Chapter 9

The Language of Science Policy in the Twenty-First Century

What Comes after Basic and Applied Research?

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The turn of this century was a peculiar period. It was accompanied by intense retrospections as well as imaginations and millennium proclamations. A further coalescing world society has tried to find answers to its own immediacies, and seems to be in need of a new language that would both frame exigent problems and bring together actors that are willing to tackle them. In this respect, old concepts live on vis-à-vis new ones, and they may peacefully coexist in some cases while causing interferences in others. Such reflections are not restricted to the sphere of high politics, the world economy, and global tensions and conflicts. It is also in the prosaic sphere of science policy that various actors try to make sense of what's happening in the present age and what has changed. Against this background, the questions we follow in this chapter are whether twentieth-century science policy concepts—such as "basic research" and "applied research"—have been overwritten by new ones, or whether old and new concepts can coexist. More specifically, we ask which new concepts bear potential to structure twenty-first-century expectations about the relationship of science and society.

Looking back at the history of basic and applied research, we have to keep in mind that this distinction never stood on its own feet, but needed symbolic and institutional backing. First, the basic/applied distinction was embedded in those master narratives that have determined science policy discourses in the second half of the twentieth century. For example, reviewing the post–World War II decades, science policy scholars in the 1990s came to the common understanding that science and society had—more or less explicitly—established a "social contract" (Guston and Keniston 1994; Sarewitz 1996; Gibbons 1999). By this quasi-contractual relationship, scientists were granted high degrees of autonomy as long as society was convinced that scientific knowledge would be translatable into technological innovations and ultimately contribute to economic welfare.

Similarly, at the organizational level, models and narratives of "technology transfer" seized prominence in the postwar period. While investments into warfare-related R&D had proved useful, the continuing and even intensifying federal R&D expenditure after the war needed extra justification, which resorted to concepts of technology transfer for civilian use. On university campuses and in research laboratories, calls for technology transfer were thus expounded by various terms, such as "fall out," "spillover," and, most notably, "spin offs" (Mowery and Sampat 2001; Mowery et al. 2004; Shane 2004: 45–48). For the scientists' autonomy, these early concepts of technology transfer were functional: they did not question the relevance of scientific knowledge production as such, but argued for auxiliaries that would make scientific knowledge transferable. In this respect, they helped sustain a "protected space" for scientists and universities (Rip 2011).

And yet, the most successful master narrative was the "linear model of innovation." Introduced and disseminated in the 1950s and 1960s mainly by economists (Godin 2006, 2017; Lax 2015), this model built on the idea that innovation could be rationally scheduled via consecutive sequences of action: basic research would be followed by applied research, the latter by development, and this last step would ultimately lead to technological innovations and profitable market products. Although the linear model was never codified or generally accepted as valid in terms of its explanatory power (Edgerton 2004), it was tremendously influential insofar as it provided a simple way of conceiving and communicating the utility of science—not least the utility of basic research (Kaldewey 2013: 371–383). In the scholarly communities, however, the linear model was increasingly challenged from the 1980s onward (Stokes 1997; Pielke and Byerly 1998; Fagerberg 2005). Nathan Rosenberg (1991: 335) put this critique in a nutshell: "Everyone knows that the linear model of innovation is dead." In the following years, such declarations became commonplace, and, as some scholars observed, turned into a cheap and polemic ritual (Freeman 1996: 27; Balconi, Brusoni, and Orsenigo 2010; Mirowski 2011: 47). The consensus in the 1990s was that the linear model of innovation could never fully grasp the complexity of innovation processes.

The rise and decline of the linear model as a master narrative can be illustrated by quantitative semantic analysis (Chumtong and Kaldewey 2017). Figure 9.1 traces the frequency of the key terms “basic research,” “applied research,” and “technological innovation” in the Google Ngram Viewer corpus. The figure makes visible how the trajectories of the three terms are

