10 What knowledge does the bioeconomy build upon?

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10.1 Introduction

Modern economies have long been characterised as 'knowledge-based economies' (e.g. David & Foray, 2002), whereby more advanced economies are distinguished by their ability to generate, disseminate and use new scientific and technological knowledge. Going forward, however, the ability of all our economies to successfully address society's daunting grand-challenges is recognised as something which is not solely about how to increase innovation in firms, universities and research institutes; it is increasingly seen as being related to improving the efficiency of innovation systems when leveraging existing investments from different parts of the economy (Bessant & Venables, 2010).

This chapter focuses on the underlying 'knowledge base' in the formative bioeconomy which extends across the established boundaries of different sectors and encompasses a range of scientific and engineering disciplines. It involves learning that takes place within organisations, but it also involves learning processes at a higher level of aggregation, including those that take place across different fields of science (agricultural science, engineering, biomedicine) and across different sectors of the economy (primary sectors, manufacturing, energy and research sectors). Although, we know something about the research agenda in the bioeconomy, less is known about the 'knowledge bases' that the bioeconomy builds on and, not least, how they are organised.

The contribution of this chapter is to provide an empirical look at how the knowledge production process is organised in the formative bioeconomy and, moreover, at which knowledge bases are involved in this important area. We have chosen two levels of empirical analysis which address the following related questions:

a *How are the links and interactions (e.g. of researchers) organised in the knowledge-base?* This question explores what we refer to as the 'organisational capital' dimension of the knowledge creation process. Organisational capital refers here to the way in which scientific and technological production are organised across organisations such as universities, research laboratories and private enterprises. Examples from the literature include the important roles that venture capital or collaborative centres housed at universities play in certain contexts. We focus on a comprehensive set of research and innovation projects financed by a central funding instrument of the bio-based economy in Norway, namely the Bionær programme organised by the Research Council of Norway (see also below).

b *What disciplines and capabilities make up the knowledge-base?* This question addresses the 'human capital' dimension of bioeconomic research more directly, in terms of the knowledge that researchers and others have accumulated in their educations and their professional careers. At this second level we utilise the CVs of researchers who are participating in Bionær projects. Following earlier work in other contexts, we use CVs by analysing the fields and disciplines that the researchers represent as well as other aspects of their current positions and their educational backgrounds.

The underlying argument of our approach is that publicly funded research and innovation programmes are important instruments, especially for a formative meta-sector such as the bioeconomy. Public policy interventions expressly seek to promote the creation, dissemination and accumulation of new knowledge in this context. One result is that the projects they support bring together one of the leading edges of the research community. We proceed on the assumption that by using the comprehensive information from this central funding instrument, we can learn more about the types of knowledge that are involved and how they interrelate. This is seen as an important endeavour since there appears to be a lack of consensus around what types of research areas the bioeconomy is based on (see Chapter 2 and Bugge, Hansen & Klitkou, 2016) and since it could help direct future public policies.

The chapter is organised as follows: the next section discusses the role of knowledge starting from the evolutionary economics and extending to the science and technology studies (STS) literature which informs our empirical approach. We go on to present our approach, introducing some generic aspects about CVs as an analytical lens. This lays the basis for our presentation of what this approach tells us about the knowledge base and how it is organised. We will then conclude with suggestions for future research, emphasising CVs as a promising data source that should be explored further.

10.2 Background

The creation, diffusion and use of knowledge are of course fundamental in advanced economies. Their importance has long been recognised, particularly in the heterodox literature by authors such as Freeman (1995), Nelson (1993) and Lundvall (1992). Improving the frameworks that promote knowledge processes has been a central focus of a range of literature such as systems literature as well as affiliated approaches such as the Triple Helix (e.g. Etzkowitz & Leydesdorff, 1995). Below, we focus on Sectoral Systems of Innovation (Malerba, 2004) as the most relevant approach with which to frame our study of the formative bioeconomy.

In this light, the circular bioeconomy can be considered a meta-discourse that engages a range of interests in academic spheres and political spheres (Pülzl, Kleinschmit & Arts, 2014). The growing academic work on the bioeconomy is echoed by policy discourse around the world that has repeatedly underlined the necessity of building knowledge for the future bioeconomy (Staffas, Gustavsson & McCormick, 2013). For instance, the European Commission's strategy for the bioeconomy (2012) calls for investments in research, innovation and skills as central policy interventions. In the US, the National Bioeconomy Blueprint has outlined support of research and development (R&D) investments, as well as updating training programmes to secure the right competences needed in the bioeconomic workforce (The White House, 2012), while in Norway, the government's bioeconomy strategy emphasises that knowledge building and investments in research and innovation are important aspects of developing a modern bioeconomy (Departementene, 2016).

10.2.1 Knowledge and the bioeconomy

In the formative 'bioeconomy', it is particularly worth emphasising the importance of knowledge and learning and the role that public policy can play to promote it. Our empirical look at how knowledge production is organised and what knowledge bases are involved in the bioeconomy starts from a longstanding evolutionary tradition in economics. The case for the importance of knowledge to innovation, industrial change and, in turn, the changing sectoral composition of the economy has been consistently and convincingly made in the evolutionary economics literature that grew out of Nelson and Winter (1982).

