their career opportunities on the part of women. Overall, there may be an information gap between students understanding of the possible careers awaiting them and the incentives to attend graduate school. Once again the question of career expectations, and expectations of success, are cut across by gender and by field of science.

Stephan (2008) compares job prospects in Germany, Italy and the US in STEM fields. Decline in career conditions in all three countries, in Europe a fall in PhDs hired by industry – pointing toward a decline in the production of knowledge. At the same time, in fields where industry R&D jobs are an attractive option there may be a switch in PhD and postdoc research topics away from basic research and toward applied topics with industry in mind. Stephan argues that the three systems have a 'demand problem' in that not enough positions are being created in these economies with the right kind of time horizon, degree of security, productive work environment and degree of autonomy. Without a sufficient demand side expression of the importance of the production of new knowledge, the talents of generations of young and innovative researchers will fail to make the contribution to growth and development they could have.

In a presentation on the Economics of the Postdoc (2014), Stephan points to a number of incentives that have contributed: a) to the rise of the postdoc position; and b) to the impact of postdoc transitions on research careers. These incentives include: specialization in research; funding for research projects; publications as a precondition for funding. In seeking to satisfy these three incentives, lab directors can choose between phds, postdocs

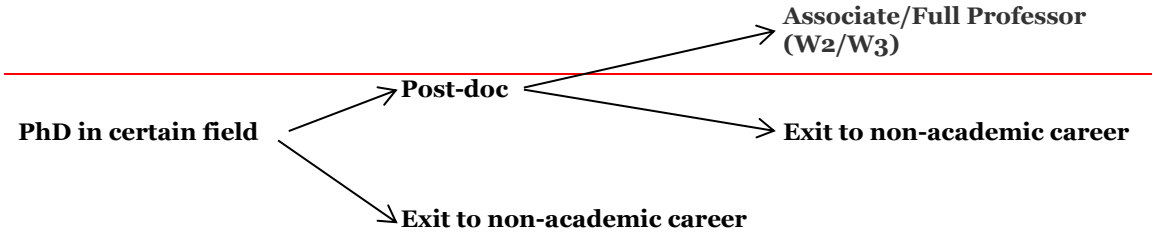
and staff – this is where costs become important. Postdocs often combine being relatively cheap, highly talented and more motivated. Postdocs remain poorly paid due to the competition, the volume of PhDs and the 'ongoing training' argument. Alternative view is that postdocs are price takers at the mercy of large institutions like NIH, which is seen as a price-setter. One of the major problems is the lack of clear information about alternative career options within and outside academy. Currently PhDs see no alternative but to pass through the postdoc mangle if they desire a research career – with the exception of an elite coterie of direct tenure track hires.

Sauermann and Stephan (2015) develops what is called a 'multidimensional view of industrial and academic science. They provide new empirical evidence regarding the similarities and differences between industrial and academic science – arguing that beyond the apparently conflicting logics there are much more nuanced institutional realities at play(890). The four dimension of their model include: the nature of work; characteristics of the workplace; characteristics of workers; and the disclosure of research results. A number of interesting findings are produced, including the relative lack of difference between industry and academia in the life sciences when compared to the physical sciences. They find that different types of R&D are relatively similar from the firm perspective (contrary to Lam). The *life sciences are singled out* as involving a 'path to freedom' in terms of research through leading a large and well-resourced lab (898). Industry scientists have greater interest in salary levels. There is a significant gap between academia and industry in terms of disclosure of research results. Overall, there are sectoral differences in terms of the nature of research, pay, patenting, however, there is also considerable heterogeneity within sectors. They also find 'strong relationships between features of the workplace and scientists' preferences consistent with theories of selection and socialization' (905)

3.3. Other related literature

Fitzenberger and Schulze (2013) develop a model of postdoc attitudes in Germany regarding their working conditions, research incentives, and perceived career prospects. They understand the effort to conduct research and the choice of applied versus basic research topics are affected by the prospects of both academic and non-academic careers (2013, 292-3). The completion of the PhD and then the postdoc phase are conceptualised as two critical exit points for an academic research career (see figure).

Career path after PhD. Note: This figure depicts in a stylized way the possible career transition after obtaining a PhD [Germany]



(Source: Fitzenberger & Schulze 2013, 292)

They develop a life-cycle phase model model, focusing on the postdoc phase to 'solve the decision problem backwards' (Fitzenberger and Leuschner 2012, 11):

'The (present) value of a postdoc position V pd depends both upon the value of obtaining a tenured professorship with associated present value V prof and upon the value of a non-academic career with value V 2 na . Both V prof and V 2 na are random variables for the postdoc. The transition probabilities along the academic career and the values of the two exits are affected by the training, the effort choice, and the working conditions during the postdoc phase. The postdoc will choose the career path yielding the higher expected utility. When V prof exceeds V 2 na , the postdoc makes the transition to a professorship at the next stage. Otherwise, he/she will eventually continue in a non-academic career' (Fitzenberger and Leuschner 2012, 11).

Using a survey of post-docs in business economics, economics, sociology and social sciences they constructed models to identify factors impacting decisions about pursuing an academic research career. They identified three clusters of postdocs: motivated optimists, confident academics and frustrated pessimists, characterised by different attitudes and perceptions of the incentives for academic research and levels of confidence regarding success in academia. Only around half of all postdocs lack strong research incentives (323). They suggest that stronger research incentives, including more support mechanisms for assistant professorships and improving the working conditions of postdocs (including longer fixed-term contracts) could improve the situation. For both men and women, having children is negatively associated with career prospects.

Lissoni and colleagues (2011) compare factors influencing the productivity of scientists in France and Italy. They focus on academic physicists. Physicists' chance of being promoted increase with age right up until 60, although this is chance is less for women. On the other hand productivity falls with age. The discussion in the paper is enlightening

as to the historical waves of hiring and non-hiring brought about by changes in governments and budgetary problems. Many scientists hired as public in waves of recruitment following periods of no positions being offered have not been productive relative to physicists of similar characteristics recruited at other times. The institutional conditions that shape these cohort effects on careers are quite possibly repeated in other MS. Any framework of research careers needs to take changes in the patterns or volumes of hiring in centralised national systems into account in understanding research careers both in those contexts and amongst emigrated nationals working in other systems.

Pezzoni and colleagues (2012) also compare Italy and France, this time the influence of social capital networks on career progress. Social capital networks were mapped using bibliometric techniques. They advocate the importance of analysing social capital networks not just as a mechanism of knowledge diffusion but also in relation to power and political exchanges (716). In support of this argument is their finding that social capital ties with senior disciplinary figures who control selection procedures is associated with career advance in Italy. In contrast, in France social capital ties with colleagues in prestigious PSOs is associated with career advance. In terms of individual factors, for both countries gender had a negative correlation with career progress, whilst productivity and seniority were positively associated with advance (716).

Petersen and Penner (2014) find that 'research careers exhibit the broad distributions of individual achievement characteristic of systems in which cumulative advantage pays a key role'. They look at the link between publishing in top-ranked journals and career progress, using a schematic of career phases common to US experience: grad student/postdoctoral fellow; assistant professor; tenured faculty (9). They search for quantitative evidence of self-reinforcing social mechanisms by analysing productivity patterns in specific journal sets that are highly competitive and widely targeted (10), and find a strong inequality in research careers in terms of publishing in high-impact journals (18). At the same time, they find a statistically significant decline in the relative impact of each subsequent paper in this journal set – which they state is quite difficult to interpret in terms of research careers (19). However, they venture familiar explanations related to ageing and the difficulty of remaining at the knwoeldge frontier (20). A key finding is that '*a system with even a subtle feedback loop, small advantages at an early stage compound over time and can produce stratification at later stages'* (20). From a policy perspective, the current system may be crowding out less established researchers,

an efficiency within the reward system that suggests the 'cream may not always rise to the top' (20) but rather that the 'early riser catches the worm'.

Sauermann and Roach (2012) analyse PhD career preferences and the degree to which there is a mismatch between scientists' desired careers and the career opportunities actually available to them (1). They investigate the role of PhD advisor encouragement for different career paths. They find an oversupply of PhD graduates wanting a tenured faculty position, coupled with a strong encouragement toward the academic field on the part of advisors. This is despite a decline in interest in research across the term of the PhD, leading to careers outside academic growing in attractiveness. An information gap, between alternative pathways outside academia and the weakening desire to continue with academic research is detected,

3.4. Contribution to developing analytical tools

The three analytical tools to be developed are: a) a typology of research careers, b) a summary of career stages; and c) the main factors shaping the career decision-making and development process.