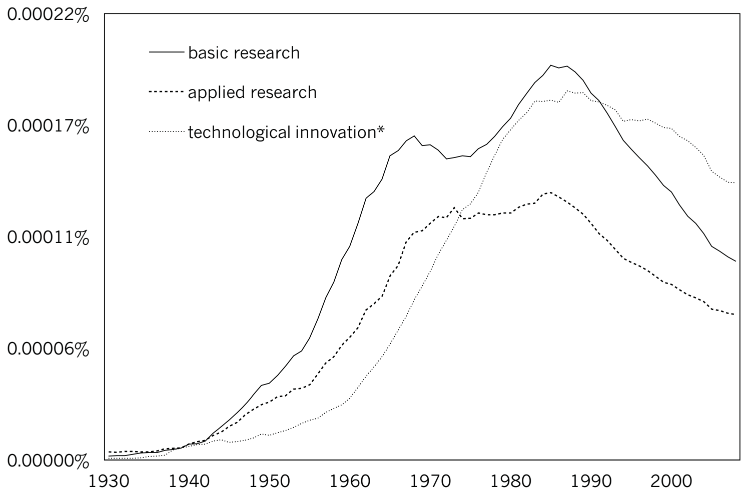

Figure 9.1. The linear model as seen through the Google Ngram Viewer, 1930–2008 (relative frequencies of the respective terms, English corpus, case-insensitive; data retrieved 8 November 2016; smoothing=3)

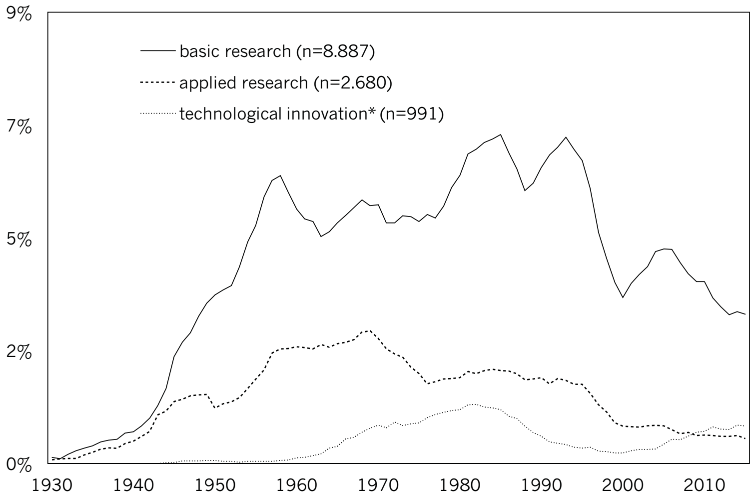

Figure 9.2. The linear model as seen through the *Science* archive, 1930–2015 (relative numbers of articles that contain the respective terms; data retrieved 8 November 2016; smoothing=3)

interrelated, how they all disseminate into everyday language in the 1950s and 1960s, and then decline in the 1990s. This data impressively corroborates the "death hypothesis" put forward by Rosenberg and others. The Google Ngram Viewer corpus, however, does not represent scientific communication in the narrow sense and cannot be used to infer anything about how relevant the respective concepts have been in more specific scientific and science policy contexts. Figure 9.2, therefore, shows how many articles in the archives of the journal *Science* contain the respective terms, relative to the total number of articles in a given year. Since *Science* is dedicated to academic scientists as its primary audience, the concept of basic research is—unsurprisingly—more prominently represented in this context than the concept of applied research. Nevertheless, both terms follow a pattern quite similar to that displayed in the Google Ngram Viewer: they had their heyday between the 1950s and the 1980s and became less commonly used at the end of the century.

Based on the data in figures 9.1 and 9.2 and the critiques mentioned above, one could conclude that the linear model did not make it into the twenty-first century. Further quantitative inquiries with a specific focus on the more recent past, however, challenge this interpretation. Figure 9.3 contains data extracted from more than thirty-five million publications indexed in the *Web of Science* core collection[1] and indicates how many of these contain the respective terms in title, abstract, or keywords. Surprisingly, in this corpus, the use of all three terms has increased constantly between 1991 and 2015. If one