Innovation systems are understood to emerge from the complex interaction between a broad range of actors that create and share knowledge, involving both the creation of new knowledge and/or the combination of elements of knowledge in new ways (Lundvall, 1992). In general, systems of innovation are seen as being 'constituted by elements and relationships that interact in the production, diffusion and use of new and economically useful knowledge' (Lundvall, 2017, p. 86). Edquist (2005) argues that the systems of innovation approach focuses on three kinds of knowledge/learning: (1) Research and development, which is conducted by universities, research institutes and companies; (2) Competence building – creates human capital through various forms of training and education; (3) Innovation – the knowledge-related asset controlled by companies.

Studies of biotechnology and information technology have shown that relationships between companies and actors such as universities and research centres can be a source of innovation and change (Nelson, 1993). The variety of connections among actors influences the dynamics in the innovation system. New knowledge can result in novel links with other innovation systems, stimulate the entry of new actors and institutions and alter the system boundaries (Malerba & Adams, 2015). The heterogeneous area of nanotechnology is another example where new knowledge and techniques help to promote innovation in a range of existing industrial contexts. Knowledge transfer across cross-sectorial connections can lead to transformation processes in sectoral systems (Malerba, 2005). This suggests a cross-sectoral perspective which we argue is particularly germane to the so-called bioeconomy. We therefore invoke the Sectoral Systems of Innovation (SSI) perspective, which serves to 'focus on systemic features in relation to knowledge and boundaries, heterogeneity of actors and networks, institutions and transformation' (Malerba, 2005, p. 398).

The systems approach is useful for designing policies which support the stimulation of a sector. The development of a meta-sector like the bioeconomy is guided by knowledge-based processes which help to direct 'the patterns of firms' learning, competencies, behaviours, and organisation of innovative and production activities in the sector' (Malerba, 2004, p. 23). Governments play a key role in the absence of existing markets. They are seen as critical in promoting learning and innovation by promoting research and innovation across the boundaries of economic sectors of universities and other higher education institutions (HEIs), public research organisations (PROs) and the full range of relevant private and non-private entities. These can help existing knowledge systems to reorganise themselves in ways that can promote the creation and sharing of new knowledge within the sector. In addition, this type of dynamic may beget new sectoral institutions and organisations (such as research centres or new educational fields), creating more knowledge variety, which again can influence the evolution of a sector (Nelson & Rosenberg, 1993).

A current focus of the innovation studies landscape is on improving the coordination of existing and emerging knowledge of different types in order to address what are known as 'societal challenges', i.e. challenges that primarily involve social payoffs rather than individual payoffs and which involve systemic change in which public policy is expected to play a more central and coordinative role. The literature has more recently recognised the new role that knowledge can play in addressing the societal challenges of the 21st century (Bessant & Venables, 2010) as well as the roles that public policy can play in this process.

What individual actors know and how they learn is thus a key component of any innovation-oriented system. This includes both new and existing types of knowledge, processes of creation as well as coordination, and theoretical as well as more practical types of knowledge. Components of knowledge are one dimension of this picture, in terms of what economic actors know. In addition, the way that the knowledge processes are organised across existing knowledge bases and learning contexts also helps to define the direction of innovation. The knowledge that researchers and other agents have (human capital) at any given point is integral to the emergence of innovative new fields, and the way the knowledge is organised (organisational capital) is instrumental in shaping the trajectory that innovation takes in contexts such as the bioeconomy.

10.3 Approach

We consider the bioeconomy to be a formative meta-sector as it cuts across several sectors and industries. Furthermore, as Chapter 2 points out, the notion of the bioeconomy is multifaceted and includes three visions. For some, the bioeconomy is about biotechnology and the promises of breakthroughs in this area (the bio-technology vision). Some see it as being about sustainability and ecological processes that, for example, will support biodiversity and prevent monocultures and soil degradation (bio-ecology vision). For others, the bioeconomy is about advances in resource-based sciences more generally and how different fields can be coordinated through new research to improve how organic resources are used (the bio-resource vision).

The bio-resource vision raises a number of questions for us, including (i) whether the underlying knowledge is firmly based on a specific field of science or whether it draws on a wider range of knowledge from different areas, and (ii) whether development is linked to specific lead entities such as universities or whether knowledge creation is more distributed. We argue that it is important to get a clearer idea of the disciplines, sources and the organisation of new knowledge in the bio-based economy. A better understanding of what knowledge the bioeconomy builds upon can be useful in several ways: it can help to clarify the boundaries of this economy; it can help consolidate the population of entities that see their own missions in terms of the bioeconomy; it can help identify knowledge strengths and gaps; and it can help inform future public policy interventions, etc.

