Chapter 2
Hidden in Plain Sight: The Impact of Generic Governance on the Emergence of Research Fields

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2.1 Introduction

The current political and scholarly interest in emerging research fields appears to focus on a select few fields. *National policies* for emerging fields are implemented only when a field is recognizable as emergent in a sufficient number of countries, promises solutions to societal problems, and is established in a country well enough to have growth potential. This role of critical mass appears to be inevitable because science policy needs to separate signal from noise, usually responds to lobbying by advocates of a field, and is more likely to promote something if this is promoted in other countries as well. The downside of this approach, from a policy perspective, is that the birth of fields cannot be promoted; mostly for the simple reason that it is not visible in the plethora of new attempts to define and solve problems.

Science studies apply a similar logic. This is inevitable whenever the impact of science policy on emerging fields is studied. Science studies are also nudged towards the study of politically relevant fields by the ever-increasing pressure towards more 'utility', or are even forced to study such fields if they are funded as 'add ons' to the large-scale promotion of science and technology, as has been or is the case with "Ethical, Legal and Social Aspects" of genetics and later genomics (e.g., Zwart and Nelis 2009) and nanotechnology (Hullmann 2008). The fields scrutinized by science studies are thus most likely to be those large enough to catch

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political attention (for synthetic biology see Meyer and Molyneux-Hodgson, Chap. 4, and Molyneux-Hodgson and Meyer 2009; for neural computing Guice 1999).

This co-construction of the empirical object 'emerging field' by science policy and policy-led science studies tends to exclude from scrutiny the earliest stages of emergence. It also tends to obscure the general background conditions for field emergence provided by national science systems because these conditions can be neutralized by political promotion: If a field is swamped by money, other conditions for its development become invisible because they can be circumvented. Thus, the study of these fields is in danger of neglecting generic governance structures and processes for the simple reason that these appear to be always already there. The latter include, among others, national career systems and academic labour markets, the proportion of recurrent and project-based funding, the governance of and within public research organisations, and ethical as well as legal regulations applying to specific types of research. These structures and processes, most of which are nationally or regionally specific, affect the emergence of fields from its earliest stages, and keep affecting emergent fields after they become the target of political promotion.

The aim of our paper is to contribute to the exploration of the local configuration of new research fields by answering the question how (in what ways and with what effects) generic governance structures and processes affect the earliest developmental stages of new fields, namely the emergence and early diffusion of new research practices. We use a comparative study of the diffusion of a new research practice – the experimental realisation of Bose-Einstein condensation in Germany and the Netherlands – for an exploration of how national systems of governance shape the opportunities for researchers to change their research practices and to begin new lines of research. The comparative approach enables a differential assessment of the role of national governance in the shaping of research fields, which can be distinguished from the role of epistemic and social factors common to all members of an international community.

We begin by embedding our approach in the literatures on emerging fields and proposing core concepts for a comparative empirical analysis (Sect. 2.2). Our presentation of empirical results starts with a brief description of relevant aspects of the two national governance systems (Sect. 2.3). We then trace the parallel diffusion histories in Germany and the Netherlands, and link them to differences in the generic governance in the two countries (Sect. 2.4). The concluding discussion identifies and reflects upon aspects of generic governance that shape national conditions for emerging fields (Sect. 2.5).

2.2 Comparing the Impact of National Governance on the Emergence of New Fields

Establishing the differential impact of (national) governance on the emergence of fields requires linking specific properties of governance to specific conditions for such an emergence. This has not yet been achieved because the relevant research trends had different foci. During the late 1960s and early 1970s, a first set of studies focused on the *emergence of "scientific specialities*", which were either traced to distinctive events, such as discoveries or original experiments, or gradual change of perspectives (see Edge and Mulkay 1976, and the case studies discussed there). Although the conditions of emergence of new specialities were systematically compared, the role of governance in producing them was not considered at all. From the late 1970s onwards, *laboratory and constructivist studies* focused on the content of knowledge production at the micro-level, which made the investigation of the emergence of fields an exception (see Latour and Woolgar 1986: 112–124 on the emergence of neuroendocrinology). A key process, the diffusion of new research practices, was studied (e.g., Fujimura 1988; Cambrosio and Keating 1995; Collins 2004). Yet these studies too neglected the ways in which governance shapes the conditions of the emergence of new research fields, a problem acknowledged by Knorr Cetina (1995: 160–163). The third and more recent research tradition investigates *conditions for exceptional research*, either by starting from new funding schemes aimed at promoting 'excellence' and asking how these schemes support exceptional research (Grant and Allen 1999; Lal et al. 2011; Wagner and Alexander 2013), or by starting from exceptional research ('creative achievements', 'breakthroughs') and asking about conditions for success (Heinze et al. 2009; Hollingsworth 2008). Findings so far include only very general relationships between governance and success. The systematic relationships between specific conditions created by governance and specific exceptional achievements remain to be specified.