3.4.1. A typology of research careers

Biddle and Roberts (1994):	typology based on occupation and occupational mobility - Technical career - Managerial career
Paula Stephan and colleagues	- Academic careers: in teaching universities versus research universities - Careers in industry
Fitzenberger and Schulze (2013)	- Academic - Non-academic
Sauermann and Roach (2012)	- Faculty career with emphasis in teaching - Faculty career with emphasis in research or development - A government job with emphasis in research or development - A job in an established firm with emphasis in research or development - A job in a startup with emphasis in research or development - Other career

3.4.2. A summary of career stages

Paula Stephan and colleagues	Stages in academic careers - Phd - Postdoc - Tenure track or tenured position (analytical emphasis on the transition from postdoc to these positions)
Fitzenberger and Schulze (2013)	Stages in academic careers - PhD - Postdoc - Associate - Full professor The PhD and then the postdoc phase are conceptualised as two critical exit points for an academic research career
Petersen and Penner (2014)	Stages in university careers - grad student/postdoctoral fellow - assistant professor - tenured faculty

3.4.3. Main factors shaping the career decision-making and development process

Paula Stephan and colleagues	- the key to success is to become an autonomous PhD directing a lab - Industry scientists have greater interest in salary levels. - Heterogeneity in scientists' preferences. Scientists self-select into the sector that best matches their needs. Those with a preference for freedom go to academia and those with a preference for money go to industry
Fitzenberger and Schulze (2102, 2013)	- transition probabilities along the academic career are affected by the training, the effort choice, and the working conditions during the postdoc phase. The postdoc will choose the career path yielding the higher expected utility. - factors impacting decisions about pursuing an academic research career. stronger research incentives, including more support mechanisms for assistant professorships and improving the working conditions of postdocs (including longer fixed-term contracts) could improve the situation.

	- for both men and women, having children is negatively associated with career prospects.
Lissoni and colleagues (2011)	Institutional conditions in centralized research systems. - historical waves of hiring and non-hiring impact following cohorts - changes in the patterns or volumes of hiring impact performance
Pezzoni and colleagues (2012)	- influence of social capital networks on career progress related to power and political exchanges. o social capital ties with senior disciplinary figures who control selection procedures is associated with career advance in Italy. o In France social capital ties with colleagues in prestigious PSOs is associated with career advance. - gender had a negative correlation with career progress, whilst productivity and seniority were positively associated with advance
Sauermann and Roach (2012)	- in line with some psychological approaches the authors link the self-evaluation of the chances obtaining a preferred job (i.e. research in academia) to the change in preferences: students realized over time that they are not competitive for scarce academic jobs and thus ceased to want them. - cohort effects: changing labour market conditions at the time of enrolment and ending of the PhD. - advisor encouragement: advisors and departments strongly encourage academic research careers while being less encouraging for other career paths.
Petersen and Penner (2014)	- levels of competition and inequality may affect scientists decisions by altering entry rate, the exit rate, and the overall appeal of careers in science. - cumulative effects have impact over time
Sent (1999)	- economic circumstances and social change impact on the demand for research and knowledge - national security challenges, economic competition, public health needs, environmental deterioration bring new opportunities for careers

4. Career theory and psychological approaches

This section summarises concepts from career theory that are of relevance to this Review. The section is a slightly expanded approach to that initially proposed in Activity Sheet No. 1 (see Section 1).

Professional careers are object of research in a number of fields including management, organizational studies and human resource management. An influential model of professional careers is that of Dalton and colleagues (1977), which was adapted by Gläser and Laudel in their work in science careers. Dalton and colleagues defined four career stages according to three dimensions.

	Stage I	Stage II	Stage III	Stage IV
Central activity	Helping Learning Following directions	Independent contributor	Training Learning	Shaping the direction of the organization
Primary relationship	Apprentice	Colleagues	Mentor	Sponsor
Major psychological issues	Dependence	Independence	Assuming responsibility for others	Exercising power

The four career stages model integrates activities and interpersonal role with a predominant psychological disposition. The development of this psychological disposition is described in some detail in the model. For example, moving into stage three requires confidence and the capacity to project this confidence onto others. At the same time, the assuming of greater collective responsibility is often associated with the movement away from technical work – which can pose problems of understanding and communication with less senior staff in relation to technical questions.

The model describes a set of expectations about the capabilities of individuals at successive careers stages. As a heuristic, its authors considered it equally valuable form an individual career decision perspective as from a management HRM planning and predicting tool. At the time many of the expectations defined were to a significant degree informal expectations, although they were regarded as linked to both informal and formal rewards systems. Increasingly, such expectations have come to be formalized in organization systems, as career development has emerged as a core aspect of professional HRM, particularly in knowledge-focused organisations.

4.1. Career theory

This section overviews contributions to career theory. There is no intention to do so even-handedly – the main focus is on the social cognitive theory of careers and on recent notions of the boundaryless career.

4.1.1. 'Big Four, Five or Six' theories

Depending on which review you read there four to six main theoretical schools of career and career guidance theorizing. All reviews tend to feature the following theories (whilst sometimes labelling them slightly differently):

- Theory of Work-Adjustment,
- Theory of Vocational Personalities in Work Environment (Holland),
- the Self-concept Theory of Career Development (Super),
- Theory of Circumscription and Compromise (Gottfredson),
- Career Optimism (García et al. 2015); and
- Social Cognitive Career Theory (SCCT) (Lent and colleagues building on Bandura).

SCCT relies on Bandura's concept of **self-efficacy** or the belief an individual has in their capabilities to organize and execute the courses of action required to attain certain goals. Self-efficacy is composed of personal exposure to success and failure, modelling others behavior, verbal encouragement or discouragement and stress and other emotional responses. Importantly self-efficacy refers mainly to individuals' assessments of whether they can carry out the necessary actions to produce the outcomes they seek, rather than an assessment of whether the outcomes themselves are a likely consequence of those actions.

4.1.2. The application of SCCT to researcher's careers

The SCCT perspective has translated most frequently to studies of academic or research career decision-making. There are indications that scientists' decisions about applying for positions at prestigious institutions or moving into careers in industry may be implicitly related to perceived self-efficacy of doing so.

In particular, scholarship on gendered outcomes of STEM has included significant discussions of women scientists' lower expectations about what they can achieve (section 2.4.2).

Berweger (2008) has developed a context specific application of SCCT to the transition from PhD to Post-Doc and tested it on a sample of doctoral students in the Humanities in Switzerland. In her longitudinal study with two time points (during the doctorate and shortly after completion) she finds a strong impact of embeddedness in the scientific community on the intention to continue an academic career in addition to self-efficacy and interests in scientific work. After the actual transition those people with greater embeddedness in the scientific community have a higher chance of working in research positions. All other effects (of self-efficacy and attitudes) only have indirect effects moderated through the intention to pursue an academic career.

Among social science faculty members Pasupathy and Siwatu (2013) have studied the effect of research self-efficacy on productivity of scientists. They find moderate effects of domain specific research self-efficacy on the number of publications of researchers.

4.1.3. 'Protean' and 'boundaryless' careers

A different type of career theorizing looks at the consequences for careers of changing conditions of work and work organization, in times of increasing demand for flexibility and responsiveness on the part of employees and employers. In a review of the literature, Sullivan and Baruch (2009)

> define a *career* as an individual's work-related and other relevant experiences, both inside and outside of organizations, that form a unique pattern over the individual's life span. This definition recognizes both physical movements, such as between levels, jobs, employers, occupations, and industries, as well as the interpretation of the individual, including his or her perceptions of career events (e.g., viewing job loss as failure vs. as an opportunity for a new beginning), career alternatives (e.g., viewing limited vs. unlimited options), and outcomes (e.g., how one defines career success). Moreover, careers do not occur in a vacuum. An individual's career is influenced by many contextual factors, such as national culture, the economy, and the political environment, as well as by personal factors, such as relationships with others (e.g., dual-career marriages).

The main currents of recent career theory have tried to take account of the declining significance of a single organization, single industry and consistent main role as the basis for understanding careers (Arthur 1994). A number of key concepts have been developed to cope with more flexible careers that span different organizations, industries and roles.