This chapter undertakes a systematic empirical analysis of the sources and organisation of knowledge production in the bioeconomy. It has a specific focus; namely publicly financed projects in the area of research and innovation activity for food and bio-based industries. Norway is among the OECD countries that have earmarked public funding to promote research and innovation of the bioeconomy. The argument is that publicly funded research and innovation programmes are important instruments to promote the creation, dissemination and accumulation of new knowledge in the area of societal grand challenges (see e.g. Mowery, Nelson & Martin, 2010).

We use information from one of Norway's key programmes in this area, the Bionær Programme, to learn more about the knowledge system of the bioeconomy. As mentioned in the introduction, we will explore two dimensions of knowledge creation and accumulation. The first involves what sorts of actors are involved and how their work is organised. This level, which we refer to as the 'organisational capital' dimension of the knowledge creation process, is recognised as being important in formative fields (see Bozeman and others in the discussion of different U-I partnerships to promote specific research agendas). We are particularly interested in the profile of entities that are involved in research and innovation activities on this front, in terms of the spread between sectors (HEI, PROs and the private sector) and the international dimension. The second level explores 'the human capital' dimension of the bioeconomy by delving into the CVs of participating researchers to understand the educational backgrounds and the positions that are involved in this research and innovative activity: is it from one scientific area or several?; is it domestic or foreign?, etc.

10.3.1 CVs as an analytic lens

Although the use of CV data is not new, it constitutes an innovative (and labour-intensive) approach which deserves special comment. CVs are rich data sources of longitudinal information about a person's career (Bozeman, Dietz & Gaughan, 2001). Researchers include in their CVs information about their educational backgrounds, their current positions and their publications. Gläser (2001, p. 698) argues that research careers are 'theoretically and practically important because they link individuals with institutions as well as social structures with knowledge production'. CVs of researchers include information about who they have collaborated with (identified as either co-authors or research collectives). Consequently, it is possible to use CVs to map researchers' networks in addition to their scholarly disciplines, affiliations and various work experience.

The use of CVs in research has become more and more prevalent since the 1990s, although its growth is still hampered by the availability of CVs and, moreover, the lack of tools to automate their analysis (Geuna et al., 2015). Cañibano and Bozeman (2009) point out that the use of this unique data source is primarily found in the research evaluation sphere where its use has shifted over time from a focus on output (in terms of publication) based on specific inputs (e.g. to evaluate the success of education and research policies) to include a greater focus on capacities (i.e. the ability to develop relevant competences). They indicate that CV-studies have generally focused on one of three topics: career trajectories, mobility and mapping of collective capacity (Cañibano & Bozeman, 2009).

In the literature, notable themes include mobility and research performance (Cañibano, Otamendi & Andújar, 2008), commercial activity (e.g. Dietz & Bozeman, 2005; Lin & Bozeman, 2006), collaboration and productivity (Lee & Bozeman, 2005) and career transitions (e.g. Mangematin, 2000). A relevant approach is suggested by Lepori and Probst (2009), who used CVs to understand the structure and dynamics of a scientific field which is characterised by conceptual, theoretical and methodological pluralism. They argue that CVs offer an easier and quicker way to look at such a community than a survey could, for example. A more recent study of entrepreneurship scholars which aimed to understand the field's knowledge base also used CVs as a data source (Landström, Harirchi & Åström, 2012). We follow the mapping focus to explore the human capital dimension in terms of how researcher capacity and competences are arrayed in the formative 'bioeconomy'.

10.3.2 Data

We utilise data provided by the Bionær (Sustainable Innovation in Food and Bio-based Industries) programme to study the organisational and human capital dimensions of the bioeconomy. The Bionær programme coordinates funding allocations from a range of ministries into research and innovation activity for food and bio-based industries. The programme aims to trigger research and innovation for enhanced value creation in Norwegian bio-based industries. The objective is to increase knowledge and expertise in order to promote sustainable industries and foster policy development and innovation in bio-based companies and bio-resource management. The requirements for being accepted into the programme are interdisciplinarity and international research collaboration, as well as having a market-oriented focus, and incorporating the concepts of sustainability and circularity (RCN, 2013). The outcome should be both strategic basic research and industry-oriented research.

The Bionær project portfolio provides a unique – if imperfect – empirical approach to research and innovation in the bioeconomy. Several strengths that recommend this programme as a lens are:

a Topicality: it focuses on research and innovation activities in the bio-based industries in general. This definition is sufficiently topical; it focuses on an array of bio-based projects including a category of projects that explicitly focus on the 'bioeconomy'.
b Duration: it has existed for over a decade.
c Extent: the funding frame is substantial, with 100 million NOK in 2018 earmarking 'bioeconomy' projects alone (in conjunction with other programmes). The projects therefore tend to be long-term and involve larger numbers of partners.
d Quality: the quality of the projects in terms of research and innovative degree is approved by a panel of international experts.