Our own attempt to treat conditions for the emergence of fields as specific, comparable and shaped by governance focuses on changes of research practices and the protected space required to develop them (Sect. 2.2.1). These concepts informed our analysis of interview data and other materials (Sect. 2.2.2) as well as the organization of the comparative analysis of cases in the subsequent sections.

2.2.1 Linking the Emergence of Fields to Governance

In our empirical investigation we use a distinctive event, the experimental realization of Bose-Einstein condensation (BEC),[1] and the subsequent diffusion of this new research practice for a *comparative study of the impact of generic governance*.

A *BEC* is a specific state of matter. When a given number of particles approach each other sufficiently closely and move sufficiently slowly they will together convert to the lowest energy state. The occurrence of this phenomenon was theoretically predicted by Bose and Einstein in 1924, and thus became called *Bose-Einstein*

[1] In the physics community, BEC is used as an abbreviation for both Bose-Einstein condensation (the phenomenon) and Bose-Einstein condensates (the state of matter resulting from Bose-Einstein condensation). We follow this practice and attempt to avoid confusion by using an article or the plural form whenever the condensates are addressed.

condensation. In atomic gases, BEC occurs at temperatures very near to absolute zero (<100 Nanokelvin). The first of these BECs were produced in 1995 by researchers from the atomic and molecular optics (AMO)[2] physics community by combining several recently developed cooling techniques (Cornell and Wieman 2002; Ketterle 2002; Griffin 2004).

Although only very few researchers tried to replicate the original experiments, the attempts to achieve BEC remained sufficiently similar to consider them as one research practice. We understand research practices as *types of research actions, which are characterised by specific theoretical frameworks, objects, methods, and objectives*. The change of any of these elements leads to a new research practice and can lead to the emergence of a new field because fields are known to form around any of these elements of research (Whitley 1974).

Besides benefits, changing research practices also incurs costs and may be risky for the involved scientists because the changes may devaluate knowledge and equipment a researcher has accumulated and necessitates the acquisition of new knowledge and equipment, because a researcher's reputation may suffer if the change delays opportunities to publish results or deviates from the mainstream of the researcher's community. Governance – including both generic governance and policies targeting 'emerging fields' – affects the creation or diffusion of new research practices by providing opportunities for researchers to bear the risks and meet the costs of the envisaged changes. These opportunities can be analysed by comparing the 'protected spaces' researchers can build for their change of research practices. Building on Whitley (2014) while adapting his definition for the purposes of our empirical investigation we define protected space as the *autonomous planning horizon for which a researcher can apply his or her capabilities to a self-assigned task*.[3] Dimensions of this variable are the *time horizon* for which the capabilities are at the sole discretion of the researcher (i.e., for which he or she is protected from direct external intervention into his or her epistemic decisions and external decisions on the amount of capabilities) and the *resources* (including personnel over which the researcher has authority and the actual time available for research).

The concept 'protected space' provides us with a framework for comparing the opportunities to change research practices as they are created by governance. In the study presented here, we estimate the size and shape of the protected space (the amount of resources and the autonomous planning horizon) that is necessary for moving towards BEC research. On this basis we can compare the actual protected

[2] AMO is a research field that studies the structure and interactions of atoms, simple molecules, electrons, and light. Uses of lasers are its most important experimental practices.

[3] The idea of 'protected space' has been previously used by Rip (1995: 86) to describe the laboratory as a space in which researchers are shielded from interference (see also Krohn and Weyer 1994; Rip 2011). Our use of that concept deviates from Rip's in that we define it at the micro-level of individual researchers and their projects, include the protection from reputational consequences in the scientific community, introduce the time horizon for which a researcher is protected, and link it to the macro-level by asking for whom these individual-level protected spaces are provided. The use of the concept of 'protected sphere' by Hackett (2005) appears to address only the protection within scientific communities, which we include as a reputational aspect of protection.

spaces researchers managed to build for themselves and the sources they could use in the generic governance systems of their countries (BEC was not the subject of targeted policies). Countries can also be compared according to the *scope* of protected space, i.e., the numbers and positions of researchers who are able to build specific kinds of protected space. In this paper, however, we focus on the micro-level of individual researchers and their projects, and ask for whom individual-level protected spaces are provided.