This section briefly describes several of these concepts, which could be considered useful for the development of a research careers framework – particularly in the context of challenges to the traditional model of the 'republic of science'.

The idea of the **protean careers** was introduced by Hall (1996). A protean career involves ongoing learning and the reconfiguration of an individual's knowledge and know-how in the interests of adapting to changing workplace demands. The individual who has a protean career trajectory is thus more able to move between organizations and roles and is viewed as having a more self-directed career. By reflexively understanding their own career as a series of learning or knowledge-context focused cycles the individual also develops a strong sensibility regarding their self-perception of career success (Hall 2004, Harrington and Hall 2007). The protean career notion was further developed in terms of specific values-driven and self-directed dimensions (including the development of an assessment scale for these two dimensions) (Briscoe and Hall 2005, 2006).

The **boundaryless career** refers to the seemingly simple idea of careers that move beyond a single organisation (Arthur and Rousseau 1996). The idea was further developed along several lines, including psychologically openness to mobility (Sullivan and Arthur 2006) along with physical mobility. De Filippi and Arthur (1994) focus on the competences of individuals and how these are matched to organizational, knowledge and occupational contexts in which careers are located, expanding beyond individual firms to include a wider perspective on how the competences embodied in individuals may fit with how knowledge is constructed, deployed and re-configured in different settings with distinct goals. Bird (1994) focuses on careers as repositories of knowledge, with important consequences for how tacit knowledge in particular is mobilized when the individual is driving its development and deployment beyond the reaches of the employing firm. Greenhaus and colleagues (2008) brought the boundaryless and protean concepts together in describing the boundaryless perspective on careers as including: *multidirectional mobility; career competences; and a protean orientation* (Sullivan and Baruch 2009: Table 1).

The **hybrid career** concept comes as something of corrective to any overemphasis on self-directed boundaryless careers. Traditional careers, in which individuals seek to climb hierarchical levels of a single organisation according to a clearly identified system of evaluations and rewards continue to be important. Hybrid careers combine aspects of new forms of career and the traditional model (Sullivan and Baruch 2009). While this concept is different to the model of sectoral hybridity in research careers (involvement in both public and private sector organisations) it is also potentially useful for analysing the different career incentives and rewards (relatively traditional in one context, relatively protean in another context) which are intertwined in some contemporary research careers.

Baruch and Hall (2004) describe the **academic career as a potential archetype of the boundaryless career**, due to their flexibility and less rigidly hierarchical and bureaucratic nature. However, they, and others, also note that the increasing corporatisation of the university and the incursion of new public management models into the university is having a countervailing impact on the nature of university based careers (Baruch and Hall 2004, Dany et al. 2011). Enders and Enders (2006) describe this process as the 'binding and unbinding' of academic careers. On the one hand, academic careers have many features of 'new' careers that cross boundaries, change organizations and are fundamentally shaped by personal objectives rather than organizational strictures – in this sense they are not bound tightly to employer organizations. On the other hand, with the major employer organization type – universities – increasingly moving toward corporate models of governance can have the effect of 'binding' employees more tightly to the mission and goals of the organization.

On the unbinding effects of new careers, Enders and Kaulisch (2006:89) foreground the universities 'search for relevance in society and the economy' as 'widening the institutional context in which academic careers unfold'. Second, the rise of non-Professorial teaching, virtual elimination of 'traditional tenure' and the growth of other staff categories such as externally financed researchers have reduced the expectations of secure continuous employment**. Calculations about moves and contracts thus become a central and omni-present aspect of academic careers** – increasing the importance of understanding the decision-frame used to make such strategic career calculations. This also suggests or reinforces the image of academic careers as 'protean' undertakings, albeit many of the 'choices' academics face *have* to be made. On the binding effects of institutional transformation, Enders and Kaulisch focus on the increased self-governance,

the growth of audit and corporate management cultures, and the expansion of university missions to be more effective and accountable in delivering specified outcomes (such as course, research degrees, etc.).

Impacts on traditional career structures include a reduction in disciplinary control over hiring and the adoption of excellence criteria that are broader than disciplinary contribution to new knowledge. Careers are more substantively bureaucratically planned and structured where universities adopt a strong control over the professional agenda of staff. Nevertheless the management dividing of teaching and research functions can have different and even opposite effects on the binding or unbinding of careers in universities. Enders and Kaulisch suggest that linking changes in overlapping institutional arrangements to career experiences and practices could focus on the **exercise of agency within institutional contexts** – including the perceptions and knowledge of rules that can shape decision-making processes in different settings (see Section 5.5.6).

Tams and Arthur (2010) describe six dimensions of **career agency**, each of which ranges on a continuum between independence and interdependence.

Features of agency	**Emphasizing**	
	Independence	**Interdependence**
Individual variation	Personality, cognitions, affective states, expectancies, motives, and biographical variables, etc.	Culturally-shaped values and beliefs, and social identity (e.g. gender, organizational or professional membership)
Social referencing	Personal priorities, goals and criteria	Priorities derived from normative expectations, responsibility to significant others, reference group, institutions, and society
Practice	Individual behaviors and strategies, e.g.: job seeking, career self-management, career change, identity work	Socially-embedded practices and collaboration, e.g. network brokering, membership in occupational groups, etc
Outcomes	Individual career outcomes (subjective and objective), e.g., satisfaction, choice, achievement, job mobility, income, and status	Collective, organizational, field-level, and societal outcomes, e.g., HRM practices, industry creation
Contexts	Context as an external reality, distinct from the individual	Context as mutually enacted through collaborative practice; multilayered (e.g., micro/macro levels); changing over time
Learning	Individual experience, knowledge, expertise, reflection, adaptation of behaviors and career strategies	Learning as socially constructed, e.g., through socialization and relational learning

(Source: Tams and Arthur 2010: 636)

The most cited source for a theoretical conception of agency in this and related work seems to be Giddens structuration theory, but utilised in a relatively simplistic way. The features of agency included do not include references to resources or power, although the authors do acknowledge the existence of a critical version of career agency that is sceptical about the existence or degree of choice available to individuals. Rather agency is viewed a bureaucratically and power-directed process in which individual careers are self-determined along prescribed and often proscribed channels.

Agency is also invoked in discussion of discussions of 'shared careers' (Svejenova et al. 2010). Dual-career couples are viewed as one type of shared career, defined by an affective relationship (often a formal family tie) and joint career decision-making processes. Ackers (2004) finds that in 'dual science career couple situations (defined as situations in which both partners in a couple are employed in scientific research) reflects high levels of mobility and generates the kinds of tensions which result in the tendency of women to 'exit' from science careers and/or fail to progress'. The salience of this study is that it highlights how partnering itself, regardless of formal family or child-rearing responsibilities, that needs to be taken into account in understanding career development and calculations. In such cases, agency needs to be conceptualized as distributed, including both members of the partnership.

Vos and colleagues (2007) conceptualize agency and institutional contexts in terms of individual career management (ICM) practices and organizational career management (OCM) practices. They focus on internal labour markets for R&D engineering professionals, to see whether lateral/horizontal movements, job enrichment or temporary movements (e.g. projects, task forces, etc.) can provide learning opportunities whilst not being based in upward vertical promotions. They find that engineers prefer job enrichment and are least attracted by lateral moves. They also found that ICM practices were influential regarding preferred moves, whereas OCM practices were very weakly related – how this weak connection should be cautiously interpreted as participants were drawn entirely from a single firm.

Understanding the tension between agency and framework conditions and/or career contexts is a rapidly developing area of career theory. To some extent these issues are already quite familiar to scholars of scientific research careers. However, the notion of a continuum or scale of career agency seems a potentially interesting one. In the context or research careers the logics of accumulation and freedom that underpin career stage

models seem potentially amenable to translation into a relative assessment of agency - if they could be defined appropriately to capture something of the differentiated capacity of individual researchers to mobilize resources, pursue self-chosen questions and benefit from the outputs of their work.

4.2. Research career development

In recent times professionalized approaches to academic and research career development have emerged. This section briefly gives an overview of one such research career development initiative.

Vitae UK is a programme run by the career development charity (CRAC) in the UK. Between 2013 and 2015 Vitae was supported by Research Councils UK (RCUK) and UK HE funding bodies: Department for Employment and Learning (DELNI), Higher Education Funding Council (HEFCE), Higher Education Funding Council for Wales (HEFCW) and the Scottish Funding Council (SFC).