There are certain characteristics of the Bionær programme that are relevant to mention:

a The programme does not account for all innovation and research activity in the area. It does not include activities that are carried out internally in companies or in universities that are not funded by the programme. For example, universities and firms may fund their own R&D work, which does not benefit from this programme (see also Chapter 11). It is also worth mentioning that there are other complementing funding programmes. As an example, RCN coordinates the BIA-programme and SkatteFUNN, which are more generic research and innovation instruments directed towards industry actors. To deepen our understanding of the competences involved in the bioeconomy, some of these programmes were considered for inclusion in the dataset of this study, but RCN encountered challenges in extracting the relevant projects from their database (due to issues of categorisation). In addition, projects involving mainly marine bioeconomy are largely organised in separate programmes.

b Although it focuses on research and innovation activity for food and bio-based industries, some individual projects may not be seen as directly relevant to the bioeconomy, depending on one's definition.

c Disclaimer: this chapter grows out of a project that is itself receiving significant funding from Bionær.

10.3.2.1 Project data

The Bionær programme funded 333 projects in the period 2005–2016. In this period the programme focused on agricultural, forest and bio-based value chains, and also included most of the seafood value chain. We obtained project and CV information from the programme itself. In this chapter, we focus on the 136 research and competence-oriented projects that were still active in 2016. The 136 targeted projects involved between one and 20 team members (lead, collaborator, associate) each and had an average team size of 5.3 members. They lasted an average of 3.7 years and involved a total funding amount of an average of 9.2 million NOK.

The projects which were active in the period 2007–2016 can be broken down into two main types. The first type is *Research Projects* (60 or 44% of the total), and as the name suggests, these tended to be explorative projects driven by research enquiry. The second type of projects tended to involve industrial partners more directly. This category includes so-called *Innovation Projects* (66 or 49%) as well as other collaborative projects with a focus on competencies and the needs of the industry (the remaining 7%).

10.3.2.2 Researcher data

A total of 611 individual participants from a total of 498 entities were identified as being directly involved in one or more of the projects. The entities represented the higher education institution (HEI) sector, the public research organisations (PRO) sector, the private enterprise sector and the government sector. From the CVs, we extracted information about what type of positions the project participants held, their field of expertise and their education levels and profiles. We also included other characteristics to inform specific questions: for example, educational degrees and experience from foreign institutions are potentially useful when investigating sources of knowledge spill-over.

In this study, access to CV information at the researcher level is constrained by two main considerations. The first is a formal constraint. A number of researchers were no longer engaged at the partner organisations at the time of our study (2017–2018) and were therefore not given the chance to opt out of the study. This led to the exclusion of 27 CVs. The second constraint is more formalistic. Not all variables (e.g. year of birth, field of science, degrees) were included in all the individual CVs. This made processing of the information difficult despite the reliance on manual processing. This constraint led to further exclusion of other CVs.

Table 10.1 indicates that roughly 570 CVs provided at least patchy information for the variables we were interested in, such as education levels, field of science (fos), age, year of graduation, etc. Most of the work involves around 430 researchers for whom we had sufficiently extensive information (either good or complete).

10.4 Empirical findings

In the following we will present our findings concerning organisational and human capital in the emergent bioeconomy. This empirical section starts by focusing on publicly funded projects in Norway. A point of departure is the literature which debates how fruitful mission-based funding can be in addressing societal grand challenges (see above). We focus therefore specifically on projects designed to promote research and innovation under the Bionær programme.

Table 10.1 The number of individual CVs available based on the earliest project participation of the researcher

Earliest project start	*Quality of processed CV*					
	Complete	*Good*	*Patchy*	*Poor*	*Insufficient information*	*Total*
2007	2	1	0	0	0	3
2010	10	2	2	2	1	17
2011	44	5	19	7	5	80
2012	11	1	3	0	0	15
2013	65	22	18	6	1	112
2014	84	13	39	12	2	150
2015	75	12	30	4	0	121
2016	74	10	25	2	2	113
Total	365	66	136	33	11	611

Source: Bionær Programme: for active projects in the period 2007–2016.

10.4.1 Organisations and organisational capital

The 136 projects involved a range of organisations, from private companies and universities, to research organisations and a range of public and quasi-public organisations such as interest organisations. A total of 498 entities from around the world contributed to the projects. The nature of the Bionær programme promotes collaborations with Norwegian actors in general: a number of the programme areas particularly promote collaborations with private entities. The breakdown of project participation reflects this (see Figure 10.1). The majority (364 or 73%) were based in Norway, with a further 21% (105) from the rest of Europe; primarily the other Nordic countries (36 or 7%). The remaining 6% (29 or 5.8%) came from the US or other countries. This suggests that knowledge in the bioeconomy is indeed global but that it is organised and anchored nationally or regionally.