2.2.2 The Empirical Investigation

The comparison of the impact of German and Dutch generic governance on changing research practices uses data from a larger comparative project that studies the impact of changing authority relations in four countries on conditions for intellectual innovations in the sciences, social sciences and humanities.[4] Our main source of data consists of semi-structured interviews with researchers who attempted to change their research practices in order to produce BECs. In addition, we analysed documents including published reconstructions of the development of BEC research by researchers and documents describing funding activities by the major funding agencies for basic research in Germany and the Netherlands.

In 2011 and 2012 we investigated 14 research groups – five in the Netherlands (seven interviews) and nine in Germany (nine interviews) – that attempted to produce Bose-Einstein condensates at various points in time since the early 1990s. Two more Dutch AMO research groups that did not conduct BEC research were included, as were informants from Dutch and German funding agencies (two Dutch, one German).

The interviews with researchers lasted between 60 and 120 min, and consisted of two main parts. In the *first* part, the interviewee's attempts to begin research on BEC were discussed in the context of the interviewee's research since his or her PhD projects, exploring the continuity and all thematic changes and reasons for them. This part of the interview was supported by a bibliometric map of the interviewee's publications that showed thematic links between publications, which was used to stimulate the recall and to prompt narratives about the content of research (see Laudel and Gläser 2007; Gläser and Laudel 2015 on the methodology). In the interview's *second* part, conditions of research and the factors influencing them were discussed. Topics included the knowledge, personnel and equipment required to produce BECs, sources of material support, and opportunities as well as constraints provided by the interviewee's organisational positions.

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[4] The project "Restructuring Higher Education and Scientific Innovation" (RHESI) was funded under the EuroHESC programme of the European Science Foundation by the NWO for the Dutch and by the DFG for the German study (see contributions in Whitley and Gläser 2014, for its main results, especially Laudel et al. 2014 for the BEC study). We would like to thank Enno Aljets and Raphael Ramuz for providing access to the interviews they conducted.

The interviews were recorded, fully transcribed, and analysed using qualitative content analysis (Gläser and Laudel 2013). With the information extracted from the interviews it was possible to reconstruct:

- histories of the international and national dynamics of BEC research,
- the necessary protected space for BEC experiments,
- the generic governance systems of the two countries,
- case histories of individual researchers and research groups attempting to build the protected space for BEC research between the early 1990s and 2012.

A comparison of these histories led to the conclusion that three phases of BEC research can be distinguished and applied to the case histories. Decision processes and changes of research practices were compared for these phases, which in turn enabled the identification of the role of generic governance processes.

2.3 Generic Governance Structures in Germany and The Netherlands

The two science systems considered differ not only in size but also in their organisational structures, funding landscapes and career structures. They have in common, however, that most BEC research has been conducted at universities.[5]

The *German* university system is still ‘chair-based’. The professors are tenured and largely autonomous in their decisions on research and teaching content. Most academics below the professorial level have fixed-term contracts as assistants (*wissenschaftliche Mitarbeiter*), postdocs or PhD students, all of which are formally dependent on the professors. Professors have the authority to decide about research and teaching tasks of their dependent staff. In the experimental sciences and engineering disciplines, professors receive substantial start-up funding when appointed and can negotiate similar packages in return for not taking up an appointment elsewhere (loyalty negotiations). Having received such a package, professors are allocated only a very small amount of recurrent funding, which in the case of experimental physics usually does not even cover the costs for consumables and maintenance of the equipment.

At German universities, experimental physics thus depends on external funding, for which the *Deutsche Forschungsgemeinschaft* (DFG) is by far the most important source. The DFG is a ‘science based’ funding agency (Braun 1998). It is largely controlled by the disciplinary communities which elect panel members as well as most members of the decision bodies. Funding is investigator-driven. All research-

[5] In Germany, institutes of the Max-Planck Society played a role in BEC research, as did one of the few Dutch non-university institutes. The differences between research institutes and universities are not systematically discussed here due to space limitations (but see Gläser et al. 2014). Information about research at the institutes is included ad hoc wherever necessary.

ers at universities and public research institutes who hold a PhD are eligible for funding.

Careers in the *Dutch* university system are characterised by early tenure and internal promotion. Since the 1980s there have been three types of positions: *Universitair Docent* (UD), *Universitair Hoofdocent* (UHD), and Professor. Over the last decade, all universities have added tenure-track positions to the mix.

Dutch academics below the professorial level have no discretion over resources, cannot independently supervise PhD students, and thus are dependent on professors. Professors typically lead groups of two tenured senior researchers (one UD and one UHD) and have access to one or two PhD positions each on a competitive basis. In addition, Dutch university leaders and even faculties have sufficient discretion over resources to invest them in the infrastructure or projects of their professors or other staff.