The Vitae programme aims to:

- build human capital by influencing the development and implementation of effective policy relating to researcher development
- enhance higher education provision to train and develop researchers
- empower researchers to make an impact in their careers
- evidence the impact of professional and career development support for researchers.

At the centre of the Vitae model of career development is its Researcher Development Framework (RDF) which replaced the UK Research Councils Joint Skills Statement. This framework is made up of four broad domains: knowledge and intellectual capabilities; personal effectiveness; research governance and organization; and engagement influence and impact. Each of these Domains contains three sub-domains which in turn include specific competences and attributes for development and management.

The RDF is designed to be used by multiple actors within a research system:

- researchers to evaluate and plan their own professional, personal and career development

- managers and supervisors of researchers in their role supporting the development of researchers
- trainers, developers, human resources specialists and careers advisors in the planning and provision of support for researchers' development
- employers to provide an understanding of the blend of skills unique to researchers and their potential as employees.

A range of tools are available online through which individual researchers/institutions can access development video and instructions and use a specific planning application to structure career planning and development. This aspect of the RDF is now subscriber access only. The RDF is a very detailed and comprehensive programme. It is in an ongoing process of development and enhancement, through conferences, workshops and training opportunities.

The professionalization of the development and management of researcher careers is a relatively recent phenomenon, but reflects the ongoing perception that highly qualified researchers are one of the keys to social and economic development. Initial public investments in the development of the RDF are designed to improve the return on public training of scientific researchers.

To some extent such a programme can be understood as an intermediary between careers organised as a bureaucratically planned process and the ongoing learning cycles approach to individual development. The RDF does not seek to eliminate individual discovery approaches to careers however, but rather seeks to improve the competences that researchers bring to both their professional roles and to the career discovery process itself.

4.3. Contribution to developing analytical tools

The three analytical tools to be developed are: a) a typology of research careers, b) a summary of career stages; and c) the main factors shaping the career decision-making and development process.

4.3.1. A typology of research careers

Sullivan and Baruch, 2009	- Traditional careers versus new/hybrid careers

4.3.2. A summary of career stages

N/A	

4.3.3. Main factors shaping the career decision-making and development process

Bandura	Perceived self-efficacy
Sullivan and Baruch, 2009	- Contextual factors: culture, the economy, political environment - Personal factors: relationships
Sullivan and Baruch, 2009	- Multidirectional mobility - Career competences - Protean orientation
Arthur 2010	Career agency: six dimensions
Vitae - UK	Dimensions of model of career development in its Researcher Development Framework: - Knowledge and intellectual capabilities - Personal effectiveness - Research governance and organization - Engagement influence and impact

5. Descriptive frameworks

In this section we review the descriptive frameworks of research careers. We compare and contrast these approaches. At the end of the section we compare these descriptive approaches with the research career stages described in the academic research literature. This section also reviews a number of European research projects that have focused on different aspects of research careers.

5.1. European Science Foundation (ESF)

The ESF Member Organisation Forum on Research Careers seeks:

• to develop a roadmap for research career development in Europe and by this means

• to create new and improve existing European level, including coordinated national, policies and programmes aimed at promoting different career stages, and

• eventually to raise the international visibility of the ERA as a common labour market for researchers.

The member forum group European Alliance on Research Career Development (EARCD) aims to adopt a common strategy to ensure the attractiveness of research careers and thereby to create and improve European-level and coordinated national policies and programmes for different career stages and career paths.

Summary of key recommendations:

• Enabling: creating a European Researcher Development Framework

• Observing: setting up an International Platform for Researcher Career Tracking and Monitoring

• Guiding: establishing guidelines to acknowledge new concepts of researcher mobility (international, intersectoral, interdisciplinary, virtual)

• Going Global: working towards a Global Forum for Research Career Development.

A major focus is an initiative that will follow up researchers' careers over a certain time period to understand researchers' career pathways. Surveys that trace back careers over several years, cohort studies at several moments in time (not just one) or longitudinal surveys are considered to fit the defined need. The gender dimension is as a specific one to take into account when considering obstacles and bottlenecks in research careers.

A taxonomy of research career stages has also been developed with the aim of describing the **academic research career** structure in Europe. The structure revolves around 4 career stages:

Stage I Doctoral training stage

Stage II Post-doctoral stage

Stage III Independent researcher stage

Stage IV Established researchers (professors, research professors, directors, senior scientists, etc.)

However, it is also acknowledged that research careers are nowadays less path dependent. They develop more and more into 'portfolio careers'. In consequence, the traditional career pipeline model is increasingly replaced by the model of a 'career tree'.

It symbolises the decreasing linearity of career paths which is accompanied by the trend to combine several part-time roles building up to one full-time role, e.g. by working part-time in different fields of employment. Intersectoral mobility is flagged as important for non-linear careers. Nevertheless the four stage model aims to **promote the recognition of correspondences** across national systems.

This framework pays specific attention to gender. It includes several concepts designed to specify career relevant factors disproportionately affecting women. These concepts include:

> **Leaky pipeline** → Statistics show the drop out of women at various stages from training through employment.
>
> Maternity/paternity/parental leave → **Work-Life Balance** (WLB)
>
> **Career breaks** due to family reasons → WLB and Women-only funding (WOF) & Dual Career Couples (DCC)
>
> **Equal playing fields** → Women in Science /Research including Gender Equality Policy /Initiatives / Networks /Mentoring / Peer Review

5.2. League of European Research Universities (LERU)

The report focuses on the objectives that Universities need to achieve to offer attractive research employment.

The framework for a research career:

- Well-designed employment
- Well-structured career opportunities
- Well-financed positions
- Effective career development
- Planning for diverse career pathways
- Shared responsibilities for research careers

For each of these objectives main challenges are discussed and a set of key principles is established.

The Report defines a four phase academic career, with associated activities and suitable tenure types

- *Doctoral candidate – Postdoctoral scientists – University scientist -- Professor*

The report also identifies a series of **academic career maps** in Europe, according to the established framework. The maps show the different research positions available in an institution, the levels of responsibility, how they are funded at each stage and how the researcher may progress from one level to the next. Appendix 1 to the Report provides the guidelines to read the maps plus career maps from institutions in Belgium, Finland, France, Germany, Italy, The Netherlands, Sweden, Switzerland and UK.

5.3. European Commission (EC) Research Career Framework (CF)

The CF starts from the Frascati Manual definition of researchers as 'professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned'. The EC sees the CF as an encompassing framework that is compatible with 'sector specific' frameworks such as those developed by the ESF and LERU.

The understanding of a research career is defined in terms of four career stages that characterize the proposed "Framework". These stages are defined in the Annex as sets of necessary and desirable research competences. Taking a competences-based approach makes the CF applicable across different potential employment sectors and scientific fields. The CF does not link the research competences specified to any other competences, such as teaching or management (6), however the competences include responsibility for and self-management of the 'research career' including improving 'employability'.

The specified 'stages' are:

R1 First Stage Researcher (up to the point of PhD)

R2 Recognised Researcher (PhD holders or equivalent who are not yet fully independent)

R3 Established Researcher (researchers who have developed a level of independence.)

R4 Leading Researcher (researchers leading their research area or field)

The primary criterion is high quality research at all stages.

Despite the seemingly developmental structure of the four stages, 'the profiles should not **always** be considered as stages on a progressive career path, although it may be assumed that a researcher in one profile will also have accumulated/acquired the necessary competences of the preceding profiles' (6, bold emphasis added).

The benefits of the CF for the European Research Area (ERA) are to:

- promote more mobility across borders and employment sectors, by enhancing comparability and transparency on career opportunities, thus also helping to:

- better attract highly skilled talent from third countries and, ultimately,

- contribute to the establishment of a single market for knowledge, research and innovation.

5.4. Comparison of descriptive frameworks

This section tabulates some key dimensions of the three major descriptive frameworks.

	ESF	LERU	EC
Career Focus		Academic	Open
Description of Phases	Positions/ Independence	Positions/Ranks	Competences/ Independence
Sector	Public	University	All
Distinguishing foci	Tracking/Gender	Shared career responsibilities	Competences
Mobility	Common ERA market/ Coordinated	Inter-organizational	Single EU market/ International competitiveness

5.5. Relevant European research projects

This section surveys a number of research projects that have explored aspects of the research system including a researcher component, or have addressed specific elements of careers or researcher activities. This includes several projects directly funded by the EC in the interests of developing a better understanding of research careers, or developing tools to aid this objective.

