Pre-print Version

This is the accepted version of the following article:

Carolina Cañibano, Richard Woolley, Eric J. Iversen, Sybille Hinze, Stefan Hornbostel and Jakob Tesch (2018) "A conceptual framework for studying science research careers", *Journal of Technology Transfer*. In Press.

A conceptual framework for studying science research careers

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Abstract

The emergence of open science and new data practices is changing the way research is done. Opportunities to access data through purpose built platforms and repositories, combined with emerging data and meta-data curation practices are expanding data availability in many fields. This paper presents a conceptual framework for studying scientific research careers, motivated by opportunities to link empirical datasets to construct new analyses that address remaining and emerging knowledge gaps. The research career conceptual framework (RCCF) emerges from a review of relevant theories and empirical findings regarding research careers. The paper reviews existing models and develops a typology of research careers. It also compiles a list of variables drawn from the literature on research careers. Two preliminary demonstrations of linking datasets to address empirical questions are outlined. The final discussion advocates an approach to emerging data opportunities that combines theories and models with empirical research questions as being superior to an approach that produces *ad hoc* explanations on the basis of 'data fishing' exercises.

Key words: Research careers, open data, RISIS platform

JEL: I23; O33; Y10

Acknowledgements

The authors would like to acknowledge financial support from the European Commission's project "Research Infrastructure for Research and Innovation Policy Studies" (RISIS, grant agreement number: 313082). The research for this paper was conducted as part of the RISIS work package "Integrating framework and dataset for analyzing research careers" (WP24). The authors would also like to thank Monica Gaughan for her advice and support in the development of the work package activities and her comments on this paper.

1. Introduction

The professional careers of scientific researchers are an important focus of research in economic, social, and policy sciences, just as they are a priority for science and technology (S&T) policies in many countries. Researchers' careers are the locus of scientific and technological knowledge growth, sharing and diffusion, as newly trained scientists join a research career, move and progress through different roles, organizations, and collaborative networks and communities. The development of research careers is also an expression of how labour markets for human resources in science and technology (HRST) function under a number of specific institutional conditions and constraints. At the same time, the unfolding of research careers conditions the type and volume of knowledge outcomes that are produced by researchers in different social and institutional contexts. As Gläser describes (2001, 699), research careers are particularly interesting and important because "they link individuals and institutions and they link social structures with knowledge production".

Understanding and promoting research careers is a priority for both research funding and research performing organizations (ESF n.d.). Among the most important reasons to track careers of doctorate holders, the OECD points to the internationalisation of research systems which leads to competition for qualified S&T talent and change toward less linear and more diversified career paths (Auriol et al. 2013). In the United States, tracing the careers of doctorate graduates has been a policy priority with statistical efforts dating back to 1957, when the Survey of Earned Doctorates was launched by the National Science Foundation in collaboration with other governmental departments[1]. In Europe, the strategy to build a common European Research Area (ERA) that is attractive to both European and worldwide researchers, led to a number of coordinated statistical efforts aimed at generating standardised information about a still very fragmented research labour market (European Commission 2011b).

Understanding research careers is also a priority for technology transfer scholars and policymakers. Knowledge workers, particularly highly qualified scientists and engineers, are the principal input to all technology transfer. This paper presents a new framework for organising theoretical reasoning regarding this topic and promotes the need to think more about non-academic careers in science and their roles in technology transfer. In addition, the paper diffuses

[1] The US National Science Foundation conducts nowadays four different surveys tracing careers of doctorate graduates: The Survey of Doctorate Recipients, the Survey of Earned Doctorates, the Early career doctorates and the Survey of Postdocs at Federally Funded Research and Development Centers (NSF: https://www.nsf.gov)

information about the European Commission data project 'Research Infrastructure for Research and Innovation Policy Studies' (RISIS),[2] which is likely to be of interest to scholars and policymakers concerned with individual and institutional dynamics within, and between, national science systems.

A very large literature exists that attempts to describe and analyse the changing 'contract' between scientific research and society. Much of this literature has emerged in the past two or three decades. A set of common themes run through this literature:

- there has been a transformation in the organisation of scientific knowledge production (Gibbons et al. 1994, for a survey see Hessels and van Lente 2008);
- public sector organizations involved in the production and utilization of scientific knowledge have experienced transformations in their missions and their expected response to societal expectations (Etzkowitz and Leydesdorff 2000);
- the matrix of authority relations involving governments, funding agencies, research performing organizations and researchers has been in a state of semi-permanent reform or revolution (Whitley, Gläser, and Engwall 2010);
- the organization of research has become more bureaucratized and industrialized, with resource allocation and governance moving increasingly to the project level (Walsh and Lee 2015);
- the framework conditions of science in a 'dynamic steady state' (Ziman 1994) with increasing competition for finite resources has led to substantive problems with the operation of scientific labour markets (Stephan 2013); and
- largely as a result of the above institutional transformations, the distinctions characterizing R&D activities, roles and careers traditionally based on sector (i.e. university, government, industry) have become insufficient (Bozeman and Crow 1990).

The combination of these changes has apparently had four major effects on research careers. First, an enlarged cohort of researchers clustered at the post-doctoral level has developed in some scientific fields. In many cases these researchers will be employed on consecutive post-doctoral contracts funded by project 'soft money' (Stephan 2013). Second, changes and constrictions in some national scientific labour markets have led to increased migration of scientists between countries and organisations in search of suitable employment opportunities. Third, global emphasis on the circulation of knowledge as a driver of innovation and socio-

[2] Information regarding the RISIS infrastructure is available at: http://risis.eu/. The RISIS dataset portal may be accessed at: http://datasets.risis.eu/

economic development has contributed to the promotion of 'scientific mobility' (Mahroum 2000) through international collaboration, policy agreements and support mechanisms (Jonkers 2010; OECD 2010). In the case of Europe, promotion of an integrationist policy framework (including the European Research Area (ERA)) that modifies national labour market and other rules facilitates researchers moving between Member States (MS) to work in research. These effects are likely to lead to a reduction in the dominance of the single-organization research career form and to a more complicated 'tracking task' for monitoring and researching scientific research careers (Franzoni, Scellato, and Stephan 2012, 2014) . Fourth, the increasing complexity (and non-linearity) of careers is further enforced by research careers that unfold at the frontier between academia and industry (Link and Scott 2005), notably with the development of research organisations serving simultaneously private and public interests and their consequent multiplying effect on the roles and responsibilities faced by their affiliated researchers (Bozeman and Bretschneider 1994, Boardman and Bozeman 2007, Garrett-Jones et al. 2010).

Empirical studies of research careers have built on a range of methodological approaches and data sources, including the use of researchers' CVs (Dietz and Bozeman 2005; Bozeman and Ponomariov 2009, Cañibano et al. 2015; Fernández-Zubieta et al. 2016), researcher surveys (Lee et al. 2010; Gaughan and Bozeman 2011; Boring et al. 2015), the exploitation of bibliometric data (Moed et al. 2013), collation and observation of population register data (Skovgaard 2014; Asknes et al. 2013), and the collection of qualitative data (Laudel 2006; Boardman and Bozeman 2007; Ackers and Gill 2008; Lam 2011; Spivack L'Hoste and Hubert 2012). A number of studies combine several empirical methods and data sources (Franzoni et al. 2014; Lawson and Shibayama 2015; Bernela 2016; Veugelers and Van Bouwel 2015). The current research landscape offers new opportunities that stem from the development of data infrastructures and platforms for depositing, accessing and (re)using research data, backed by advances in open science practices such as meta-data preparation and repository curation.