Similar to German universities, Dutch universities provide basic infrastructure in laboratories. Project funding and fellowships are provided by the Dutch funding council (*Nederlandse Organisatie voor Wetenschappelijk Onderzoek*, NWO). Most project funding for fundamental experimental physics has been provided by a dedicated funding agency (*Stichting voor Fundamenteel Onderzoek der Materie*, FOM), which is a science-based funding agency like the NWO and the DFG. All researchers holding a PhD are eligible for FOM funding. FOM heavily relies on international reviews but panels composed of Dutch physicists take the final decisions.

2.4 Building Protected Space for Changing Research Practices in Two Science Systems

From first attempts until the early 2000s, to manufacture BECs of atoms was an exceptionally complex, risky and expensive undertaking even by the standards of experimental low temperature physics. While BEC had been analysed theoretically, it was not clear at all for gases of which atoms it could be achieved experimentally. This means that for each new element with which researchers wanted to produce a condensate, strategic uncertainty – the uncertainty concerning the existence of the effect – was high.[6] The technical uncertainty – the uncertainty concerning the possibility to experimentally produce an effect – remained high for all BEC experiments well into the 2000s. The experimental set-up requires researchers to go through a long sequence of steps of adjustment and fine-tuning. At least until the early 2000s, the process usually took several years. It was always possible that the researcher could not solve the technical problems involved, in which case the experiment failed. This technical uncertainty still characterizes many BEC experiments.

[6] We borrow the concepts 'strategic uncertainty' and 'technical uncertainty' from Whitley's (2000) comparative analysis of scientific fields but use them differently, namely for distinguishing between two kinds of epistemic uncertainty. In contrast, Whitley applied the term 'strategic uncertainty' to describe the uncertainty of gaining reputation.

The necessary protected space for such an undertaking was correspondingly large. Until today, achieving BEC in atomic gases requires the combination of the most advanced techniques for cooling atoms and trapping those with the lowest energy. The researchers usually built complex task-specific equipment from components. Depending on the research prior to the move to BEC, several of the more expensive components might already exist in the laboratory.

The necessity to build a complex task-specific experiment and the uncertainties involved in BEC research require a protected space that is large in both the resource and time dimensions. The research capacity required to achieve BEC includes 100,000 to 500,000 Euros depending on the equipment already available in the laboratory. At least two PhD students fully engaged in the project are necessary to develop the experiment; parallel work of more PhD students is an advantage. For the first decade of BEC research, the time horizon of the necessary protected space extended beyond the usual 3-year grant cycle and was difficult to predict. The reputational risk involved is high because little can be published until the experiment is successful and because the experiments can fail entirely due to the strategic and technical uncertainties. This is why the time horizon had to be even longer: researchers needed protection until the publication of results let them gain sufficient reputation for new grant applications.

Although the reproduction of the early experiments has become much easier today and 'standard BECs' used as tools can be manufactured relatively easily, much of the original difficulties remain for those who attempt to manufacture new BECs, e.g., condensates of new atoms or exceptionally large BECs. We now compare the attempts of German and Dutch researchers to build such protected spaces in three phases of BEC research and demonstrate the role of generic governance in these attempts.

2.4.1 An Endless Quest? The First Attempts to Produce BEC

While physicists have conducted theoretical research on BEC ever since the work of Bose and Einstein, it had always been clear that the experimental realization of BEC depended on achieving extremely low temperatures. Atomic gases were assumed to liquefy or turn solid at these temperatures, which is why experimental physicists assumed that BEC could be achieved only in hydrogen. Major experimental efforts began in the 1980s, when condensed matter physicists first attempted to manufacture BEC in spin-polarized hydrogen gas by combining several cryogenic methods.

In the early 1990s, the condensed matter physicists who had been trying to achieve BEC from hydrogen were recognized as leading experts concerning BEC. However, most AMO physicists doubted that a breakthrough could be achieved in the near future. A small minority of US researchers including Wolfgang Ketterle (at MIT) as well as Eric Cornell and Carl Wieman (both at Boulder University, Colorado) put forward the idea to produce BEC from alkalis with the help of a recently developed cooling technique, so-called laser cooling. This suggestion was met by even stronger scepticism than the hydrogen route because all other atom gases were thought to immediately condensate into droplets or become solids at the low temperatures. One interviewee remembered the reactions that Ketterle and his colleagues experienced when they presented their ideas at international conferences.