5.5.1. Careers of doctorate holders project (CDH)

The CDH project was an initiative of the OECD, with the cooperation of UNESCO and Eurostat. The core objectives were to better understand the labour market, career path and mobility of the doctoral population. A pilot data collection was conducted in 2005 in Argentina, Australia, Canada, Germany, Portugal, Switzerland and the USA. A second

and larger-scale data collection was done in late 2007 with 25 participating countries. These data were then processed to focus on those who received their PhD between 1990 and 2006, improving comparability of the results. A further data collection was then conducted in 2009.

The study did not adopt a specific definition of or framework for research careers. International comparative classifications were used to define educational degrees (ISCED), professional occupations (ISCO) and sectors of employment (NACE).

The survey proposed the definition of a "research career path job" as a job that will help further career plans in research or is a job in research, in which the respondent wants to make his/her career.

The CDH questionnaire addressed the following aspects of doctorate holders' careers:

- PhD duration and country
- Attributes and behaviours (including competences) after completing PhD
- Early career research positions
- Employment situation: sector, occupation, earnings, full time / part time, temporary /permanent of current / last job and previous job within the last 10 years
- Behaviours – attitudes (competences) in current principal job
- Overall time working as a researcher
- Reasons for working as a researcher
- Mobility: time in each country of work, reasons to move, links and collaborations with origin country

An interesting variable within the CDH data collection is the perception of the relation between doctoral training and current job among doctorate holders.

The CDH project provides some interesting insights into the employment role and labour market relations. It also provides interesting data on the perception of doctorate holders of the suitability of their PhD training for their work. The limited coverage of countries limits the comparative potential of the CDH data, as does the inconsistency in the questions asked in different countries – which further reduces the number of available country comparisons.

There is limited consistency between iterations of the CDH surveys and between the years in which they were deployed in different countries.

(Main contact at OECD: Laudeline Auriol)

5.5.2. The Global Science Research Project (GLOBSCI)

GLOBSCI was funded by the National Bureau of Economic Research (USA) and Regional Government of the Piedmont Region (Italy). The project investigated the dynamics of mobility, performance and collaboration patterns of over 16,000 scientists from 16 countries by means of an online survey. Data was collected in 2011.

The study was not designed specifically to model research careers, neither does it adopt a definition of career. However, since the focus is on mobility patterns, the survey focuses on whether certain career milestones have been attained.

According to the project's outcomes, the GLOBSCI questionnaire addresses the following aspects of researchers' careers. The questionnaire is not available to the RISIS team.

- Country of origin
- Current country of residence
- Reasons for leaving the origin country
- Periods of education or work abroad
- Type of initial entry in the host country (master / bachelor, PhD, Post-doc, direct employment
- International networks of research collaboration
- Individual characteristics: age, gender, job position, type of affiliation, field of research

The results show that researchers decide to be mobile to improve their career prospects. The empirical investigation focuses on the mobility dynamics and its connection with scientific productivity and collaboration.

Relevant results indicate that mobile scientists are more prone to establish international links, have links with a larger number of countries and exhibit superior performances in international collaborations than natives with no prior experience of mobility. Results also indicate the existence of a performance premium for both the foreign-born and the returnees over the non-mobile.

(Main authors: Chiara Franzoni, Giovanni Scellato and Paula Stephan)

5.5.3. The Study of International Mobility and Researchers' Career Development (SIM-Rec)

SIM-Rec was funded by the European Commission and launched in 2011 by the Institute for Prospective Technological Studies (European Commission, Spain) with the participation of NIFU (Norway) and Logotech (Greece) and the University of Athens (Greece).

The study did not adopt or propose a specific definition of or framework for research careers. It surveyed "experienced researchers" defined as researchers with at least 5 years of research experience since completing their highest educational degree.

The project's questionnaire assigns specific relevance to the following milestones:

- Time of highest degree
- Five years of research experience
- All job positions held in the target period of study
- International job mobility

The description of job positions (up to a maximum of 5) includes the following variables:

- dates, country, type of institution, sector job description
- type of position: permanent / fixed term; Full time / part time
- teaching load
- research agenda – level of autonomy
- funding sources
- salary& benefits for each position
- reasons for taking each job positions: salary; job security; personal reasons; access to permanent position; research autonomy; opportunity to work abroad; opportunity to work in another sector

The published results to date address the connection between researchers' mobility profile and the likelihood of holding a permanent position, the motives for changing jobs and the extent to which these are influenced by mobility patterns and the gender dimension of the registered motivations for job changes depending on the parental status and the mobility profile of researchers.

(Main contacts: Eric Iversen, Ana Fernández-Zubieta, Susana Elena-Pérez)

5.5.4. An Observatorium for Science in Society based in Social Models (SISOB)

The main goal of SISOB project was to develop novel tools making it possible to measure and predict the social impact of research. More specifically, SISOB focused on measuring the *social appropriation of scientific knowledge, generated by research*. The project was developed between 2011 and 2013 by a consortium of seven institutions and coordinated by the University of Malaga.

An important outcome of the project is the SiSOB data extraction and codification tool, (Geuna et al. 2015). The tool aims to provide an automatized system for collecting and structuring information on scientific researchers from publicly accessible websites and CVs. The tool has been tested for two samples of researchers to address mobility and the connection between mobility and publication productivity. The development of the tool does not rely on a specific conceptualisation or framework for research careers. The career is understood as a sequence of positions. Mobility is classified into the following categories: Forced mobility versus voluntary mobility; job-to-job mobility: which may be international, inter-sectoral, and may or may not imply 'career mobility' (career progression).

(Main contacts: Aldo Geuna and Ana Fernández Zubieta)

5.5.5. Mapping the population, careers, mobilities and impacts of advanced degree graduates in the social sciences and humanities (POCARIM)

POCARIM was funded by the 7TH Framework Programme from the European Commission and carried out between 2011 and 2014 within a consortium integrating 13 European countries.

The following issues and topics were addressed throughout the empirical research, which consisted on a survey and a set of in-depth interviews in each country:

- The nature of SSH careers and movements between labour market sectors
- The impacts of SSH PhD graduates' work, both on their environment and on their own careers
- The nature and role of networking in SSH work and careers
- The nature and outcomes of cross-disciplinary activity in the studied population
- The degree, nature and impact of international mobility and other cross-border activities

- The effects of partnering, parenting and other caring responsibilities on work and careers

The study did not adopt or propose an aprioristic definition or framework for research careers. POCARIM data includes more than 300 in-depth interviews conducted across the participating countries.

Relevant results provide interesting input for renewed conceptualisations of research careers. For instance, interviews point out the important role of discovery and learning in career shaping. The final project report defines the research career as a *networked learning process embedded in contextual institutional settings*. The data also point to the important role of circular progress and reinforcing mechanisms in careers. The project research and reports also devote special attention to conceive of research careers as processes *conditioned by family and parenting*.

(Main contact: Louise Ackers, project coordinator)

5.5.6. The MORE2 project

MORE2, or "Support for continued data collection and analysis concerning mobility patterns and career paths of researchers", was funded by the European Commission between 2011 and 2013. The project's objective was to provide internationally comparable data, indicators and analysis in order to support further evidence-based policy development on the research profession at European and national level. The project conducted a series of surveys and case studies:

- A survey of researchers currently working in Europe in higher education institutions (HEI) regarding their mobility patterns, career paths and working condition
- A survey of researchers currently working outside Europe regarding their mobility patterns, career paths and working conditions
- A case study on the working conditions and career paths of early career researchers in selected countries
- A case study on the remuneration of researchers in selected countries

The study adopted the definition of the European Framework for Research Careers (European Commission, 2011).

The study addressed mobility as a "multidimensional concept", distinguishing between international and inter-sectoral mobility, PhD and post-PhD mobility, mobility of more than three months and less than three months; employer mobility and virtual mobility. The surveys also addressed the phenomenon of non-mobility within careers.

The database resulting from the project as a high potential for exploring links between mobility patterns and career development patterns. Other than the project reports in our review of the literature we have not found any published papers based on this data at this stage.