10.4.1.1 Norwegian partner entities

Roughly 360 of the entities that participated in the Bionær programme during the period of study were based in Norway. The following Figure 10.2 groups the activities of these Norwegian entities into aggregates of primary NACE rev2 classification. Following from the figure above, the bar-diagram can be divided into two broad sectors. The private sector, which accounts for slightly more than half of the entities, is arrayed on the lower part of the

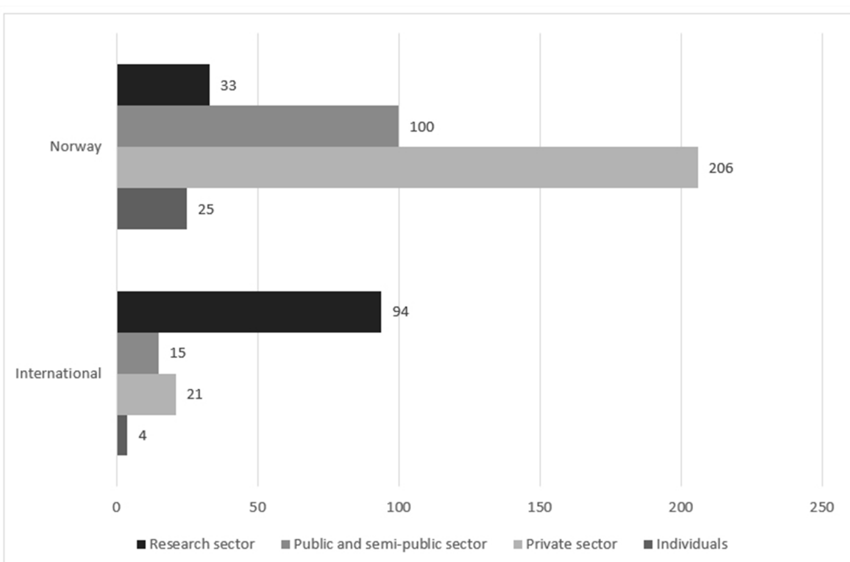

Figure 10.1 Types of organisations by region: gross breakdown ($n = 498$): projects active in the period 2010–2016.

Source: Compiled by NIFU based on raw data from the Bionær programme, 2017.

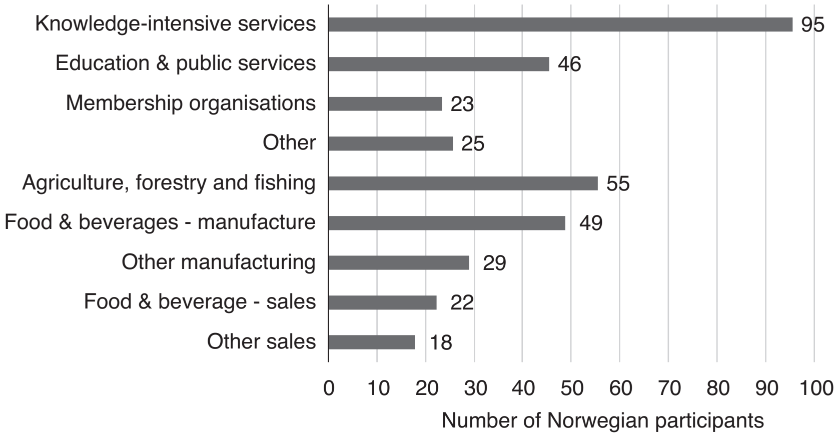

Figure 10.2 Norwegian participants by NACE activity (*n* = 362), 2007–2016.
Source: Compiled by NIFU based on information from RCN's Bionær programme.

figure. Primary industries (agriculture, forestry and fisheries) feature prominently here, followed by the manufacture and sale of goods (food, beverages, lumber, etc.) from these industries. In addition, there is a smaller share of companies involved in the manufacturing and sale of other products.

The upper part of the diagram consists primarily of the non-private sector entities, including higher education institutions, public research organisations (the 'knowledge-intensive services'), as well as an array of government and quasi-governmental organisations ranging from municipal authorities to interest organisations for involved industries. In reality, the division is not so stark between the sectors: a number of entities involved in knowledge-intensive services are in fact private while a number of entities in the primary sector are not purely private (they include publicly owned/controlled companies).

Public research programmes provide a vehicle for bringing together different types of expertise and knowledge to explore/exploit the research and innovation possibilities that are emerging in this field. The bioeconomy is not only about 'biotech' firms. An important point is that the bioeconomy involves an interrelationship between different types of organisations in different sectors. We emphasise here that the bioeconomy builds on competencies which are located across a range of entities from the HEI, the PRO, the governmental area and the private sector.

Chapter 11 looks in more detail at a broader register of Norwegian entities that are involved in research and innovative activities in the 'bioeconomy' in the country. The 360 entities included in this study are central to that register.

10.5 Human capital and researchers

We turn now to the question of the type of fields science researchers in the bioeconomy represent. As discussed above, the CVs provide detailed information about the disciplines the researchers represent, their affiliation (university, research institute, private sector) and their seniority (professors, post-docs, PhD students). This offers us a vantage point on the human capital that goes into RD&I projects and so allows us to better understand the knowledge bases that the bioeconomy builds upon. This section will review the sectors of the economy, the fields of science and the types of research bioeconomy research stems from.

10.5.1 Researchers

The 611 researchers who participated in funded Bionær projects in the period were predominantly affiliated with research organisations. Almost 80% stemmed from public research institutes (295) and from universities (188). The following Table 10.2 provides an overview of the general characteristics of the project participants by sector of employment. Two thirds of project participants were male, although the share is higher in the HEI sector (77%) and lower for PROs (61%).