This paper proposes a framework for the study of researchers' careers – the Research Career Conceptual Framework (RCCF, see section 4) - specifically motivated by opportunities to link empirical datasets to construct new analyses. An example of such an emergent opportunity is the European Commission RISIS project mentioned above (see section 3). RISIS' aim is to open up and integrate a variety of datasets to the science, research and innovation policy community, including data on research careers. The RCCF is conceived as a conceptual tool or template facilitating consistency and replicability of studies of research careers across the broadest possible range of contexts in which research is performed. The rationale for the RCCF is that while expanding data opportunities may increase the capacity to address knowledge gaps and under-explored research questions, it does not reduce the need for theoretical and

conceptual framing of these questions. On the contrary, conceptual models and testable hypotheses will be needed to structure choices about variables that should be designed, or used, to link datasets from different projects and contexts in the interests of answering specific research questions and addressing practical policy issues. It should be stressed that this paper is thought of as an initial step in trying to link the existing knowledge base on research careers to emerging data infrastructures. It will not surprise the authors if it is rapidly superseded.The RCCF is not prescriptive; it is researcher and research question driven. It is intended to assist in the design of inquiries into research careers.

The RCCF (section 4) emerges from a functional review of relevant theories and empirical findings regarding research careers (Woolley *et al*. 2016). The framework is structured around the identification of 1) the main types of research careers, 2) the key milestones in the development of these career types, and 3) the main factors affecting research career decision-making, including personal, organizational, scientific community, job market and national research system factors. The paper proceeds in the following way. Section two summarizes the state-of-the-art research on research careers to develop elements for the career framework. Section three introduces the RISIS data infrastructure, while section four describes the main concepts in the research career conceptual framework and provides two examples of its operationalization using RISIS. The paper finishes with some concluding remarks.

2. What does the state-of-the-art research have to say about research careers?

There are a variety of ways of conceptualising careers analytically. The most common definition of a career has been as a series of jobs. The corresponding common 'objective' benchmarks of career progress have been increments in wages or salaries (financial rewards) and vertical promotion within organizations, usually to positions of greater responsibility (Arthur et al. 2005; Heslin 2005). However, more recent career theory has broadened the definition of professional careers, as "the evolving sequence of a person's work experiences over time", arguing that this "avoids any constraining assumptions about where people work or what represents careers success" (Arthur et al. 2005, 178-9). This 'opening up' of the definition of a career within career theory thus expands the view of careers from formal markers of careers to the inclusion of experiential and horizontal career dimensions.

Research careers are work lives lived through the performance of scientific research. While there is considerable biographical literature on the lives of scientific researchers and on the structure and characteristics of research careers, there is no common definition of a research

career. The Careers of Doctorate Holders Project (CDH[3]) defined the careers of doctorate holders as a sequence of "research career path jobs" that help further career plans in research (Auriol et al. 2013). In the context of the POCARIM project on careers of social science and humanities[4] (SSH) doctorate holders' it was argued that the trajectories of careers involve "knowledge and skills acquisition and re-construction. But these are also actors having expectations, discovering new possibilities, exploring them and learning also about what are their own skills and interests. They perform themselves to identify their capacities" (Vinck 2014, 4). These conceptualisations reflect the alternative focus on sequences of jobs or on experiential dimensions (including self-discovery) found in the general career theory literature.

2.1 Models of research careers

There are three distinct theoretical perspectives on research careers in the literature. The first of these is the sociological model of the institutional processes that structure academic research careers developed by Grit Laudel and Jochen Gläser (Gläser 2001; Laudel and Gläser 2008). A career is defined in an open fashion as a 'series of interconnected work situations' (Gläser and Laudel 2015, 13). However, the model of an academic researcher's career includes interacting cognitive, peer community and organizational careers. The concept of cognitive career reflects the importance of the content of research, which conceives of the career as a series of connected research projects that construct a research trail (Laudel and Gläser 2008, 390). The contribution a researcher makes to the knowledge relevant to this community also structures the status and work role that an individual holds within their peer community. A peer community career is a sequence of role bundles within a specialty or discipline with four stages: apprentice, colleague, master, elite (Laudel and Gläser 2008, 390). Finally, the organizational career is the sequence of jobs an individual holds within universities. Each of the three careers evolves according to its own dynamic to some extent, but the overall career is also shaped by interactions between the three career processes. However, variations in the trajectories produced by the three interacting processes 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 (Laudel and Gläser 2008). Career decisions always take the cognitive, community and organizational dimension into account concurrently (Gläser and Laudel 2015).

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[3]Information regarding the UNESCO-OECD-EUROSTAT CDH project may be found at: http://www.oecd.org/innovation/inno/oecdunescoinstituteforstatisticseurostatcareersofdoctorateholderscdhproject.htm

[4] POCARIM was a 7th Framework Programme project of the European Commission. It focused on mapping the population, careers, mobilities and impacts of advanced research degree graduates in the social sciences and humanities. More information may be found at: http://cordis.europa.eu/project/rcn/101868_en.html

A second conceptual approach to research careers can be found in the economics of science work of Paula Stephan and colleagues (Black and Stephan 2010; Fox and Stephan 2001; Sauermann and Stephan 2012; Stephan 2008). Stephan uses a human capital framework modified to include research productivity alongside income as incentives for scientific careers. This inclusion is 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 (Merton 1973). Stephan has also collaborated extensively in broadening the definition of what are considered 'market factors' to include family and gender dimensions. A significant part of her work has considered the impact of changing market conditions on research productivity and the consequence for scientific careers. Important findings include that research productivity either declines with age or increases initially with age before declining – with the differences apparently due to scientific field specific conditions (Levin and Stephan 1991), and that early stage research career transitions to independence are breaking down, in part due to the prevalence of 'soft money' positions that focus on project outcomes and/or extended post-doc periods focusing on the research programs of chief investigators (Stephan and Levin 1997).

The third theoretical perspective is the scientific and technical human capital (STHC) approach developed by Barry Bozeman and colleagues (Bozeman et al. 2001; Bozeman and Rogers 2002). STHC is 'the sum of researchers' professional network ties and their technical skills and resources' (Bozeman and Corley 2004, 599). Technical human capital has three dimensions: cognitive skills – cognitive abilities largely independent of context; substantive scientific and technical knowledge; and context skills – knowledge accumulated by doing and creating (Bozeman and colleagues 2001, 726-27). 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. It is defined along two dimensions: the institutional setting of the network partner (firm, NGO, Govt. institute, etc.); and the role of the partner (entrepreneur, colleague, funding agency, etc.). Each individual scientist has unique 'loadings' of STHC that shape their career, which is defined as a series of job transformations. Scientific careers can thus be understood in this model as a function of the acquisition and interplay of complements of technical and social capitals and how this impacts on the evolution of research capacities, performances and individual 'fit' with professional work contexts over time (Dietz and Bozeman 2005; Lin and Bozeman 2006).

As a model of researcher careers, the theoretical underpinnings of the Stephan model place the emphasis more heavily on individual agency. This emphasis is tempered somewhat by the modifications included to address the incentive of research productivity, given that scientific research is largely produced and validated collectively. At the opposite end of the scale, Laudel

and Gläser emphasise institutionally and collectively produced processes over individual agency. The STHC model lies somewhere in between. The differences between the three models have implications for the types of questions that are framed in empirical studies of research careers. Table 1 summarises the different empirical approaches to research careers associated with the three models.