> Ketterle, and in particular Wieman, told everyone, and you can read it in the books, how he wants to make BEC. Everyone laughed at him. (German BEC researcher)[7]

A large majority of the *German* physics community was sceptical concerning BEC in hydrogen and even more so concerning alkalis. Among the sceptics were important contributors to the development of laser cooling technologies who enjoyed a high reputation within the AMO community. They believed in various theoretically predicted limits of laser cooling (and other cooling technologies) as well as the problems of keeping atoms other than hydrogen in a gaseous state.

> There was this topic Bose-Einstein condensation, which at the time was very exotic, because it was thought 'My God, an important topic but nobody knows whether it works. And the two [Ketterle and Cornell] do that and they are in fact on a suicide mission'. (German BEC researcher)

Still, a few German AMO physicists shared the early visions of Ketterle and his competitors. These included two of our interviewees who, however, did not join the race for BEC in spite of the considerable protected space they could have built as professors. Our interviewees perceived the risks involved in attempting BEC (which they did not want to impose on their PhD students) and their disadvantage compared to the vast experience of the US groups. Furthermore, laser cooling had opened up many alternative attractive research opportunities such as atom interferometry, optical lattices, or atomic clocks. They spoke about BEC as the 'holy grail', which would be found in the far future.

Like the German AMO community the majority of the *Dutch* AMO physicists did not believe, in the early 1990s, that it is possible to produce BECs. Quite interestingly, the 'Holy Grail' metaphor was used as well, accompanied by a consideration of BEC as "a little bit esoteric" (Dutch BEC researcher).

One of the very few groups worldwide actively pursuing the BEC in atomic hydrogen as early as the 1980s was located in the Netherlands and had made substantial contributions on the route to BEC. Despite large skepticism in the Dutch physics community that this approach would work, the funding agency NWO awarded the group leader (a professor) a prestigious grant for this purpose in 1990. He could extend his infrastructure as well as the number of postdocs and PhD students for working on the BEC experiment.

Another Dutch AMO researcher became interested in BEC by results presented at international conferences. He was on a tenured non-professorial position working

[7]All quotes from German BEC researchers are our own translation. Dutch interviews were conducted in English. For reasons of confidentiality we do not further specify the roles and positions of our interviewees.

under a professor who would have supported this move. However, he failed to acquire project funding for BEC in alkalis from FOM before 1995. Consistent with the views of the international community, the reviewers seemed not to have believed in the possibility of success.

In this *early period*, the scientific communities and their beliefs had the strongest influence on possible moves to BEC. In Germany, the opportunities to build protected space were not ‘tested’ by researchers. Those researchers sharing the minority view that BEC in alkalis is possible felt that they cannot compete with the US researchers given the latter’s head start and the risks involved in the project. In the Netherlands, one researcher continued to work on BEC in hydrogen, while another researcher who tried to follow the BEC in alkali route did not manage to build protected space.

2.4.2 The End of the Quest or a New Beginning? Responses to the First Experimental Success

In the summer of 1995, first empirical evidence of BEC in an atom gas (of rubidium atoms) was presented at an international physics conference at Capri. Until the end of the year, three US research groups, one of which led by Ketterle, achieved BEC. In his later Nobel lecture, Ketterle described the protected space he could build at MIT. When he became assistant professor, he received a start-up package for independent research. In addition, his former professor gave him full discretion over a lab that was newly equipped for BEC research and over two experienced PhD students. He could fund two more PhD students, one of them with an NSF grant received for BEC research in spite of the high risk of what he planned (Ketterle 2002). In terms of resources this was twice as much as most of our interviewees had at their disposal.

The experimental realisation of BEC was immediately regarded as an outstanding achievement by AMO physicists and the wider physics community. However, the international AMO community was undecided whether the achievement implied the end of the long quest for the ‘Holy Grail’ of BEC or rather the beginning of a new journey. Would the experimental realisation of BEC open up opportunities for interesting new physics or was it merely the experimental confirmation of a theoretical prediction that would turn into a “text book experiment”, as a German BEC researcher put it?

Even some members of the US research groups that already had produced BEC turned away from the field. The international community was also still divided over the question which elements would be suitable for BEC besides alkali gases. Could BEC also be achieved in rare gases or more complex particles like molecules?

Many AMO physicists in *Germany* seriously doubted that in-depth explorations of the BEC phenomenon would reveal further insights. While the success of Ketterle and his colleagues was widely acknowledged, the majority continued their 'business as usual' by exploiting other opportunities created by the new cooling techniques. A researcher who was a postdoc at the time of the Capri conference was looking for advice whether he should or should not take up BEC research:

> Interestingly enough, the bunch of people I asked for advice, all of them experienced professors in Germany, all told me one should not do anything anymore. Everything had been done already. Wolfgang Ketterle had already done everything and it would not pay to do more research. (German BEC researcher)

The doubts concerning BEC experiments were especially strong among members of the older generation immersed in their lines of research. However, younger researchers with the best qualifications in laser cooling did not immediately move to BEC research either. Interviewees reported that, at the time, they underestimated possible theoretical outcomes of BEC, avoided competition with the US groups whom they considered superior, or expected other AMO fields to promise better career chances. Again, the opportunities to build the necessary protected space were not tested.