The MORE2 case study on the working conditions and career paths in selected countries relies on the IFQ conceptual framework to study academic career systems (section 5.5.7). Following Gläser (2001), the complexity of academic careers is understood as caused by the fact that researchers work simultaneously in several social contexts: the science context, the societal context and the higher education context (MORE2 2013: 19). Academics' career paths are conceptualised as guided by the formal and informal set of rules that emerge from these three institutional contexts. Such rules are collapsed into five basic sets that capture these complex and overlapping dynamics: academic's employment; credentials; intra-organizational practices; inter-organizational relationships and academic disciplines (21).

The data collected by MORE2 to build a **country classification of academic career systems** relies on the five sets of rules framework (section 5.5.7, table). Each set of rules is operationalised using a corresponding set of variables (2013: 28):

- Academics' employment: staff structure, autonomy of researchers, employment security, performance-orientation in career advancement, selection procedures, importance of international mobility, financial rewards to climb the career ladder and general social security levels.
- Credentials: The extent to which doctoral education is structured, the necessity of a second post-graduate research degree such as the Habilitation and the variety of institutions which are allowed to award doctorates
- Intra-organizational practices: Site where positions are mainly advertised the source of funding of R3 positions, the level of HEI autonomy and the organization of selection.

- Inter-organizational relationships: Degree of sectoral differentiation, intersectoral mobility as prerequisite to pursue specific career paths, vertical differentiation of HE system, attractiveness of positions outside academe for young researchers and autonomy of universities to set employment conditions.
- Academic disciplines: strength of discipline-specific conditions

In addition, a set of variables is defined to address the factors that have an influence on the sequence, timing and likelihood of academic careers (2013: 25):

- the age range at which positions are obtained
- the typical type of contract awarded
- the task division between research and teaching
- the level of researchers' autonomy
- the type of funding typically associated with positions at the stage
- whether tenure-track options are available at this career stage

5.5.7. IFQ conceptual framework to study academic career systems

Kaulish and Salerno (2005) describe a conceptual framework that can be used to analyse academic career systems in comparative perspective. Like many others (e.g. Glaser various, Enders various, Musselin various) these authors consider academic careers to be produced by the overlapping influence of scientific, social and higher education sector institutional characteristics. Like Glaser and Laudel (various) they also note the tension and potential conflict between the 'logics' of these institutional contexts. To capture the different logics and forms of authority embedded in each of these institutional contexts, and to allow comparisons between different national systems, the authors focus on the *formal and informal rules* the guide behaviour and outcomes. They categorise these rules into five different sets.

Sets of Rules	Rules
Set of rules regarding academics' employment	Rules on organisational hierarchies in terms of university governance, staff structure, financial rewards Rules on power distribution within the hierarchy Rules on career ladder Rules on selecting candidates for positions Rules on employment conditions Rules on retirement
Set of rules regarding credentials	Rules on entry qualifications Rules on importance of doctoral degree and design of doctoral studies Rules on the design of the post-doctoral phase
Set of rules regarding intra-organisational governance	Rules on external governance Rules on internal governance Rules on selecting criteria
Set of rules regarding inter-organisational relationships	Rules on inter-organisational prestige Rules on job mobility
Set of rules regarding academic disciplines	Rules on doctoral phase Rules on post-doctoral phase Rules on performance criteria

(Source: Kaulisch and Salerno 2005: 7.)

Kaulisch and Salerno use these sets of rules to compare the sequence, timing and likelihood of major career events in the German, English and US academic systems. Their results highlight the heterogeneity of national academic careers.

	England	Germany	USA
Sequence of major career events	(PhD), (fixed-term contracts), Lecturer on probation, Lecturer	Scientific collaborator, Privatdozent, Professor	PhD, (Post-doc), Assistant Professor, Associate Professor
Timing of major career events	2-3 y, (2y), 3y, permanent	Up to 12 or more years with series of fixed-term contracts with various lengths, 2-3y, Permanent	5-6y, (2y), 6y, Permanent
Likelihood of major career events	After obtainment of lecturer position very likely to receive permanent status	After each contract new decisions if someone can get financed, relatively long period of searching for a professorial position	After obtainment of assistant professorial position a good chance to obtain permanent status

Important influences on these career events	Disciplines and their supply and demand of staff (determining the likelihood of contract researching positions)	High dependency of scientific collaborators on professorial goodwill (regarding academic work and employment opportunities at university) Credentials are obtained during employment relationships	Prestige of doctoral degree granting university very important predictor for employment opportunities

(Source: Kaulisch and Salerno 2005: 17-18.)

The extent of the differences on these career characteristics is quite marked. This study provides a warning that a framework for European research careers needs to consider carefully the design challenge of heterogeneity. The results also suggest that a focus on sets of rules is a viable approach for developing categorisations or typologies to streamline the heterogeneity of European research careers for analytical purposes.

5.5.8. The ProFile project

The ProFile project starts tracing doctoral candidates at the beginning of their candidacy and follows them over the course of their doctorate until the early career entry of up to five years after conferral of the degree (WP). ProFile aims at identifying determinants of postdoctoral career development and providing information on conditions of doctoral education in a comparative perspective via a monitoring approach. Special attention is paid to the effects of structured doctoral programs (Graduate Schools) on doctoral education, which have emerged increasingly during the past years. ProFile applies decision-making as well as goal/intention frameworks for studying careers.

Important results of the project show that training conditions affect career intentions to a large extent (Hauss, Kaulisch and Tesch 2015). Moreover, the introduction of structured doctoral training has affected the training conditions in general (Hauss et al. 2012).

5.6. Contribution to developing analytical tools

The three analytical tools to be developed are: a) a typology of research careers, b) a summary of career stages; and c) the main factors shaping the career decision-making and development process.

5.6.1. A typology of research careers

The ESF and LERU frameworks apply mainly to academic careers while the European Commission one may be used for all sectors and for hybrid careers.

5.6.2. A summary of career stages

ESF	**Stages for academic careers** **- Doctoral training** **- Post-doctoral training** **- Independent researcher** **- Established researcher**
LERU	Stages for academic careers - Doctoral candidate - Postdoctoral scientist - University scientists - Professor
European Commission	Stages for research careers R1 First Stage Researcher R2 Recognised Researcher R3 Established Researcher R4 Leading Researcher

5.6.3. Main factors shaping the career decision-making and development process

CDH	- **Attributes and behaviors, including competences** - **Mobility**
GLOBSCI	- International collaboration networks - Mobility
SIM-Rec	- Mobility
SISOB	- Mobility
MORE2 **Kaulish and Salerno, 2005**	Five sets of rules model: - Academics' employment: staff structure, autonomy of researchers, employment security, performance-orientation in career advancement, selection procedures, importance of international mobility, financial rewards to climb the career ladder and general social security levels.

	- Credentials: The extent to which doctoral education is structured, the necessity of a second post-graduate research degree such as the Habilitation and the variety of institutions which are allowed to award doctorates - Intra-organizational practices: Site where positions are mainly advertised the source of funding of R3 positions, the level of HEI autonomy and the organization of selection. - Inter-organizational relationships: Degree of sectoral differentiation, intersectoral mobility as prerequisite to pursue specific career paths, vertical differentiation of HE system, attractiveness of positions outside academe for young researchers and autonomy of universities to set employment conditions. - Academic disciplines: strength of discipline-specific conditions
POCARIM	- Gender, family and parenting - Networking - Mobility and internationalisation - Institutional settings
ProFile	- Structure & conditions of training

The models and projects included in this Review point to the complexity and heterogeneity of understanding research careers using a comprehensive and comparative institutional perspective. A research career framework for Europe would ideally be designed in such a way that it does not create exceptions to the principles proposed. Options for the design might be to:

- Describe relatively general institutional dimensions, so that distinctive national systems and the research careers they produce all fit, but with the likely consequence that heterogeneity is somewhat concealed
- Include a great deal of detail to capture the diversity of institutional characteristics (such as compiling sets of rules) that can allow the fullest possible description of research career heterogeneity
- Try and find a mid-range where some institutional variety is absorbed into categories that reduce heterogeneity to manageable typologies of national systems that understood to produce common types or patterns of research careers.

6. Social mechanism-based approaches

Mechanism-based approaches by themselves do not pose a coherent and comprehensive framework of scientific careers or career decisions. Instead the debate on social mechanisms (Hedström, 2005) provides a new perspective on causal explanations as not being deterministic but rather context dependant. Mechanism-based approaches strive to identify necessary and optional causes for explaining career trajectories. This may be concepts like the "cumulative advantage" or Matthew effect (Merton, 1968), "self-fulfilling prophecies" (Merton, 1948), "vacancy chains" (White, 1970; Chase, 1991), or 'social networks' (Burt 1992, Granovetter 1973).