Table 1 Theoretical approaches to research careers

	Laudel & Gläser	**Stephan & colleagues**	**Bozeman & colleagues**
General theoretical research question	What are the career effects produced by interactions among overlapping institutional fields?	How do the markets for scientists and scientific knowledge allocate individual research careers?	How do configurations of technical and social capitals evolve and with what career effects?
Model of career stages	Evolving role sets (Apprentice; Colleague; Master; Elite)	Labour market & sector defined, sequence of jobs (Post-doc, tenure track, tenured; contract)	Labour market & sector defined, sequence of job transformations (Post-doc, tenure track, tenured; contract)
Indicative empirical research questions	How do cognitive, community and organisational career processes effect career stage transitions? What institutional conditions favour or hinder switches in cognitive research trails?	What is the impact of the individual life cycle on scientific productivity? What incentives drive market preferences for postdocs over tenure track positions?	Which configurations of experience and productivity contribute to more rapid career advance? What motivations drive collaboration strategies?
Main types of data	Bibliometric (research content, research trails) Interview	Bibliometric (research productivity) Survey	Interview Survey CVs

It is evident from Table 1 that each of these three models will shape empirical research questions differently. The definition or model of career adopted will structure the broad research questions asked about careers and the empirical research questions that are investigated through data collection/use and analysis. For example, whether a research career is defined conceptually as a sequence of job changes or as evolving role sets will prompt different types of empirical research questions. Not all empirical research questions will be theory driven. Exploratory/descriptive empirical research questions may be used as a mechanism to interrogate

an available dataset, without any pre-identified understanding of causal relations. However, such questions should still ideally be linked to some kind of theory or model building work.

2.2 Models of research career stages

We have identified four explicit models of research career stages. Laudel and Gläser develop their model of research career stages based on a combination of conceptual and empirical work (Laudel and Gläser 2008). The remaining models have been developed by European institutions to facilitate policy making and statistical exercises in the context of a still very fragmented European research labour market: the European Commission (EC), the European Science Foundation (ESF) and the League of European Research Universities (LERU); all organisations with interests in research careers and related (European) policy settings (Boulton 2011; ESF n.d.; European Commission 2011b). The EC and ESF models are designed to be applicable as much across employment sectors as across countries. The LERU model was specifically designed to frame European academic careers. In the United States, surveys from the National Science Foundation (i.e. Survey of Doctorate Recipients, Early Career Doctorates Survey) collect information regarding faculty rank, tenure status, academic positions and activities performed in the different employment sectors among other variables, but a model of research career stages is not made explicit[5]. Table 2 summarises the models of research career stages identified.

5 Of course, there are also models or maps of career stages that are implicit to much of the empirical work on research careers, usually based on sequences of jobs and promotions

Table 2 Research career stages

	Laudel & Gläser	European Commission (EC)	European Science Foundation (ESF)	League of European Research Universities (LERU)
Career Focus	Academic research	Open		Academic
Description of career stages	- Apprentice - Colleague - Master - Elite	- R1 First Stage Researcher - R2 Recognised Researcher - R3 Established Researcher - R4 Leading Researcher	- Doctoral training - Post-doctoral training - Independent researcher - Established researcher	- Doctoral candidate - Postdoctoral scientist - University scientists - Professor
Defined by	Role sets/ Interdependence, Authority	Competences/ Independence, Leadership	Positions/ Independence	Positions/ Rank
Sector	University	All	All	University
Distinguishing foci	Work/ Community	Competences	Tracking/ Gender	Shared career responsibilities

All the models distinguish between four stages of a research career. The mechanism by which transition between stages occurs differs between the models. Laudel and Gläser emphasize the evolution of individual role sets to meet the expectations of scientific communities and, increasingly, to play a role in identifying the research questions prioritised by that community. This is the only model of research career stages that is associated to a conceptual model of the processes (three careers) that generate career stage transitions.

The EC model specifies the acquisition of technical and administrative competences, including research leadership. The ESF and LERU stage models are defined by job changes associated with vertical promotion to a higher level within research performing organizations. The ESF and LERU models imply independent researcher status is achieved in the third of four stages, whereas this status is achieved in the second stage in the two other models.

2.3 Typology of research careers

The available research on research careers usually differentiates careers according to the context (type of RPO) and the specialization (scientific field or discipline) in which they occur. The usefulness of the standard industrial-governmental-university distinction has been challenged (Crow and Bozeman 1987), but remains a common method for distinguishing between RPOs.

The vast majority of research on research careers focuses on academic research careers conducted in universities. However, some studies have also paid attention to scientists working in government laboratories and/or industrial R&D (Gerpott, Domsch, and Keller 1988; Pelz and Andrews 1976) and the types of involvement of star scientists with private firms (Zucker and Darby 2006; Zucker, Darby, and Torero 2002).

An important body of literature has emerged to study research careers at the evolving frontier between academia and industry. Notable among these are the overlapping and intertwining strands that focus on (knowledge and) technology transfer (e.g. Cohen et al. 1998) and on university-industry relations more generally (e.g. Mowery and Ziedonis 2002). More specific areas of inquiry include those that look into sector mobility (Dietz and Bozeman 2005; Edler et al. 2011) or into the increasing array of organizational structures for cross-sector collaboration, including the entrepreneurial university (Bercovitz et al. 2001), university research centres (Ponomariov and Boardman 2008), and a range of other more or less formalized research alliances (see Bozeman and Boardman 2013, 2014, for an overview). Studies of university based multi-disciplinary research centres that cooperate with industry and assist their interests (Bozeman and Boardman 2004, Boardman and Gray 2010) have addressed the effects of affiliation with this type of centre upon researchers' productivity patterns and collaborations (Ponomariov and Boardman 2010), researchers' involvement with industry (Boardman 2009; Gaughan and Corley 2010), satisfaction and perceived benefits (Coberly and Gray 2010) and career outcomes (Gaughan 2009).

The 'industrial involvement scale' proposed by Bozeman and Gaughan (2007) indicates that there is a spectrum of involvement between the different sectors. A common denominator here is that the activity and arrangements on the frontier are changeable and changing, not least in the medical area. Careers linked to clinical research in medicine are not well understood (Keller and colleagues 2014; Thomas and colleagues 2004) possibly due to the multiple simultaneous affiliations of many clinical medical researchers (in hospitals, universities, private clinics, for example). However, there is evidence that hospitals are significant sites for innovation in clinical and translational research (Consoli and Mina 2009; Gelijns and Rosenberg 1994; Nelson and colleagues 2011). Relatively little literature has been published regarding research careers in the private non-profit/charitable sector.

General career theory has emphasized the emergence of new 'protean' and 'boundaryless' careers and the declining significance of old single organization, single industry and a consistent main role as the bases for understanding careers (Arthur and Rousseau 1996; Khapova and Arthur 2011). Academic careers (Baruch and Hall 2004) have been characterised as an example of hybrid old/new careers, which have been argued to concurrently involve the 'binding and unbinding' of individuals to organizations (Dany, Louvel, and Valette 2011; Enders and

Kaulisch 2006). In general, there is an acceptance in this literature that professional careers pathways have multiplied and diversified. However, the tension between established ladders of career opportunity, characterised by competition and some degree of 'up-or-out' progress, and emergent research career paths is likely to endure and provide one important focus for future studies.