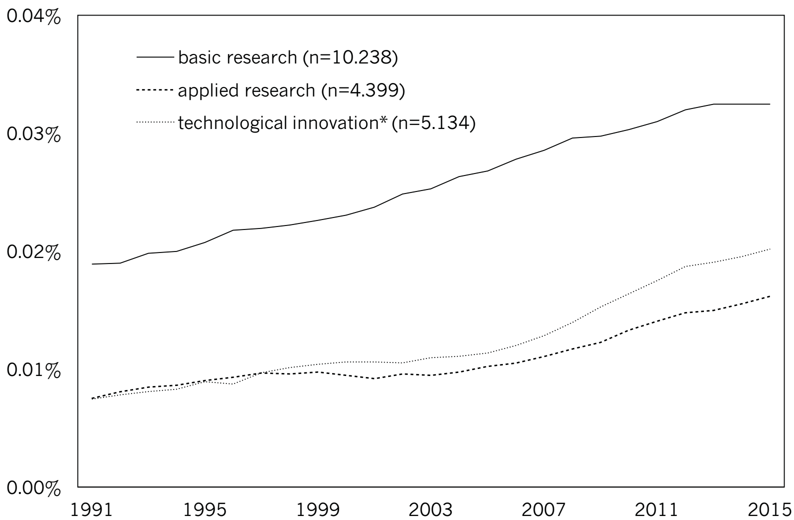

Figure 9.3. The linear model as seen through the *Web of Science* core collection, 1991–2015 (relative numbers of publications that contain the respective terms in title, abstract, or keywords; data retrieved 11 August 2016; smoothing=3)

compares the three figures, the overall picture becomes blurry. On the one hand, figures 9.1 and 9.2 indicate that the linear model of innovation lost its status as a master narrative; on the other hand, figure 9.3 indicates that the key terms are firmly established in "normal" scientific communication.

Why then did the linear model, and the concepts nested within it, persist despite the scholarly critique? One reason is that the linear model of innovation and the idea of a social contract of science were, for several decades, coupled and integrated in the same policy rationale: that the state—amid decreasing competitive market advantages for companies—needs to provide public goods. Basic scientific knowledge was assumed to be an important public good that everyone could take advantage of (Schauz 2014: 299). This rationale has sustained its importance despite the fact that economists and other scholars disagree.[2] Another reason for the persistence of the linear model is, simply, that so far there seems to be no alternative master narrative available. Ulrich Wengenroth (2000: 28) thus concisely summarized the debate at the end of the century by admitting that the linear model "is now dead," while at the same time stating that "it has not yet been successfully replaced by a new orthodoxy." Roger Pielke (2012: 341) recently put forward a similar argument asking if and to what extent "a new political consensus" may emerge that can "replace 'basic research' as a central, organizing symbol." In our view, the same question should be asked with respect to all concepts nested in the linear model ("basic research," "applied research," "research and development," "technological innovation").

Against this background, the questions of whether basic and applied research denote distinct activities within the logic of the linear model, and whether the model is more or less appropriate in describing or planning reality, do not seem instructive for us. Instead, we contend that concepts are powerful not necessarily due to their analytical accuracy, but rather due to their *symbolic* function in science policymaking. Because concepts—old and new ones—are embedded in a narrative structure, they represent more than strategic language games: they open avenues to unfold alternative identities, for individual actors, organizations, and science in general.[3]

In view of these considerations, we propose to take a closer look at those science policy concepts that have gained prominence in the last two decades, and to reflect on how these new concepts relate to the old ones. In contrast to those science policy scholars who aim to show how one conception of the science/society relationship follows the other ("mode 1" versus "mode 2"), we assume that new concepts are related to the old narrative in a more complex way. We focus on the reuptake of two concepts in particular, both of which have become particularly prominent in the transnational research policy of the European Union (EU), while at the same time being rooted in ideas originally stemming from the United States of America.[4] First, we reconstruct the history of the "frontier"-metaphor in science policy contexts, particularly the European Research Council's strategy of reframing "basic research" as "frontier research." Second, we trace the idea of "grand challenges" in science policy discourses in the United States and Europe, as it has, though mostly implicitly, come to replace older notions of "applied research." Figures 9.4 and 9.5 illustrate that and how these concepts have gained traction in scientific communication—and how the trajectories (though not their absolute frequency) outperform the old concepts of basic and applied research (as seen in figure 9.3). Such quantitative analysis, however, is of heuristic value only, and must be handled with care whenever the goal is to explain actual historical transformations. Therefore, the following analysis of contemporary discourses employs a more qualitatively oriented methodological strategy, which, similarly to the other chapters of this volume, builds on insights from historical semantics.