Three quarters of the population held degrees from Norwegian universities. Of the 420 researchers for whom we have valid data, over 80% had PhDs. One hundred researchers (of the 420) held degrees from abroad, where the majority of degrees were from Sweden (19%), Denmark (14%), the UK (12%), the USA (12%), Germany (9%) and Finland (6%).

The average year of birth was 1964, which means that the average age of the researchers was 54 years. However, the average age of the whole bioeconomic research population as a whole is likely to be lower. One aspect that will affect the CVs represented in the applications is the strategic or tactical choices made during the application phase. Although the Bionær programme plan states that the participation of young researchers is valued, it is not unlikely that more experienced researchers will be considered a positive asset for funding probability. As a result, there might be a biased representation of the experience level among the persons in the application teams (limitations are discussed further in the concluding section).

The breakdown does, however, reveal some interesting aspects of ongoing research, development and innovation (RD&I) activities that focus on the bioeconomy. It indicates that this economy involves a broad range of sectors. Research institutes and universities lead the effort, but they work together and with private enterprises as well as with the government sector. In addition, over 25% of the 500 organisations that were involved are located abroad. The share of PhD holders was higher than usual for the sector. In part this reflects the point made above. What is perhaps more interesting is that a large proportion of those PhD holders took their

Table 10.2 General breakdown of researchers by sector of employment, gender, mean age and academic degree

Sector	*Number*	*Percent of valid data* (n = *421)*			*Mean (year)*		
	Total (valid)	*Male*	*Norwegian degree*	*PhD*	*Degree*	*Birth*	*Position*
HEI	188 (118)	77	57	92	1997	1964	2006
PRO	295 (241)	61	84	87	2000	1966	2007
Private	69 (44)	71	82	43	1996	1965	2006
Government and other	15 (7)	67	70	45	1992	1962	2008
N/A	44 (7)	56	57	71	2003	1968	2013
Total	***611 (421)***	***67***	***76***	***83***	***1999***	***1965***	***2007***

Source: compiled by NIFU based on information from RCN's Bionær programme.

doctorate degrees in another country, indicating a level of spill-over from other innovation systems.

10.5.2 Field of science

Formal education provides an important indication of where knowledge of the formative field comes from. We used the CV information to categorise the fields of science in which the project participant held his/her highest degree. The fields of science were translated and manually categorised into a standardised (ISCED) schema which distinguishes between a number of main fields, namely agricultural sciences, engineering sciences, health sciences, physical and life sciences, social sciences and other categories such as humanities or applied service fields (e.g. accountancy).

The following Table 10.3 indicates that the broad area of agricultural sciences was the most represented field. Of the 384 individuals for whom we have data, the greatest number hailed from the broadly aggregated fields of agricultural sciences (123), followed by the social sciences (79), physical and life sciences (63), and engineering, manufacturing and construction (61). Most of the researchers with foreign doctorates were in the fields of agriculture (including forestry and fisheries), physical and life sciences, and social sciences, business or law.

Table 10.3 Researcher field (and subfield), n = 384

Fields	*Subfields*	*Number of researchers*
Agriculture	Agriculture, forestry and fishery	109
	Veterinary	14
Engineering, manufacturing and construction	Engineering and engineering trades	47
	Manufacturing and processing	10
	Engineering, manufacturing and construction	4
Health and welfare	Health	21
Humanities and arts	Humanities and arts	16
Physical and life sciences	Life sciences	50
	Engineering and engineering trades	1
	Physical sciences	6
	Computing	3
	Mathematics and statistics	3
Services	Services	21
Social sciences, business and law	Business and administration	43
	Social and behavioural science	22
	Law	14
Grand total	Total	384

The table confirms that RD&I work in the bioeconomy is not isolated to a single field of science. It shows that the bioeconomy is based on an array of fields, ranging from the agricultural sciences and the life sciences, engineering and the physical sciences, to a variety of social sciences and professional studies. To further get a sense of the contributing knowledge, the table disaggregates these broad fields into more specific subfields. For example, veterinary sciences can be distinguished from other parts of the broader field of agriculture, while life sciences can be separated from physical sciences. This helps us to appreciate the relative importance of life sciences, engineering and business administration in particular.

10.5.3 Sectors and seniority

As indicated above, many of the project participants are currently affiliated with the PRO sector, principally SINTEF, NOFIMA and the former Norwegian Forest and Landscape Institute, now merged with Bioforsk and the Norwegian Agricultural Economics Research Institute into the Norwegian Institute of Bioeconomy Research. The importance of this sector extends through many of the fields and subfields. The HEI sector accounts for the second largest group, largely from the Norwegian University of Life Sciences, the Norwegian University of Science and Technology (NTNU) and the University of Oslo. We note that a number of the major institutes were merged or otherwise reorganised during the reference period, and some research institutes became part of the HEI. In addition, we see that bioeconomy research is not led solely by universities or even the HEI and the PRO sector; the private and government sectors are also very much involved.