A broader point relates to movements between research and non-research jobs as part of the career. The POCARIM project found that inter-sectoral mobility allowed for "the discovery of the possibility to valorise the PhD for holders of social sciences and humanities (SSH) doctorates, moving outside the academy into management, design, consulting, innovation, etc.", creating opportunities to "reshape the meaning of their research skills" (Ackers 2015, 11). The linking of types of research careers to shifts into other non-research careers (exit), and whether further steps can include the return to research (re-entry), can potentially provide important new information regarding both the value of PhD level research skills in the broader labour market (Lee, Miozzo, and Laredo 2010) and the potential emergence of mixed research/non-research career trajectories.

Established research career types, conducted in different types of RPOs with differing missions and goals are shaped by reward systems tailored to the performance of these missions and goals. There is a voluminous literature dealing with the systems of incentives and rewards which characterise academic research careers (Merton 1973; Stephan 2010). There is also a significant literature that looks at the reward systems in bureaucratically structured industrial R&D (Pelz and Andrews 1976) and in more recent forms of extended industry labour markets (Lam 2005, 2011). Attempts have also been made to compare and contrast the logics that underpin the academic and industrial research systems, including how salary and publications incentives impact on these systems (Sauermann and Stephan 2012). There is some evidence that shifting into government RPOs can present career risk for individuals precisely in relation to breaks in the continuity of participation in cumulative academic reward systems (Coberly and Gray 2010; Garrett-Jones and colleagues 2013). The extent to which tailored systems of incentives and rewards structure research careers in the clinical, medical, and non-profit sectors remains uncertain.

Overall, there is considerable ongoing debate about the relative influence of the goals and missions of RPOs, the degree of similarity/difference between 'academic' and 'market' or 'commercial' logics in the performance of research, and the importance of the public or private ownership of research results (secrecy) in the shaping of science (Dasgupta and David 1994; Murray 2010; Sauermann and Stephan 2012; Stokes 1997).

Different types of research careers identified can thus be thought of as structured by specific *logics of accumulation* – of competences, research results, papers, patents, products, profits, etc. – that characterise different mixes of scientific field, RPO type and institutional logics. The evolving character of institutions, organisations, markets and knowledge ensures that the specific logics of accumulation structuring different types of research careers are mutable archetypes and should not be regarded as fixed. The researcher attributes that are most valued in a specific research performing context will also vary over time. The specification of the logic of accumulation[6] that drives progress in, and shapes the trajectories of, different types of research careers at particular points in time is thus ultimately an empirical question. Of course, whilst a specific logic of accumulation structures different research career types, at the level of the individual career accumulation may also cease (e.g. stagnation in work role), be interrupted (e.g. severe illness), or go into reverse (e.g. de-skilling), under certain circumstances. An individual researcher's capacity to accumulate under the various logics of that shape progress in different types of research careers is an empirical question.

Research into research careers contributes information to both the definition of research career types and to the work of comparing and differentiating between them. Two categories, RPO type and sector, are typically used to position careers within the mix of institutional and organisational influences that shape career patterns. Two dimensions, *mix of activities* and *logic of accumulation*, can then be investigated empirically to define more precisely the characteristics of particular research career types and delineate in a more fine-grained manner between them.

2.4 Critical junctures in research careers

The previous sections have considered models of research careers, how these careers can be analysed as sequences of cumulative stages and how careers are differently patterned according to the types of RPOs and sectors in which they occur. In this section the focus is on the synchronic dimension and, in particular, career-shaping choices and decisions.

Whilst research careers are longitudinal and cumulative, they are also punctuated by critical junctures, when individuals make choices among possible futures. These critical junctures include making decisions about changing employers, but are not limited to purely labour market questions. Equally, research careers are shaped by decisions taken on the selection of research topics (Knorr-Cetina 1981), including switching to new topics or discontinuing a research line (Gläser and colleagues 2014). Decisions regarding the opportunity to be geographically mobile (Fernández-Zubieta *et al*. 2015), electing whether to work for a period in international locations

[6] This is similar to Bourdieu's conception of the 'stakes of the game' (Bourdieu 1975) that structure scientific fields.

or remain within the 'home' context, can also have varying outcomes for scientific performance (Franzoni and colleagues 2014) and career progress (Lawson and Shibayama 2014).

In the literature on start-up companies, the term 'critical junctures' refers to that which must be overcome in order to make the transition from one phase of development to the next (Vohora, Wright, and Lockett 2004, 150). Adapting this idea to the context of research careers, critical junctures can be defined as characterizing the transition between different phases of the career. For the career to reach its full potential the transition between different phases of development needs to be made. Successful transition through a critical juncture demonstrates that a researcher's professional capabilities have undergone a transformation that is recognized by peers. We label the process of making decisions linked to critical junctures in research careers the 'research career decision frame'.

The basic idea of the research career decision-frame is that choices that the researcher makes—or is required to make—can be more or less decisive at specific points in time to career development. As such, a range of relevant institutional, professional and personal variables may be taken into account as part of the decision-making process. At issue is how the individual understands and aligns personal preferences and criteria with the pressures of relevant institutional conditions and rules during the decision-making process. The focus of study here is on the synchronic dimension of the research career; it considers specific information, expectations, and other aspects that individuals factor in as relevant when making career calculations at particular critical junctures. Changes in positions or in research topics can be seen as critical events that punctuate the unfolding of the career at particular points in time.

A prominent example of research that focuses on a critical juncture can be found in studies of decisions made by doctoral graduates about whether to pursue a career in academic research. Research on this front is varied in terms of disciplinary approach, methods used and dependent variables constructed. For example, research on this topic focuses variously on productivity and preferences (Balsmeier and Pellens 2014), gender and family (Fox and Stephan 2001), perceptions of incentives (Fitzenberger and Schulze 2013), the determinants of exit from academic research (Geuna and Shibayama 2015), informational problems leading into PhD study (Mangematin 2000), trade-offs between salary and publication freedom (Sauermann and Roach 2014), issues regarding mentors capacities to provide information on a diversity of potential careers (Bozeman and Gaughan 2011; Sauermann and Roach 2012), the existence of suitable role models (Steele, Fisman, and Davidson 2013), the geographical location of suitable industry jobs (Sumell et al. 2009) and the market power of star scientists (Zucker and Darby 2006; Zucker and colleagues 2002).

2.5 Limitations in the state-of-the-art research on research careers

Research into research careers confronts a complex and evolving research object. It is therefore not particularly surprising that the state-of-the-art research on research careers has a number of identified weaknesses, including:

- the lack of a comprehensive approach to researching research careers. The complex nature of research careers means that research tends to focus either on institutional determinants or individual choice, but attempts are rarely made to link the two approaches;
- there is a conspicuous lack of attention to research careers outside of academic research careers – and existing research generally neglects that university researchers also have significant teaching, administration and other roles;
- comparability between cohort studies of research careers is lacking, not least because there have been very few attempts to construct variables based on universal categories (Kaulisch and Salerno 2005);
- a limited capacity to account for temporality and the evolution of institutions due to the emphasis on cross-sectional data;
- a lack of clarity about the range of research jobs that exist (Miller and Feldman 2014). Some research roles appear to be 'invisible' or appear only as 'stepping stones' to the established career pathway when there is evidence that these roles may be persisting and form significant element of contemporary careers (Miller and Feldman 2014; Stephan 2013);
- neglect of the research career characteristics of medical doctors, surgeons, and other clinical professionals; and
- a general lack of understanding of mixed and hybrid careers (Lin and Bozeman 2006), although some recent attempts have been made to understand the impacts on researchers' career aspirations resulting from working in hybrid public/private organisational forms (Garrett-Jones et al. 2013; Gray et al. 2011; Lam 2011).