By selecting these two cases, we do not propose that the "frontier" concept finally replaces basic research, or that the concept of "grand challenges" supplants older notions of applied research. Many more concepts would be worth further exploration—for example, "excellence," "interdisciplinarity," and "breakthrough research" as circumscriptions of basic research, or "impact," "transdisciplinarity," and "translational research" as new formulations of what used to be called applied research. Studying the whole semantic field

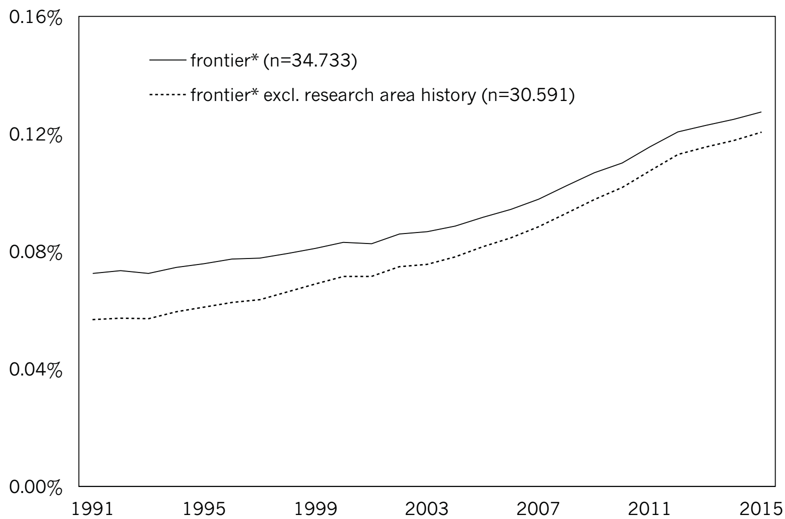

Figure 9.4. The frontier metaphor as seen through the *Web of Science* core collection, 1991–2015 (relative numbers of publications that contain the term in title, abstract, or keywords; data retrieved 13 July 2017; smoothing=3)

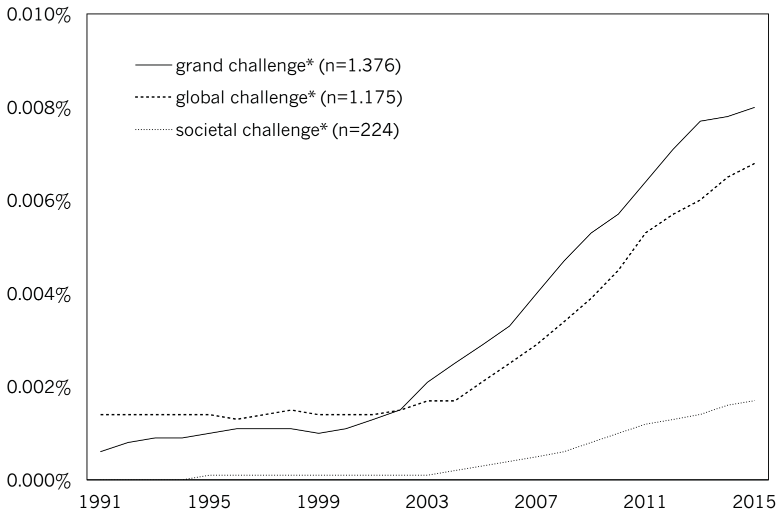

Figure 9.5. The grand challenges discourse as seen through the *Web of Science* core collection, 1991–2015 (relative numbers of publications that contain the respective terms in title, abstract, or keywords; data retrieved 14 February 2017; smoothing=3)

that builds on and transforms the twentieth-century basic/applied distinction would go beyond the scope of this chapter. Furthermore, in view of the linear model, we do not inquire into what happened to the final link of the chain, "technological innovation." Here, again, a wide field of new conceptual variations has developed in the last decades—concepts such as "social innovation," "open innovation," "sustainable innovation," or, most recently, "responsible innovation."[5] Nevertheless, the two case studies presented in this chapter point out that conceptual history and metaphorical analysis are helpful not only in understanding the history of old concepts, but also in reflecting on quite recent developments and transformations in the language of science policy.