We know of only three German researchers (two 'early believers' and one 'convert') who entered BEC research after the first experimental success was announced at the Capri conference (Table 2.1). In each case, the access to state-of-the-art infrastructure suitable for BEC research reduced the amount of additional funding that was necessary to build the protected spaces. All three group leaders encountered some difficulties obtaining money from the DFG, which they attributed to their community's strong doubts concerning the potential of BEC. However, all three group leaders were able to 'bootleg' money from other projects in order to start their research immediately.

As concerns the *Dutch* AMO physics community, several groups became interested in BEC after its experimental realisation was announced at the Capri conference. Other researchers did not consider any move towards BEC because they were pursuing other interests.

Table 2.1 German researchers entering BEC in the second phase

Cases	*Entering*		
Career position	Professor	Professor	Junior group leader at research institute
Discretion over infrastructure	2 PhD positions and state-of the art equipment from start-up packages		Granted by director: 1 PhD position, equipment from previous experiments, some additional money
Additional resources required	One small grant (equipment)		
Approach to building protected space	Acquisition of grants delayed but successful, immediate start by 'bootlegging' money from other projects		

> For instance the groups in [town X] that knew about laser cooling, I don't think that they ever seriously considered switching to Bose Einstein condensation. They were interested in atoms that have to do with radioactive isotopes and spectroscopy. And they are still very successful in this line of research. (Dutch BEC researcher)

This quote illustrates the complexity of decisions concerning a change of research focus. The situation considered by researchers includes the risks and the potential of the new line of research (in this case, BEC) as well as their current investments, interests in their current research and the potential of that research to produce interesting results (see Hackett 2005 for a related analysis of problem choices in the molecular life sciences).

Between 1995 and 1997, five researchers became interested in pursuing BEC research in alkalis (including the researcher who originally worked on BEC in hydrogen) but only three of them could immediately pursue this interest (Table 2.2). Similar to their German colleagues, the Dutch groups already held substantial parts of the equipment that was necessary for setting up a BEC experiment. They also employed postdocs who had obtained the necessary knowledge in laser optics and cooling technologies in the leading laboratories abroad. The universities provided excellent technical workshops, which were very important for building the experimental setup.

As far as we could reconstruct the situation between 1995 and 1997 from interviews, FOM was reluctant to fund BEC research beyond grants for the single researcher who had already worked on BEC in hydrogen since the 1980s. The other researchers began BEC work by 'bootlegging' money from other grants. Two further researchers on non-professorial permanent positions did not start their BEC research at this time because their professors would not "lend" their infrastructure for this topic, and because they believed to be in a bad competitive position compared to the US groups.

Although this *second phase* in the development of BEC research began with the crucial scientific event – the experimental realization of BEC – researchers who wanted to move to BEC faced the same problems as in the first phase. The necessary

Table 2.2 Dutch researchers continuing and entering BEC research in the second phase

Cases	*Continuing (change to alkalis)*	*Entering*	
Career position	Professor	Professor	Tenured non-professorial
Discretion over organisational resources (some personnel, parts of the necessary equipment, machine workshops)	Yes		Limited (granted by Faculty)
Additional resources required	Large grants (personnel and equipment)		
Approach to building protected space	Sufficient resources from BEC grants	No BEC grants, 'bootlegging' money from other projects	

protected space could be built only by combining control of infrastructure and external funding. Control of infrastructure required a professorship or at least the consent of a professor, while the securing of external funding depended on the dominant perception of the scientific elites in both countries. Two interesting properties of external funding landscapes become apparent in the second phase. First, the German community was more pluralistic in its approach than the Dutch. It enabled BEC funding, albeit reluctantly, despite the dominant belief that BEC was not worth doing. In contrast, the Dutch physics elite, which decided centrally on the topics to be promoted, was highly selective in its allocation of grant funding for BEC research. Second, both funding systems included mechanisms that limit the influence of the elites of national physics communities, namely the autonomy of researchers to use grants that were already awarded as they saw fit.

2.4.3 New Quests: The Growth of BEC Research Since 1998

In autumn 1997, 2 years after the initial success, the first BEC outside the US was produced. The following year witnessed new BECs being produced in many countries. This research soon moved beyond the replication of the original results as it became obvious that BECs provided many opportunities for interesting theoretical and experimental research, and could be turned into a research tool for several other research areas. Until today, more than hundred research groups worldwide achieved BEC.