The final table (10.4) illustrates how project participants are distributed at different levels of seniority. The first category of researchers (R1 and R2, according to the EU schema) consists of PhD students and post-docs, and general researchers, while R3 consists of associate professors and researchers. Lead researchers include professors and research professors, while administrative leaders include heads of departments and other directors. In addition, a range of other positions such as R&D coordinator or operating managers were placed in the non-classified category.

Table 10.4 Researchers by sector of affiliation and level of seniority

	R1–R2 researchers	*R3 established researcher*	*R4 lead researcher*	*Administrative leader*	*Not classified*	*Grand total*
HEI	29	56	126	8	2	221
PRO	105	83	14	31	21	254
Private				20	48	68
Government and other		2	1	2	10	15
Total count	134	141	141	61	81	558

The categorisation system is not perfect. For instance, the HEI and the PRO sectors employ different rankings which, in the latter case, may depend on the given institute. In addition, the rankings are skewed towards the more advanced due to how CVs are included in project proposals. The table does, however, provide a good indication of which parts of the organisations are involved in this activity. Again, we see a balance between the most senior positions (200 professors, lead researchers and administrative leaders) and the younger researchers (275 from the low- and middle-rank positions). In the PRO sector especially, we also find a range of ancillary positions in the unclassified category that do not correspond to generic positions but are more involved in the running of projects, etc.

10.6 Concluding discussion

The chapter provided an empirical look at how knowledge production is organised in the bioeconomy and which knowledge bases are involved. Its purpose has been to improve our understanding of the 'knowledge base' which will hopefully comprise the knowledge necessary to identify and exploit new and sustainable value propositions in organic waste streams. We noted a general need to solidify what is known about this dimension of the formative meta-sector. One dimension involves public policy, which, as we observed, is dedicated to increasing the allocation of resources to this area. In this light, it is useful for public policymakers to know what fields of science are involved in innovation and how they are organised, as this will help to appreciate the strengths and challenges present in this changing context.

To do so, the chapter has drawn on literature about the role of knowledge in emerging areas. Our starting point was the tradition of sectoral systems of innovation. The relevant literature pioneered analysis of the role of knowledge in order to understand the integral role of innovation in industrial change and, in turn, in the changing sectoral composition of the economy. A second strand of literature that we followed in our empirical strategy is from the STI literature. Here we have used the work of Bozeman and colleagues, who integrated the concepts of human capital and organisational capital into the STI tradition and, in doing so, have pioneered the use of CVs as data in their studies.

This strand of the literature has especially inspired our empirical work. Not least, this is due to its focus on human capital and the way that it is organised, and to the fact that this approach has previously explored the role of scientific and technological knowledge in emerging meta-sectors such as biotech (Corolleur, Carrere & Mangematin, 2004) and nanotech (e.g. Bozeman, Larédo & Mangematin, 2007). These are themes that lend themselves well to our study on the emerging bioeconomy.

The chapter has furthermore followed their pioneering work by using CVs to study human capital and how it is organised. Taking our cue from this literature, we differentiated between two dimensions of knowledge creation and accumulation in the bioeconomy:

1 *How are the links and interactions (e.g. of researchers) organised in the knowledge base?*
The basic dimension, which we have dubbed 'organisational capital', looked at how the collective knowledge is being brought together to create new forms of scientific and technological knowledge in the bioeconomy. Here we focused on the role of project data from a large-scale research and innovation programme in Norway to study the links between different agents in different sectors. Several interesting observations emerged from this exercise.

    a The 500 entities that contributed to the 136 projects were used to study the distribution of what sorts of agents are involved in Norwegian RD&I projects in the bioeconomy. The chapter indicates that around three quarters are domestic, while a further 20% are from other Nordic countries or elsewhere in Europe. This suggests that knowledge in the bioeconomy is indeed global but that it is organised and anchored nationally or regionally.
    b We also found that the projects were based on collaborations between different sectors of the economy: the PRO sector, the HEI sector, the private enterprise sector and the government sector. Although the inclusion of different sectors may in part be shaped by the Bionær programme requirements, the material illustrates that there is an active division of labour between the different sectors.
    c The chapter focused on the Norwegian participating entities. It showed that, next to the HEI and PRO sectors, the private sector involvement largely featured the primary industries (agriculture, forestry and fisheries) and the manufacture and sale of goods (food, beverages, lumber, etc.) from these industries.

2 *What knowledge and capabilities make up the knowledge base?*
We then took stock of the 'human capital' that is embodied in the individual contributor to the researcher project (the 'researcher'). Here the CVs of project participants were used to gauge inputs to RD&I projects, in terms of the knowledge that researchers and others had accumulated through their education and their professional careers. This labour-intensive exercise revealed a number of aspects about the knowledge base that the bioeconomy is building upon. The chapter indicated:

    a that the different sectors contribute with different types of knowledge to the bioeconomy RD&I;
    b that participants in the Bionær programme tend to be male, although the balance differs between sectors;

c that their highest degree tends to be from a Norwegian institution, although the share of foreign PhDs is markedly higher in the HEI sector;
d that they tend to hold PhDs, where the degrees of PRO researchers tended to be slightly more recent than those of participants from the HEI sector.