Frontier Research

In April 2005, the European Research Council (ERC) was established by the European Commission as part of a legal proposal for the Seventh Framework Programme for Research and Technological Development (FP7) and finally enacted in December 2006 by the European Parliament and the Council of the EU. The new thing about the ERC was that for the first time in the history of the European Communities (EC), its central institutions allowed for investigator-driven and strictly peer-reviewed basic research funding. While calls for such a funding mechanism are as old as the EC themselves,[6] these initiatives never gained momentum, a reality best reflected in the unfortunate development of the European Science Foundation (ESF) since its establishment in 1974 (Darmon 1997). Part of the reason is that after the first big European crisis in the 1970s, research policy on the supranational EC level had been (re) established in view of one primary goal: the revitalization of European integration via the internal market project (Garrett 1992; Guzzetti 1995; Peterson and Sharp 1998). Among other policy fields, scientific research was chosen, and thus subordinated, to serve the competitiveness of European business enterprises, in particular against U.S. and Japanese firms. Thus, the initial Framework Programmes (FPs)—BRITE, EURAM, ESPRIT—channeled political expectations toward the ideal of economic utility. As a consequence, the Commission's directorate general pursued a strictly utility-oriented research policy (Banchoff 2002). As early as with the Third Framework Programme (1991–1994), however, that path-dependent development no longer matched reality: public research institutions drew close with private entities as regards their extraction of funding from the FPs (Peschke 2001). Thus, there was a mismatch of expectations, which ran toward a dichotomy between the proffered applied research funding (aiming at economic utility) and a self-determination of actors from public research institutions (being sympathetic with basic research).

Against this backdrop, proposals to finance basic research on a pan-European level were prompted in the mid-1990s—for example, from the European Molecular Biology Organization (EMBO), the Royal Society, and from policymakers of smaller European countries (Flink 2016: 105). The Commission was relentlessly criticized for keeping the FPs oriented toward application-oriented, cross-national collaborative R&D, which were not only regarded as bulky and red-taped, but also inadequate to serve the free play of knowledge production.[7] Still, the fact the ERC project was actually going to walk the walk, with the idea of inducing purely scientific peer-review principles of the highest standards and allowing individual researchers of all scientific fields to apply for funding, did cause a sensational bang in and far beyond the limbo of Brussels' office corridors.

The Commission initially ignored, then argued against, the idea of investigator-driven basic research funding (Nature Editorial 1997: 661; Schulz-Forberg and Stråth 2010: 149–150), as the organization was bound legally and politically to other funding rationales (Flink 2016). First, the *principle of subsidiarity* required that actions should be regulated, if possible, on a lower level of European governance (e.g., communal, regional, and national). Second, required to deliver *European-added value,* the Commission needed to itemize its potential actions as specifically beneficial for actors of cross-national range and scope. Third, the consortia profiting from the FPs were well rehearsed in lobbying for every euro. Therefore, the ERC initiative and most certainly the Commission were likely to face the strong counter-argument that basic research would not lead to profitable, innovative products serving the European market. From early on, most advocates of the ERC initiative might have strategically anticipated such forthcoming counter-arguments and therefore continued to stress the economic utility of basic research. Yet the term itself was problematic as it conveyed notions of pure curiosity and uselessness. Against this background, the European Commission (2005: 3, 6, 36, passim) in her legal proposal of FP7 replaced "basic research" with a new term, "frontier research." This swift semantic shift—which was legitimized by a body of experts who had delivered a report titled *Frontier Research: The European Challenge* (Harris et al. 2005) only two months before the legal proposal—is remarkable not only because "basic research" was obliterated, but because the experts and the Commission chose the specific alternative of "frontier research." Thus, this kind of conceptual politics is an intriguing case to study in order to answer the questions put forward in this chapter: (how) are old concepts overwritten by new ones, and is it possible that old and new concepts coexist?

"Frontier" is not a common term in Europe, and was rarely used in the continent's national science policy discourses during the twentieth century. Rather, it draws on a longstanding historical legacy of the United States, where it finds use both as a popular, conventional daily-life metaphor and as a term employed in science policy discourse.[8] The concept became most famous in the nineteenth century's "Wild West" era and portrays a movement of exploring and exploiting the Americas from east to west and further south (Ceccarelli 2013). Thereby, the frontier does not primarily denote a border but rather a transitional contact zone for adventurous "frontiersmen" penetrating the unknown territory. While moving the frontier as a literal process terminated with the pioneers reaching the natural borders of the Americas, the late nineteenth century turned the frontier into a powerful metaphor that was no longer bound to an actual process of exploring new lands.