As was the case with the international community, the perception of new research opportunities led to a fundamental shift in attitudes towards BEC research within the *German* AMO community. Physicists turned from questioning the use of BEC experiments to acknowledging their great potential. In Germany, the first researchers who moved to BEC were successful in late 1997 and early 1998 and thus belonged to the first non-US groups to achieve BEC. While the 'fastest' group by and large replicated the US experiments, subsequent research began to exploit the opportunities that resulted from moving BEC research in new directions. Today, about 15 experimental groups are investigating BEC topics at universities and public research institutes across the country.

The growth of BEC research depended on the availability of professorships because researchers needed the basic supplies that came with them. The institutionalization of BEC research at German universities was made possible by a major shift in German physics. German (and even Dutch) interviewees recalled that the federal government phased out its funding of nuclear research in the early 2000s and that faculties responded to this shift by changing the denomination of vacant professorships from nuclear physics to AMO.

Owing to the crucial role of start-up and loyalty packages for building the infrastructure for BEC research, German universities had a de facto veto position in each instance of BEC research. One researcher received a start-up package that was sufficient to achieve BEC within 2 years without applying for additional external funding, while another had to wait several years for the agreed-upon start-up package due to budgetary cuts. The university's refusal to pay delayed the BEC experiments for many years and almost threw the interviewee out of the race. The other cases were situated in between these two extreme poles. It should be noted, however, that the decisions of university leaders were often indifferent to BEC research, i.e., not linked to intentions of making BEC a major part of their research profile.

This pattern confirms the importance of being a professor for conducting BEC research. No researcher below the professorial level could realise an independent BEC experiment. While some were successful in receiving external funding, their protected space remained insufficient. Only the leader of a junior research group at a well-funded German research institute could move to BEC research before he became a professor (see Gläser et al. 2014).

The physics community's change of mind about BEC research was reflected in the changing attitudes of the DFG: Interviewees agree that, from 1998 onwards, almost all proposals for BEC research received funding. This means that access to external funding became exceptionally easy. Several interviewees reported that, according to their recollection, the DFG and its reviewers suspended some of their rules by tacitly accepting that building BEC experiments took more than the 3 years for which grants were provided.

> Well, I must say that we have always been supported by the *Deutsche Forschungsgemeinschaft* especially with these high-risk projects. So in the case of BEC, which as I said took seven years, you could have said many times 'that's it' and 'there will never be results'. Nevertheless, we have always been successful in writing applications. (German BEC researcher)

The DFG funded several collaborative research networks that investigated 'cold quantum gases'. While none of these programmes was specifically dedicated to BEC, all were thematically close enough to enable the membership of BEC groups in networks dedicated to related topics. Almost all groups whose leaders we interviewed benefited from one or more of these programmes.

In the *Dutch* physics community, the change of mind in the international community did not reverberate as strongly as it did in the German one in spite of an early success. The total number of groups pursuing BEC research grew to five after the two researchers whose move to BEC research in the previous phase was delayed due to their lack of access to university resources could begin (Table 2.3).

The first Dutch group to achieve BEC was headed by a professor who belonged to the international elite and was the director of a state-funded non-university institute. He could use the institute's infrastructure, personnel and technical support as well as external grants.

The researcher who obtained a 5-year tenure-track position was granted the necessary time horizon for his research by his faculty, which suspended the mid-term evaluation for the position.

The access of researchers to grant funding improved only temporarily due to the community's continuing reluctant attitude towards BEC research. About 1998, several Dutch researchers interested in BEC research joined forces and submitted a

Table 2.3 Dutch researchers continuing and entering BEC research in the third phase

Cases	*Continuing*			*Entering*	
				(Delayed by 5 years)	(Delayed by 6 years)
Career position	Professor	Professor	Tenured non-professorial	Professor	Five-year tenure track
Discretion over organisational resources	Yes	Yes	Yes, but more limited (granted by Faculty)	Yes	Yes, from start-up package
Additional resources required	Large grants (personnel and equipment)				
Approach to building protected space	From grants for BEC	Temporarily from grants for BEC, otherwise 'bootlegging' money from other projects			Fromgrants for BEC
First publication of experimental success after	Four years	BEC research abandoned	Ten years	Six years	Six years

proposal for a funding programme to support BEC research. In 2000, the funding programme "Cold Atoms" was set up by FOM, benefiting all five groups. After 3 years, the programme was evaluated and then stopped because no further BECs were achieved after the first success in 1999. In contrast to the German cold-atoms community, the Dutch community did not take into account the technical uncertainty involved in the experiments and the resulting uncertain time frames. A second funding programme, starting in 2004, concentrated all funding on two researchers, one of whom was the professor who already had manufactured a BEC.