In summary, this section has reviewed parts of the literature on research careers relevant to the development of a framework for conducting research on research careers, which is outlined below (section 4). However, in the following section we first introduce the RISIS data infrastructure, which will then provide the concrete examples used to demonstrate the operationalisation of the research career conceptual framework.

3. The RISIS data infrastructure

Researchers are often confronted by the lack of available empirical information, particularly data-sources that would be necessary to undertake more structural enquiries. Large-scale datasets have traditionally been out of reach of the wider research community. They have been expensive (e.g. large scale surveys such as the Changing Academic Profession survey - CAP (Teichler et al. 2013) or CDH (Auriol et al. 2013), cumbersome to analyse (e.g. large batches of CVs) or otherwise off-limits (e.g. the registry-based panel studies of the NSF). However, a growing momentum exists within science and policy communities with regard to organising the practice and communication of science in a more 'open' fashion. There is an increasing focus on making research data more openly accessible, including for reuse and to facilitate reproduction studies and validation trials (European Commission 2011a; Moedas 2015). The development of significant online architectures for the distributed production, diffusion and use of research data is accelerating in many fields (e.g. ELIXIR in bioscience)[7], including the social sciences (RISIS).

The RISIS infrastructure is designed to provide the research community with access to a set of databases and of empirical tools that can be used to support science, technology and innovation studies. To this end RISIS provides a space in which the researcher can access (to date) 13 datasets that cover a range of entities, including universities and other public research organizations, populations of MNEs and fast-growing firms. The datasets include register information about firms and universities as well as complementary information (such as patents, publications, as well as some survey data). For example, firm information is linkable to R&D data (for MNEs) as well as to patent data; university information is linkable to data covering publications (Leiden Ranking) as well as data about public financing of research projects (EUPRO). New open data practices combined with smarter computerised processing techniques are likely to result in an increasing number of large-scale datasets becoming available through RISIS.

The infrastructure also provides a number of tools to help the researcher to link, organize and enrich data. The researcher may use the infrastructure to access, select, build and treat data, depending on the research question. The intention of the infrastructure is to improve the quality and usability of these data, by developing new ontologies and user tools for searching, combining and downloading data. By developing software tools and platforms RISIS thus aims to support researcher workflows in a flexible manner.

[7] http://www.elixir-europe.org

The RCCF is a conceptual tool designed to orient future research and to facilitate access to open datasets relevant to research on research careers. Datasets linked to the RISIS infrastructure provide different types of data and information relevant to studying research careers, including:

- MORE1 and MORE2 – surveys of researcher mobility inside and outside Europe;
- ProFile – panel data on training conditions and preferred occupational activities of doctoral candidates in German universities (Lange and colleagues 2016);
- The European Tertiary Education Register (ETER), structured as a database of characteristics of higher education institutions in Europe; and
- The Leiden Ranking of major universities worldwide.

To date these datasets have been used separately to address a number of questions regarding research careers. Veugelers and Van Bouwel (2015) combine the data from MORE1 and bibliometrics to address differences in publication productivity and career development of researchers with different international mobility patterns. Børing and colleagues (2015) used the MORE1 data to address differences in mobility mobility patterns of researchers working in the higher education sector and those in the non-university research laboratories across Europe. The data from the MORE2 survey has been used to address the dynamics of return mobility of European researchers (Cañibano et al. 2017) and are currently also under exploitation, to study mobility profiles by research career stage and to address the potential association between international mobility and career progress (Cañibano et al. 2016). Profile has been used to analyze how different formats of doctoral training prepare doctoral candidates for research careers (Hauss et al. 2015; Ambrasat and Tesch 2017), as well as the individual and institutional determinants of the post-PhD job-placement of doctorate holders (Lange *et al*. 2016). The development of open datasets platforms like the RISIS infrastructure offers the possibility of 'aggregating' datasets allowing sets conceived separately and for different purposes to enrich each-other when 'common' or 'linking' variables exist[8].

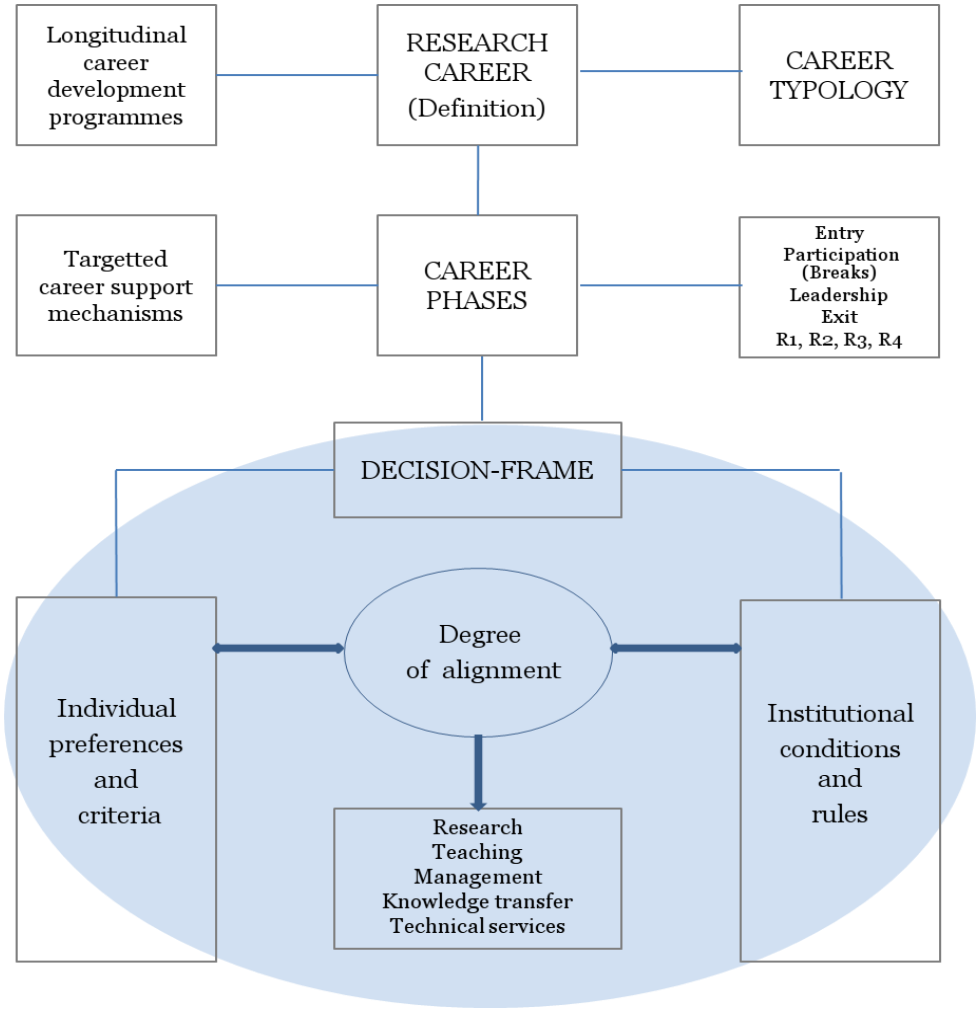
4. The research career conceptual framework (RCCF)