In 1893, historian Frederick Jackson Turner presented the first version of his famous treatise on *The Significance of the Frontier in American History* to the American Historical Association in Chicago (Turner 1893; see also Coleman 1966; Rushing 1986).[9] Though he revised his presentation numerous times until the 1920s, his basic idea remained stable: extending the actual frontier with all its implied boldness and risk had forged a "special American character . . . marked by fierce individualism, pragmatism, and egalitarianism" (Cronon 1987: 157). Amid the cessation of the literal process of expansion, the frontier would have been perpetuated in a spiritual manner that vindicated Americans for being "savagely exploitative, and firm in [their] conviction that opportunity was boundless," no matter in what field they were active (O'Donnell 2000: 83; see also Ceccarelli 2013: 35).

In the early twentieth century, historians scathingly criticized Turner for his post-Darwinian truism of an existing American exceptionalism.[10] It is noteworthy that, despite the academic origin and immediate contestation, Turner's metaphorical concept fell on fertile ground in the general public and became a highly praised portrait of an American "pragmatism." Turner was fascinated that the American settlers, most of them European immigrants, "were separated from their past and forced to assume a new physical and spiritual appearance" (Coleman 1966: 36). As an implication, the miraculous frontier could not allow the individual or society to be limited by tradition-based intellectual—that is, European pondering. In other words, the frontier concept can be viewed as a mundane and aggressive version of liberalist thinking. Accordingly, frontier-inspired liberalism attached little value to governmental oversight, alleging that it would hamper both the individual in thriving on its freedom, and society in forming a collective identity vested with the values of the pioneering frontiersman (Turner 1920: 271–272). Still a breach was left to be filled: as not all men were pioneers during the actual process of expanding the frontier, so could not everyone in society become a frontiersman in the metaphorical sense. Given that problem, Turner (1920: 284) was quite explicit in choosing "university men" as the new pioneers: "Scientific experiment and construction must be applied to all of nature's forces in our complex modern society. The test tube and the microscope are needed rather than the ax and rifle in this new ideal of conquest."[11]

Turner's translation of the literal frontier into a metaphor describing the modern research enterprise has been extremely influential for decades. In 1922, later U.S. President Herbert Hoover (1922: 64) published his book on *American Individualism* and conjectured that "the days of the pioneer are not over . . . . The great continent of science is as yet explored only on its borders, and it is only the pioneer who will penetrate the frontier in the quest for new worlds to conquer."[12] After 1945, following Vannevar Bush's report *Science—The Endless Frontier,*[13] such references became convention in science policy-making whenever new programs were to be justified. The frontier concept was prominently employed, for example, in John F. Kennedy's (1960) advocacy of the Apollo program: "Beyond that frontier are uncharted areas of science and space." Another two decades later, Jimmy Carter (1979) stood up for his plans to spend federal money on R&D amid decreasing tax revenues: "We are pushing back the frontiers in basic research for energy, defense and other critical national needs." As for its semantic dissemination, the frontier had already been incorporated into dictionaries in the 1950s, which defined science as a way to explore the unknown territories of knowledge. On the one hand, this popularization is an indication of a "dying metaphor." On the other hand, the fact that "it does not appear in all dictionaries suggests that the frontier of science is a fairly recent locution and that its historic resonances are not lost on the interpretive communities that encounter it" (Ceccarelli 2013: 33).