These two groups were the only ones whose BEC research was not hindered by insufficient external funding after 2003. The other three groups faced funding shortages. One group had to give up, and the research of the other two groups was delayed.

There exists an interesting difference between Germany and the Netherlands in this *third phase*. While BEC research grew rapidly in Germany as researchers perceived its potential and received opportunities to employ it in the context of new professorships in atomic and molecular physics, it shrank in the Netherlands after the community's elite had decided that success came too slowly and funding had to be concentrated. However, there is an interesting commonality that concerns the scope of protected space. Even after the scientific potential of BEC research had been recognized, it could be exploited only by professors or with their approval. The necessity to build protected space from both university infrastructure and external funding limited the scope of protected space to those who controlled the infrastructure and thus could either use it themselves or grant it to others.

2.5 Conclusions: Generic Governance and the Diffusion of New Research Practices

Long before political support for emerging fields can be mobilised and parallel to national and regional policies targeted at the promotion of emerging fields (see Bensaude Vincent, Chap. 3 and Vinck, Chap. 5), generic governance structures shape the conditions for the birth and early growth of new fields. Our findings confirm that the local configuration of new research fields depends on generic governance structures, which together may create markedly different conditions for early stages of field development.

1. When a change of research practices requires access to organisational resources, the scope of protected space depends on the way in which access to these resources is distributed in the organisations. In the two countries we investigated, access was restricted to professors by default, although Dutch universities could override this principle. German professors could acquire the resources necessary for a change of infrastructure only at certain points in time (appointment or loyalty negotiations).
2. The necessary contribution to protected space by the grant funding system makes researchers dependent on views and decision practices of their communities. The impact of pluralism respectively collectivism on the diffusion of research practices, and thus the role of national decision styles of scientific communities in the national shaping of research fields, has become obvious in our comparative analysis. It seems much more difficult to counter a community's majority opinion in the Netherlands than in Germany.

These findings are likely to hold beyond the extreme case studied here. Generic governance structures also make a difference to changes in research practices that require less protected space as long as researchers require some autonomous planning horizon during which they don't have to follow the majority opinion of their community or hierarchical directions from senior researchers, and resources they can use during this time.

In this chapter, we identified career structures, access to resources provided by universities and decision practices of scientific communities as elements of generic governance that influence researchers' opportunities to change their practices. The first two factors slightly favoured Dutch physicists, while the latter clearly favoured their German colleagues. The impact of all three elements can be neutralised when an emerging field enjoys political attention. Large politically controlled funding programmes can circumvent decision processes in scientific communities and they can create positions with sufficient autonomy and access to resources. However, they can do this only temporarily. The impact of generic governance structures both precedes and follows them. And even during the high times of political promotion researchers in emerging fields often have difficulties to create long-term career opportunities.

We would like to conclude this chapter with a further theoretical and a political point and will begin with the first. Our empirical observations provided material for an interesting extension of Whitley's (2000) argument about relationships between epistemic and social structures of fields. We showed that researchers cannot build protected space that shields them from their community when they depend on external funding. This is why a community needs mechanisms to protect its members from its majority opinion to foster novel research. The German community did this with pluralistic decision-making on funding, while the Dutch did not. Both the German and the Dutch community had the additional mechanism of being lenient with the actual use of grants once they were awarded.

This means that even within one field, i.e., for national communities that share most of the epistemic and social features described by Whitley, different modes of control of resource allocation are possible. At least two more factors appear to create variation between national communities. One of them may be size or wealth, both of which can affect the extent to which the community considers it necessary to centrally plan the tasks on which their researchers spend the 'community money'. Another one can be tradition, i.e., a nationally specific culture of decision making. We could not disambiguate these factors in an investigation of only two cases. More comparative research is needed to understand the translation of international community opinions in national decision processes.

Our *political* point follows from the observation that both German and Dutch researchers seemed reluctant to enter the competition for producing BECs at all. Most referred to the superior experience of their colleagues in the US. However, it also became clear that the US groups who first produced BEC had significantly larger protected spaces and provided this space to young researchers who would just give BEC a try. This raises the question whether competition for project funding is the best condition for high-cost high-risk research, and how alternative conditions for such research could be shaped. The very early developmental stages of new research fields are inevitably ambiguous and insecure. Promoting fields in these stages requires political actors and managers to take risks, too – be it only the risk to promote research *before* US-American researchers have proven that it opens up promising new fields.

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