6.1. Cumulative advantage

Merton's classic concepts remain important reminders of the social structures of the scientific field and how recognition and rewards are distributed. Contemporary scholarship continues to pay very serious attention to the ways in which success tends to breed success within the scientific system.

For example, Petersen and Penner (2014) undertake an analysis of cumulative advantage by looking at the time to repeat publications in high impact journals. They compared results for natural sciences (using Science, Nature and PNAS) and fourteen highly cited economics journals. They found 'broad distributions of individual success characteristic of competitive systems in which cumulative advantage plays a key role' (18). Overall the time between publications in these top journals decreases the more the author publishes with the journals. It appears likely that a history of high impact publishing means the next publication is also likely to have a high impact. However, in reality there is a statistically significant decrease in the impact of each subsequent publication (19). The authors see a negative impact of cumulative advantage here – 'it is difficult to interpret the decreasing impact trend (s less than 0) as a desirable property of cumulative advantage in science' (19) – although it is true the declining impact is measure relative to the author's own average citation and not publications more broadly. The authors refer to Stephan in invoking ageing as another possible explanator for this outcome. The authors suggest that the repeated publication of papers by authors well known to top journals may be 'crowding out' less established researchers, 'an inefficiency within the reward system of science suggesting that 'the cream may not always rise to the top' (20). Gross and colleagues (2008) found that disciplinary differences exist in terms of the criteria

required for promotion to a professorship in Germany, with varying emphases on publications and a mix of other meritocratic and social factors contributing to who rises to the top.

Institutional systems for measuring and evaluating the 'excellence', 'quality' and more recently 'impact' of science have tended to focus on the most obvious quantifiable 'outputs' of the research system – journal articles, patents and completed postgraduate supervision. External income has also come to stand as proxy for 'relevance'. Institutional systems increasingly rely on 'metrics' such as citation counts (impact) and scales such as h-index to normalize metrics to allow the comparison of researchers and their heterogeneous contexts within the research system. Concern has started to emerge about the way metrics in particular can create perverse incentives for researchers and biases in evaluations (Hicks et al. 2015, Wilsdon et al. 2015). The call for 'responsible metrics' is largely a reflection of the fact that monitoring and evaluation processes are creating self-reflexive strategies among researchers that are tailored toward evaluation rather than scientific outcomes. Already many funding or promotions schemes request applicants to conduct a bibliometric self-assessment, particularly in relation to journal impact factors (JIF) and measures such as the H-Index. There is likely to be some 'lag' before the full consequences of monitoring and metrics practices for research careers are revealed although impacts on researcher behaviour have clearly been observed (Whitley et al. 2010).

6.2. Networks as the mechanism for knowledge diffusion

Arguably the social mechanism that has emerged as the most important with regard to science careers in the so-called shift to the 'knowledge economy' is the social network, which is an important mechanism of knowledge diffusion. In recent years, a large volume of studies have followed Granovetter (1973) and Burt (1992) in studying the characteristics of network ties in the networks of different professions. Network characteristics including (different forms of) centrality and density have been widely studied with regard to how they facilitate or hinder the diffusion of different types of knowledge and/or information.

Social network analysts group interpersonal connections into two categories: strong and weak ties. Strong ties are based on trust, friendship, reciprocity and relatively high frequency of interaction (Levin and Cross 2004). Weak ties are characterized by

infrequent interaction and not based in friendship, trust or reciprocity. The benefits of strong ties include coordination of joint activities and lowered uncertainty, while the benefits of weak ties include the possibility of connecting diverse social groups (Granovetter 1973, 1983; Krackhardt 1992; Uzzi 1996). The literature suggests that strong ties are better for transferring profound or complex information (Hansen 1999; Uzzi 1996), provide higher quality exchanges due to their reliability (Rowley, Behrens & Krackhardt 2000), and that sensitive or confidential information is more likely to be transferred through strong tie links (Podolney et al. 1997) where confidence about its interpretation already exists (Nahapiet et al. 1998). Burt (1992) points out that the resources available and accessible to an individual will be similar to those available to socially proximate others. However, in the case of gender, Durbin (2011: 99) argues, that an informal social system or "old boy's network" tends to hold and control strategic tacit knowledge at upper levels of academia. Villanueva and colleagues (2015) fund evidence for such a restriction of strategic information to women in nanotechnology networks. As Bozeman and colleagues describe, social networks are thus a form of capital that can shape the resources an individual can bring to their job – with potentially profound outcomes for careers - depending also to some degree on the precise position of individuals within such networks.

6.3. Contribution to developing analytical tools

The three analytical tools to be developed are: a) a typology of research careers, b) a summary of career stages; and c) the main factors shaping the career decision-making and development process.

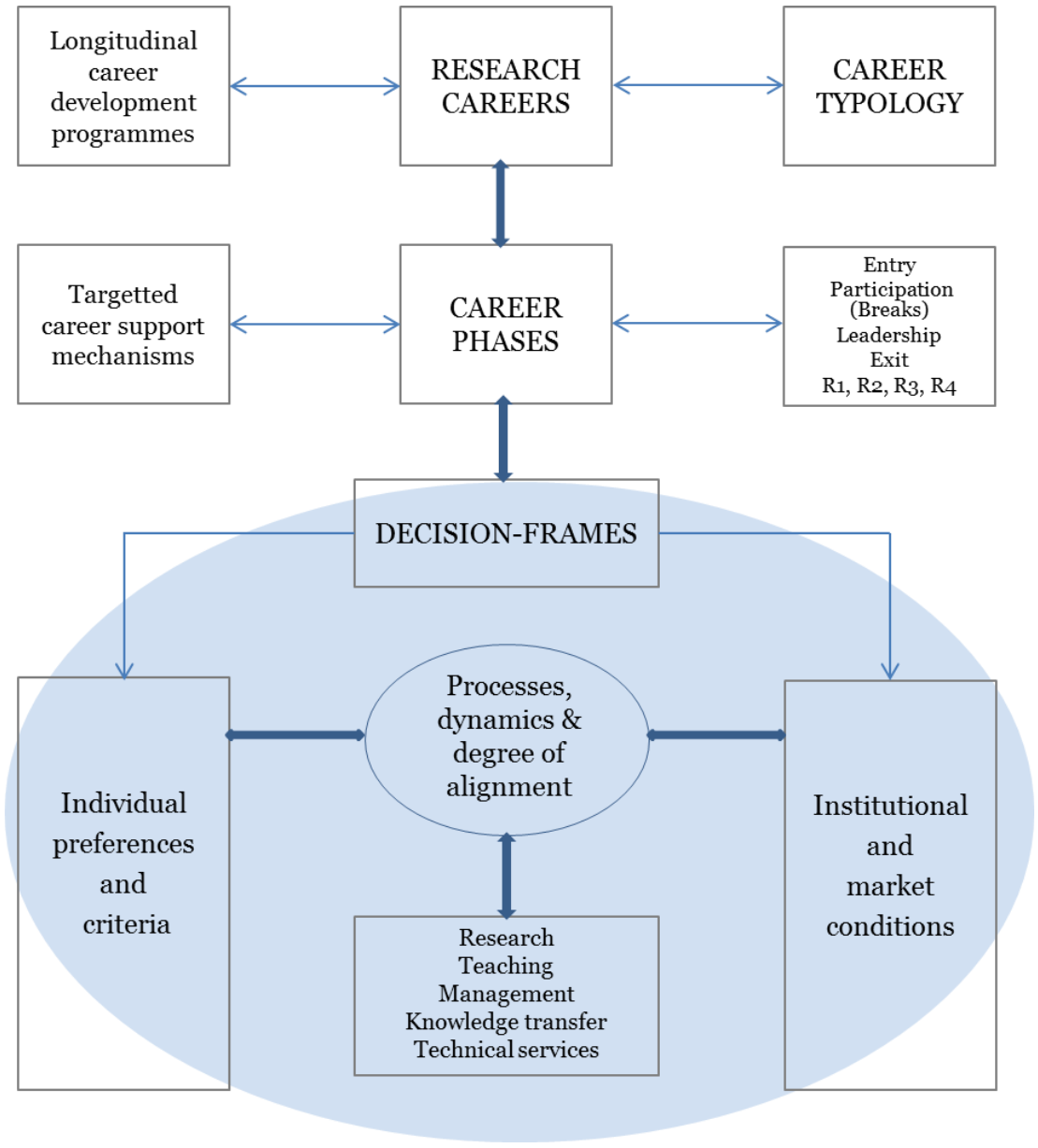
Whilst cumulative advantage is suggested by increasingly frequent publication in high impact journals by individual authors, there appears to be a decreasing impact of each subsequent publication in terms of citations. This could be crowding out less established entrants despite reducing scientific returns. Evaluation systems based on publication impact factors could have skewing effects on career progress in some fields.