The RCCF is a heuristic framework linking existing theories and models of research careers with the increasing number of datasets that are now becoming more widely available to the

[8] An example of 'aggregation' of two RISIS datasets is provided by Lepori and colleagues (2015) who link ETER and EUPRO (Database on European Framework Programmes) to address the link between the characteristics of higher education institutions and their participation in European Framework Programmes.

research community to study them. The availability of data-resources opens new vistas for study but it also creates new challenges for research design. The emergence of large-scale data-sets that are increasingly open and linkable is a new phenomenon that breaks from the situation the researcher was traditionally confronted with. There is a danger that the focus on the new possibilities of data becomes unmoored from theoretical perspectives, which can easily lead to 'data fishing' exercises that are simply interested in establishing statistical links between variables. The wealth of data opportunities may leave researchers wondering where to begin. This is where the RCCF can be of help. Figure 1 provides a schematic overview of the research careers conceptual framework.

Figure 1 Overview of the Research Careers Conceptual Framework (RCCF)



4.1 Main components

The RCCF includes four main concepts for organising research into research careers: research career definition; research career phases; a research career typology; and the research career

decision-frame. The definition of a research career used in any specific study is researcher driven and will frame the types of empirical research questions that can be posed. This in turn will shape the types of data that are suitable to address these questions and the methodologies required to create primary data and/or utilize secondary data. Section 2 introduced three definitions of a research career, as:

1. A sequence of academic research jobs
2. A mixed series of interlinked work situations
3. The progressive acquisition of competences

It is neither the purpose of the RCCF to advocate for a particular model of research careers, nor to develop a new definition of careers. Rather, the definition of research career used will shape which already-available datasets (in RISIS for example) will be useful, and which variables within those datasets are relevant for the research question(s) posed.

As was outlined in section 2.2, research career stages can be defined as transitions in roles sets, competences or positions, or by a combination of these elements. Adopting one or more of these career stage transition elements then shapes whether the empirical research questions to be asked will be predominantly about employment history, practices and organisation, or tasks and learning, respectively.[9] The RCCF adopts an open, researcher-defined model of research career transitions, which can be populated in advance using existing conceptual models or developed *ex post* as an outcome of empirical inquiry.

Different types of research careers are produced in large part by a complex set of institutional and organisational processes, including explicit policy measures, forms of organisational planning and professionalised forms of management. As a result, research careers have increasingly been seen as objectified, designed and produced phenomena. Career support mechanisms such as fellowships can be understood as being designed to 'smooth' critical junctures and/or career transitions (Hornbostel and colleagues 2009). Professional career development programs, which can be understood as designed to enhance the competences and labour market suitability of individuals.[10] Such measures try to achieve more efficient research labour market entry, enhance performance and improve continuity outcomes, ensuring the progressive optimisation of returns on public investment in the highly skilled workforce.

Research into research careers largely focuses on established types of research careers that are relatively strongly defined. However, potential for other types of research careers to be better

[9] Developing a new model of career stages and defining these could also be facilitated by the RCCF, whether this proceeds from a conceptual or an empirical starting point.

[10] See for example http://www.vitae.ac.uk

described and analysed is also pointed out in the literature. Figure 2 depicts a typology of research careers that follows the existing literature in categorising these careers by sector and RPO type.

Figure 2 Component of the RCCF – Research career typology

RPO type	**Sector**	**Research career type**		
Universities	Public or Private	*Academic research careers*	*Mixed careers*	*Hybrid careers*
Combined organizations (i.e. CRCs, ERCs)	Public and Private			
Firms	Private	*Industrial R&D careers*		
Government laboratories, institutes, organizations (including international organizations)	Public	*Government research careers*		
Hospitals	Public Private			
Non-profit organizations	Private			

Three relatively 'traditional' research career types are identified in the typology: academic research careers; government research careers; and industrial R&D careers. No typical research career pattern has been identified in the literature linked to RPOs in the clinical medical and non-profit sectors. This appears to be a significant existing research gap.

Two further categories are included to reflect more mobile career pathways. 'Mixed research careers' are those careers that move between RPO's of different types sequentially, thereby contributing to these organizations' missions and goals at different times (Bozeman and Ponomariov 2009; Su and Bozeman 2009). 'Hybrid research careers' are those that take place

concurrently in multiple RPOs of different types, thereby contributing to these organizations' missions and goals at the same time.[11] These last two categories remain under-explored in careers research, despite the possibility that they could be of particular importance in relation to technology transfer.

The research career decision-frame helps to organise thinking about the process of making choices at critical junctures in research careers. The RCCF includes a provisional list of relevant variables associated with career choices drawn from the literature. Every research career takes place under specific institutional conditions, with specific rules, which may be investigated empirically. Equally, individuals' attitudes, circumstances, motivations and personal criteria that contribute to their decisions, can also be investigated empirically.[12] In the RCCF a distinction is thus made between two categories of variables that may influence decisions made at critical career junctures: 'institutional conditions and rules' and 'individual preferences and criteria'. Table 3 lists the major variables included in these two categories, although it should be emphasized that this is not a closed list and additional relevant variables may be identifiable in the literature or may emerge as research systems evolve.

Table 3 Component of the RCCF - research career decision-frame variables

Institutional conditions and rules		**Individual characteristics, preferences and criteria**	
National/ Organisational	Country Research and innovation system Research governance & authority relations Labour market dynamics & rules Employer RPOs/sector Gender and family policies	Plans and preferences	Goals Intentions Preferences Action outcome expectations
		Knowledge and Learning	Competences, knowledge and skills Research experience Work experience Mobility experience
Scientific/ Professional	Scientific discipline & conditions of training		

[11] The degree to which mixed and hybrid research careers are prevalent in any national research system is itself an empirical question that requires attention.

[12] Of course, the RCCF does not try to prescribe a rational choice model of maximizing or satisficing on the decision-frame calculation (though this may be a relevant heuristic in some cases). It is perfectly possible that career defining choices are made without foregrounding the possible benefits and costs, or even without particularly well-informed consideration. Some careers 'choices' can also be colloquially described as 'pushing on the only open door'.

	Position descriptions/job design Forms of incentives & rewards Funding sources Career support mechanisms	Personality and Self-awareness	Risk attitudes Personality traits Self-efficacy
Other	Global trends Cultural norms	Society and culture	Family socio-economic background Gender, partnering and children Social capital and networks Life-cycle stage Crisis, biographical breaks and health problems

The research career decision-frame tries to capture the process by which individuals evaluate the degree of alignment between institutional and individual elements. The greater the degree of alignment between the institutional conditions and rules that shape a possible future step and the individual preferences and criteria that structure what that individual expects or desires, then the greater is the likelihood that researchers will decide to make a change in order to try and reach professional goals and fulfill their career expectations. 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, requires careful empirical investigation.

4.2 Two examples using RISIS and the RCCF

Having set out the main components of the research career conceptual framework, this section operationalises it in the context of utilising the RISIS data infrastructure. As described above (section 3), RISIS provides open but controlled access to various datasets that can be used to study research careers. The datasets can be accessed as stand-alone data-sources or, more importantly, they can be linked together in certain ways.