Coordinated, integrated R&D efforts are important to the Norwegian bioeconomy agenda. The projects integrate a range of knowledge across different science fields. It is worth recapping the role that different fields of science play in the bioeconomy, as this is an important contribution of the chapter. We find among the CVs for which we have good data that the highest share represents the agricultural sciences, broadly construed. This is a confirmation of what one might expect in the bioeconomy field. It is interesting that a range of other fields complement this core area. Prominent among these is the field of life sciences (combined with medicine and health). A second major component is the participation from engineering and the physical sciences, while a third, made up of social sciences, humanities and professional degrees (business administration, law), is also important in these cross-sectoral collaborations. We argue that this broad involvement of various disciplines and capabilities is especially important in the development of a circular and sustainable bio-based economy. If the evolving bioeconomy is to contribute towards solving some of the 21st century's complex societal challenges, its knowledge base must be inter- and transdisciplinary.

10.6.1 Limitations

Before we discuss the possibilities for future work, some of the limitations associated with using this data should be mentioned. The chapter has previously stated a number of recognised problems associated with utilising CVs. In addition, we review the more specific limitations our work encountered:

1 The Bionær programme is a major public policy intervention to promote RD&I in the bioeconomy in Norway. However, it clearly does not represent the full scope of all work being done here. First, we excluded information from unsuccessful applications. Second, the selection was skewed more towards the HEI and the PRO sectors and offers comparatively little insight into what is happening in private enterprises (see Chapter 11 for more information on the contribution of the private sector).
2 The data covers a period of time during which researchers may develop in ways that are important to the analysis. We focused on the first project a researcher participated in and may have excluded updated information (e.g. PhD year). In addition, a number of entities changed sectors during the period (from research institute to a university).

3 Not all project participants were included in the granted applications. We noted that project CVs tended to include those contributors with the longest track-records and favoured PhD holders over non-PhD holders, due to requirements of the funding agency. The teams were also subject to change, especially in the longer projects. Researchers changed jobs or retired, which left the actual composition of the team quite different to its composition at the time of application. A small number of CVs were also not available in our analysis due to formal reasons.
4 CVs are notoriously labour intensive to work with, although techniques are improving. There are recognised challenges associated with non-standardised formats of the documents themselves (Cañibano & Bozeman, 2009; Dietz, Chompalov, Bozeman, Lane & Park, 2000). In addition, there are several types of translation involved that may lead to non-standardised categorisations. For example, career descriptions vary according to institution, country and disciplinary context. The type of unification problem this creates can make the integration of sectors, seniority and fields of science a challenge.

10.6.2 Future paths of research

This study builds on a composite set of linked data, involving basic project data, information about participant entities and the CVs of individual researchers. This approach has proved to be time-consuming and has involved formal hurdles as well as the practical challenges of compiling the datasets, especially the CV data. However, data-extraction tools are continuously improving (see Geuna et al., 2015). This is taking analysis in a direction where the challenges of extracting and coding data from CVs will be reduced. This can help to make CV studies an important source of information that can help shape the national bioeconomy agenda going forward.

In this context, our chapter represents an explorative starting point which can open the way for other studies. We see several avenues available to explore. The first broad avenue is to more fully exploit the information from the combined dataset. A unique aspect of the dataset that we developed here is that it combines information about the project participant ('researcher'), information about the affiliated enterprise or institute and information about the collaborative project. This combination affords a number of potential vistas for exploration, including studies of the subsequent direction of collaboration and careers of involved researchers, or of the publication or patenting profiles of their affiliated organisations. There is further scope to explore how research is organised in a formative meta-sector like the bioeconomy. This line of study can help indicate potential links between research sectors and the private enterprise sector and other stakeholders. This would then have implications, for example, in terms of identifying which configurations work well in which contexts.

A second broad avenue involves using more specific information from the CVs. So far, we have primarily looked at current affiliation and latest degree, but CVs contain considerably more information about the careers of the researcher, their publication records and other projects that the researcher has been involved in. This information can be used, in general, to follow up existing studies that have used CVs to focus on scientific careers and on research evaluation (see Cañibano et al., 2018 for discussion). There are multiple possibilities for pursuing existing or emerging lines of enquiry. One important topic involves sectoral mobility. Here there is a need to better understand how researchers contribute to the integration of intersectoral research, especially those that link the private enterprise sector to the research sectors and other stakeholders. Another important topic involves career trajectories, especially those of recent PhDs. One current question is what happens to PhD holders after graduation and during their early careers. A more general question is whether and how they contribute to emerging RD&I agendas such as the bioeconomy. Finally, we note that CV-based studies can be used to map human capital and to understand future needs for the appropriate training of tomorrow's workforce. Such knowledge can support educational institutions and policy makers in their planning of educational programmes and of interventions to support industry development.

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