Network interdependences shape the flow of information and resources available to individual researchers. Evidence suggests that scientific networks are gendered, potentially influencing career outcomes for women and men, particularly in STEM fields where women are a numerical minority that is exacerbated at higher levels of organisational authority.

7. Research careers and research career decisions

This section contains an initial career overview diagram and components.

F7.1 Research career overview



T7.1 Institutional and market conditions, provisional definitions

Country	Research careers take place in the context of one or more national socio-economic, science and research systems.
Research system	Research systems are a matrix of different activities organized in occupations. A variety of different types of careers are required to fit together in an evolving division of labour. Not all research careers can, or should, be identically motivated. Neither should outcomes be expected to be uniform or uniformly measurable.
Research governance	Research systems include monitoring and evaluation systems. Researchers are evaluated using formal peer review processes and through metrics and indicators of output and impact. Metrics create incentives that also impact research strategies and careers.
Discipline	Scientific disciplines are characterized by specific forms of intellectual and social organization.
Labour market rules	The basis of employment of researchers varies between national legal frameworks and national, regional and organizational forms of contracting and tenure.
Funding sources	The availability of independent sources of funding influences the protective space researchers may create in which to conduct research relatively free of external influence.
Employer organizations	A range of different types of organization employ researchers. The mix of universities, private firms, government research institutes or other state agencies, international organizations, and private non-profit organizations that are based in a particular place shapes the career opportunities in localized areas. Organizations in different socio-economic sectors have different goals and functions.
Position descriptions	The expected tasks and responsibilities that are associated with a particular job vary greatly in research systems characterized by relatively autonomous organizations while other systems may be characterized by high degree of formal task standardization. The mix of activities that characterize a specific job will be tailored to the needs of organizations and the labour market context.
Forms of rewards	Reward systems for researchers are dependent on the context of their employment. Traditional academic reward systems include considerable emphasis on disciplinary prestige and recognition in addition to collectively negotiated basic conditions. Industry rewards are normally more strongly based on financial and other material forms of reward. Recognition is firm and industry based.
Career support mechanisms	Include tenure-track positions, fellowship awards and other policies and programs that are designed to support the development, continuity and progress of research careers. Career support mechanisms are typically targeted at particular career phases. Also includes career development programs run internally by organizations or by external specialist organizations.
Gender and family policies	Less common are mechanisms to support the conciliation of work and family care and the re-entry into research careers following breaks for child-rearing, for example.
Global trends	Include political developments on the supranational level such as treaties as well as technological advancement.

T7.2 Individual preferences and criteria, provisional definitions

Goals (intentions)	Individual goals have a motivational quality, meaning the desire to achieve a specific outcome. Moreover, goals have a volitional quality meaning the will and the commitment for certain activities or results. Among others, occupational learning-, career goals as well as goals in private life can be distinguished (Abele 2002). Occupational learning goals target the incentive to carry out certain activities for gaining more knowledge and further cognitive individual self-development. Career goals are purpose goals, meaning goals to achieve more income or promotion. Goals in private life can be broken down further into relationship goals and leisure goals. Individual goals may change depending on the individual situation in the life course. Scientific goals are a key consideration in research careers, as is the recognition that attaining scientific goals is often a collective achievement.
Self-efficacy	The extent to which one believes to be able to achieve a certain outcome through one's own action. Individuals will only strive to achieve outcomes they see themselves capable of achieving. In other words self-efficacy limits the possibilities of all possible choices to realistic choices. The level of self-efficacy may changes e. g. as a result of prior actions or as outcome of learning processes. Self-efficacy can be assessed domain specific. It is considered to be the central predictor of individual behavior by the Social Cognitive Career Theory (SCCT).
Action outcome expectations	Meaning the anticipated physical, social and self-evaluated outcomes of certain actions which may lead to not choosing to perform certain behavior if its consequences are incongruent with individual goals or beliefs.
Interest development	Interests for certain activities develop over the life course through learning experiences. Individuals develop interests only for areas they believe they can- or have dealt with successfully. Interest is closely related to intrinsic motivation.
Personality	Includes key personality traits such as risk taking and the Big Five. The Big Five are broad dimensions of personality factors resulting from a five factor model with the factors openness, conscientiousness, extraversion, agreeableness, and neuroticism. Personality traits are considered to be more or less stable in adulthood.
Research experience	The scientific recognition gained in one's field primarily through publications and the partnerships and collaborations completed with other peers will influence future research endeavors. For careers in research it should constitute the main learning experience in the sense of the SCCT.
Work experience	Can be working experience in different economic sectors, experience with leadership at work or autonomy. Working experience will impact work related decisions in the sense of learning experiences.
Mobility experience	Same here, experience with (inter-)national mobility will impact the frame of reference for geographic alternatives. This will be more diverse regionally if the individual has been mobile in the past. This too is understood as learning experience.

Competences, knowledge and skills	On the one hand these can be subsumed as research competencies which entail diligence, logical rigor and the ability to strive for original knowledge. These skills are closely related to research experience as defined above. On the other hand management competencies or specific knowledge may be important for careers in other sectors. The challenge here lies in assessing competences in a reliable and efficient way. Viewed from SCCT, competences need not to be considered since they are reflected through self-efficacy.
Social capital and networks	Embeddedness in social networks implies shared norms and values. Networks also provide social resources including mentoring, social support or employment opportunities. Adding a power dimension to networks allows for a perspective of inequality due to different amounts of social resources at different positions in the social structure.
Family socio-economic background	A person variable closely related to theories of Bourdieu and Sorokin. In Bourdieu's view it is shaping the individual opportunity structure since available choices result out of a socialization processes specific to particular social strata.
Gender, partnering and children	Gender strongly interacts with other factors, primarily self-efficacy. Moreover, childcare is still carried out by women to a large extent which in turn can have an effect on career planning. Partnering links to dual-career strategies and choices. Highlighting that decision-frames can be collectively and concurrently determined based on more than one research career.
Life cycle	These shall be characterized as distinctive stages in the private life which are primarily shaped through partnership and the relationship to one's children. Age is also a relevant factor.
Crisis, biographical breaks and physical problems	Cannot be foreseen but will most likely have a substantial effect on career decision making.

(Main sources: Berweger 2008, Abele 2002, Kahlert 2013)

7.1. Research careers and decision-frames

The research career decision-frame is a model for understanding the interaction of factors and dynamics impacting on the important events that shape an individual career trajectory. Decisions about changing jobs for example, involve a range of individual/internal and contextual/external factors that implicitly or explicitly affect the exercise of agency and the eventual course of action. Such factors can support or hinder change. From an SCCT perspective background contextual affordances (distal factors) and contextual influences proximal to choice behavior (proximal contextual factors) are both at play, but are not clearly independent.

Of course research careers evolve and transform continuously over time, not simply at moments of transition or foregrounded choice. The dynamics of scientific knowledge and the organisation of knowledge production profoundly determine what kinds of

disciplinary research careers are required and how such careers 'fit together' into the complex productive structures of science and research systems. Logics of accumulation and autonomy leading to the acquiring of responsibility and leadership underpin models of research careers. To some extent a model of rational actors seeking to maximize rewards whilst accruing power over scarce resources does suggest itself. But this is an inadequate simplification that neglects that research careers are irreducibly collective and socially constrained phenomena.

Understanding the relative importance of individual, bureaucratic, scientific, family or myriad other considerations in the development of a research career, and upon the decisions taken at critical junctures within that development process, is thus largely an empirical matter. Understanding patterns of development and of decision-making can allow the construction of research career typologies – whilst failing to capture any single career in its entirety. A useful research career framework therefore might be one in which both the institutionalization and replication of certain types of research careers and the unfolding of idiosyncratic and diverse research careers could both be interpreted and their drivers understood.

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