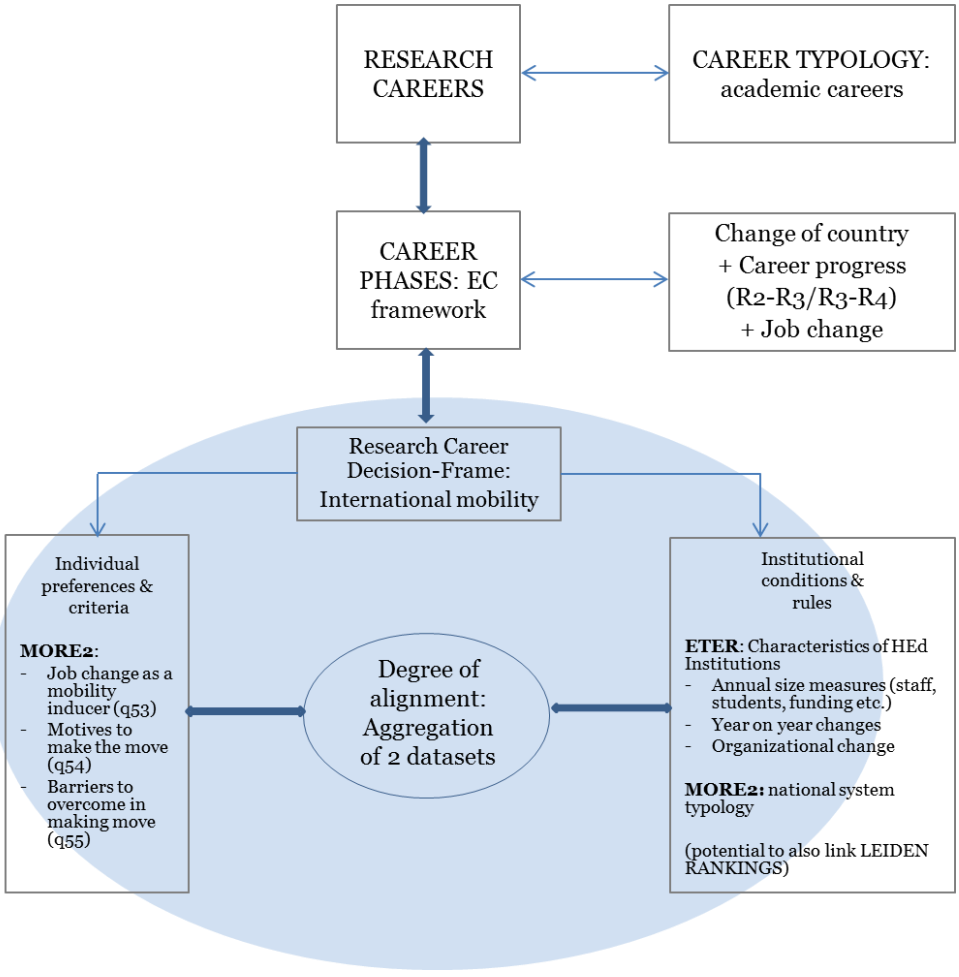
4.2.1 Like a rolling stone: research careers and geographic mobility

Our first example involves the role of geographic mobility in research careers. This is an area where there has been a long-standing policy interest, often associated with concerns about the so-called 'brain drain' (Cañibano and Woolley 2015), and extending through the OECD Canberra Manual in the mid-1990s to the current policy initiatives under the European Research

Area. There are currently over 30 policy initiatives directed at research mobility in the Nordic counties alone (NordForsk 2014). From the point of view of individual careers, regional or international job mobility is often the marker of a critical juncture that reconfigures the contexts and networks in which researchers work and therefore conditions their careers.

A potential research question therefore is: in what circumstances will researchers move to another country to work? Addressing this question requires information on the personal and institutional push-pull factors that are most important and most commonly aligned in facilitating mobility. From the individual perspective, we might ask: what motivated a researcher to move to another country to work?; and, did this mobility impact on career progression? From the institutional perspective, we might want to know: what are the characteristics of RPOs that are 'magnets' for mobile researchers?; and, are the characteristics of 'magnet RPOs' different to those of RPOs overall? These questions can be addressed using data available through the RISIS data infrastructure, including the MORE1, MORE2 and ETER datasets.

Figure 3 Using the RCCF with RISIS: mobility and career progression



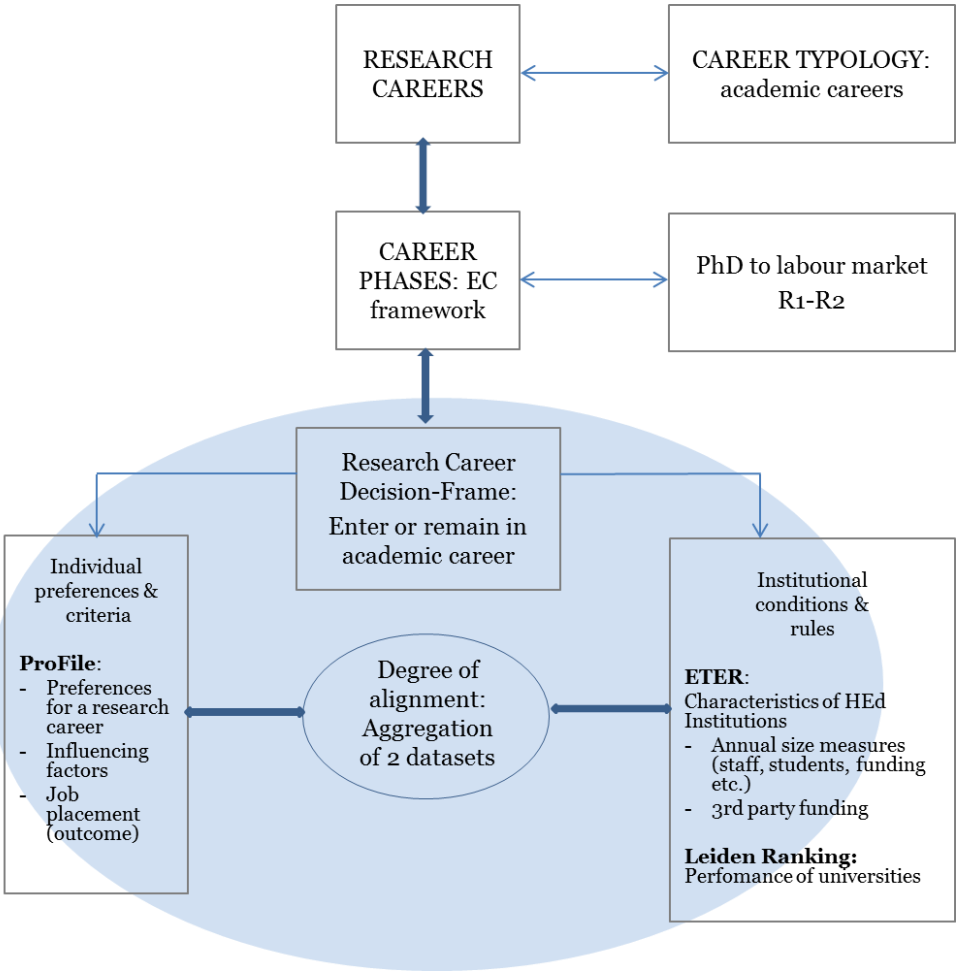
In relation to individual preferences and criteria, the MORE2 dataset includes variables relevant to decisions to move to another country such as job change, motivations and barriers (Figure 3). These can be linked to critical junctures in career progression, defined as moving from career stage R2 to R3, or from R3 to R4 (according with the EC career stage model). In terms of institutional conditions and rules that shape the mobilities observed in MORE2, the outcomes observed can be linked through RISIS to the ETER registry of European institutions. Actual mobility data coupled with university characteristics can be used to determine which types of institutions may be 'mobility magnets'. These results can also be compared along other analytical dimensions such as geographic distribution or by scientific field.

The RISIS data infrastructure is exploited in this example by linking different research mobility outcomes to certain organisation profiles, providing an overall picture of how individual and institutional factors align in observed mobility patterns. A further typological variable could also be potentially applied to these linked data, as the MORE2 study also categorises national academic research systems into four groups depending on a range of institutional and labour market factors. A potential further link could be made through RISIS to a proxy for the productivity (and hence prestige) of individual unversities, using the Leiden Ranking.

4.2.2 Should I stay or should I go?: embarking on an academic career

As was mentioned earlier, a prominent area of career research relates to decisions to enter into an academic career. A general research question is: under what circumstances will researchers decide in favour of a research career? From an individual perspective we can ask: what are the perceived major (positive and negative) factors affecting the decision to pursue an academic career? From an institutional perspective we can ask: what are the characteristics of RPOs in which early stage researchers decide more often to continue a research career? These questions can be addressed using the ProFile, ETER and Leiden Ranking datasets via RISIS (Figure 4).

Figure 4 Using the RCCF with RISIS – entering academic careers



In relation to individual preferences and criteria, the ProFile dataset includes variables relevant to career decisions. With the longitudinal information contained in ProFile it is possible to observe the transition from R1 to R2 and connect conditions experienced during doctoral training to post-doctoral job placement. Comparisons can be made between disciplines, for example the transition rates of engineering and social science doctorate holders. In terms of institutional conditions and rules that shape career decision making, the outcomes observed can be linked through RISIS to the ETER registry of European universities to determine which types of institutions appear to support or induce decision-making that favours research careers. The information could be complemented by institutional performance data from the Leiden Ranking.

Of course, there would be considerable limitations to our two examples pertaining to both the quality of the various data used and to the interpretations that can be made of the linked data constructed. (This would be accentuated if there was no predictive model or theoretical basis for an explanation of the results.) Our purpose here is simply to illustrate the possibility of linking

data for studying research careers, in this instance using the RCCF and the RISIS platform. Future empirical papers will report the actual results of these and other studies undertaken using data-linking techniques and will evaluate the quality of the results and findings produced.

5. Conclusion

This paper has outlined the development of a conceptual framework for the study of research careers. The development of the research career conceptual framework was driven by three main perceptions: 1) that the science and research systems are changing in ways that have profound impacts on research careers; 2) that transformation in data access opens new avenues for research into scientific research careers; and 3) that the knowledge about research careers produced over the last two decades can be systematised and organised so as to support the exploration of new research questions and the exploitation of data that address existing and emerging knowledge gaps. The Research Career Conceptual Framework (RCCF) is a result of a review of existing knowledge, but not so much as a stocktaking exercise but to develop a framework to support further research. The RCCF is also an open object, with this initial version constituting a starting point to be developed and improved through further iterations.

The paper has described a set of basic components derived from an analysis of the empirical studies and conceptual models of research careers found in academic literature and policy documents. The objective of the framework is to provide an organising mechanism for linking these conceptual elements with empirical datasets containing information on research careers. The framework also provides a conceptual reference point for researcher-defined questions about research careers. In the future it should also provide pathways to exploit available datasets (particularly those included in the RISIS infrastructure) and aid in the identification of gaps in the available data for addressing specific empirical research questions.

We believe the RCCF is a timely development motivated by the research opportunities presented by an emerging era of data practices, characterised by increased openness, data sharing and data re-use. To fully exploit the potential of data-linking the conceptual framework needs to be accompanied by technical protocols. Such work is underway in the context of the RISIS project, with a view to developing linking variables between datasets. In the future, such protocols should also encourage the design of empirical studies, particularly surveys, that foresee linking to existing datasets and prepare these instruments accordingly. Our two data-linking examples highlighted both the practical possibility of linking survey data with institutional databases and the national datasets with European or global level data collections. The potential of future data-linking opportunities appears rich, particularly once such foresight is included in new study designs.

This paper has insisted on the sanctity of the connection between theories and models and the development of hypotheses to enable empirical tests for predicted effects. This due to scepticism regarding the expansion of data possibilities if this were to lead simply to growth in the production rate of studies that offer *ad hoc* explanations for statistical relationships established within these data. More data means more statistically significant relationships can potentially be revealed. But detached from a model to test or theoretically informed question to answer, explanations tend to be made to fit the data rather than the phenomena these data represent.

In relation to research questions, the study of research careers combines perspectives on career trajectories with those on critical junctures and trajectory-altering decisions. Shifting the unit of analysis in research career studies between longitudinal trajectories and what we have called the 'decision-frame' is conceptualised in the RCCF as a process of aligning institutional and individual factors. Studies that can retrospectively identify and reconstruct key decisions and their effects on the unfolding of a career thus seem to be one important avenue for further development of empirical analyses based on the framework.

The development of expanded data opportunities will undoubtedly provide avenues to address existing questions regarding scientific research careers. What is unknown at this point in time is whether these opportunities will allow the pursuit of questions about research careers that were previously impossible. A number of remaining knowledge gaps have been identified, notably regarding medical careers, careers at the frontier between academia and industry, and mixed and hybrid research careers - all of which depart from the traditional model of linear careers deployed in a single sector or organization. Better knowledge regarding these careers would contribute to improved understanding of the links between the formation, organisation, and deployment of scientific human capital and its impact in terms of research, innovation and technology transfer outcomes. An additional and important emerging question that has been identified is whether science governance processes, including research evaluation systems and assessment processes, change the content of research (Gläser and Laudel 2016). Transposing this question to research careers, we might similarly want to ask whether the conditions and processes that are shaping contemporary research careers change research content. Hopefully, emerging opportunities to link and re-use datasets via platforms such as the RISIS will enable researchers to provide both better answers to old questions about research careers and initial responses to new ones.

Conflict of Interest: The authors declare that they have no conflict of interest.

Glossary

CDH: Careers of Doctorate Holders (OECD Project)

EC: European Commission

ERA: European Research Area

ESF: European Science Foundation

EUPRO: Database on European Framework Programs

ETER: The European Tertiary Education Register

HRST: Human Resources in Science and Technology

LERU: League of European Research Universities

MNE: Multinational Enterprise

MS: Member State (of the European Union)

NSF: National Science Foundation (USA)

POCARIM: Mapping the Population, Careers, Mobilities and Impacts of Advanced Degree Graduates in the Social Sciences and Humanities (European Project, 7th Framework Program).

RCCF: Research Career Conceptual Framework

RISIS: Research Infrastructure for Research and Innovation Policy Studies

RPO: Research Performing Organization

SSH: Social Sciences and Humanities

STHC: Scientific and Technological Human Capital

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