Against the background of the specific meaning of the frontier in the American context, the question that needs answering is why EU research policy makers, as well as the body of experts who advised the Commission (Harris et al. 2005), adapted the metaphor. To recall, the Commission resorted to the frontier concept in its legal proposal for establishing the ERC under FP7, although everyone knew that the ERC was all about funding "basic research." So why exactly was it that "frontier" rather than any other qualifying term was used to pinpoint the ERC's mission, given that EU policy-makers could resort to concepts more conversant in Europe? To answer this question, a functional perspective on language is helpful: the frontier helped European policy-makers circumvent the traditional distinction of basic and applied research—with its potential antagonistic meaning. This evasive strategy was even made explicit on the ERC's website: "Today the distinction between 'basic' and 'applied' research has become blurred. . . . As a result, the term 'frontier research' was coined for ERC activities since they will be directed to fundamental advances at and beyond the 'frontier' of knowledge."[14] At first sight, frontier research seems to get reduced to a fill-in concept, as the ERC and the Commission would endanger their own legitimacy by touching upon the social assumptions pertaining to "basic" vis-à-vis "applied" research and embracing the former. At the same time, the ERC attempted to clarify the term "frontier research" by stressing that it reflects a new understanding of basic research: "On the one hand it denotes that basic research in science and technology is of critical importance to economic and social welfare, and on the other that research at and beyond the frontiers of understanding is an intrinsically risky venture, progressing on new and most exciting research areas and is characterized by an absence of disciplinary boundaries."[15] Read sequentially, the ERC and the Commission substitute "basic research" with "frontier research." Additionally, the description of frontier research first promises economic growth, and only second promises social welfare, before it actually points to the original meaning of the term—that is, glorifying "an intrinsically risky venture." That the EU discourse can resort to these fairly old interpretive schemas points to both the impressive capabilities of the Commission as a policy entrepreneur and, more importantly, to how the historical baggage of concepts survives even if these concepts travel through time and space.

The rhetorical move of the Commission seems to have been carefully prepared in the course of policymaking. As mentioned above, before releasing its legal proposal for FP7, the Commission ordered a "high-level expert group report," which was delivered in February 2005 (Harris et al. 2005) and confirmed that the distinction between basic and applied research was obsolete for modern research undertakings. The Commission resorted to a specific mixture of expertise, as it put together scientists; science, technology, and innovation (STI) policy scholars; high-ranking industrial representatives; and members of the Commission. It is noteworthy, however, that the same line of argumentation had been presented by the Commission one year before in the official communication, *Europe and Basic Research* (European Commission 2004), while neither this nor any other earlier document had mentioned the term "frontier research." Given the close interaction of policy experts from the commission and academic experts, it is difficult to assess who was responsible for the decision to introduce the new term. Nevertheless, the point is that these actors in the end came to a common understanding.

The functionality of the new concept for EU science policy was not restricted to the problem of obtaining competencies in basic research funding surreptitiously. Another crucial point emphasized in all reports and legal documents using the frontier metaphor was the geostrategic importance of science in an alleged "war for talents" fought against the United States, Japan, and other new global powers (e.g., European Commission 2004: 7–10). While this geostrategic demarcation discourse shielded both European science and the European Union's internal market from outsiders in a very blunt way, as in the ratified document of FP7, some of this preparatory work needed to be delivered with a subtle package. The best example is given by the title of the aforementioned report, *Frontier Research: The European Challenge,* obviously a combination of two famous book titles, but with some decisive modifications. The first component, *Frontier Research,* evidently referring to Vannevar Bush's report *Science—The Endless Frontier* (1945), implies the necessity of establishing a new European organization functionally similar to the U.S. National Science Foundation (NSF). The second component of the title, *The European Challenge,* alludes to Jean-Jacques Servan-Schreiber's international bestselling book, *The American Challenge* (1968), which presented the United States and Europe in the state of an economic and innovation war,[16] also known as the "technology gap."

The European Union's adoption of the "frontiers of science" metaphor has some notable aspects. Both the Commission and the ERC employed "frontier research" in order to cover tracks that could lead back to the distinction between basic and applied research. While other concepts could have been employed (for example, "strategic research" or "use-inspired basic research"), one cannot dismiss that the NSF was viewed as a role model for the establishment of the ERC. Some would even concede that this remodeling bears traces of the forlorn leitmotif of Europe as being fully integrated in a federalist nation—that is, the "United States of Europe" (Majone 2006: 610). Furthermore, paying tribute to Herbert Hoover's and especially Vannevar Bush's ideas of the frontiers of science alludes to the positive sides of risk-taking that go hand in hand with pioneering research activities. The Commission and the ERC presented all kinds of benefits resulting from frontier research, be it the vast number of U.S. Nobel Prize laureates, the immediate technology transfer from this allegedly breakthrough-type of research into successful market products, or the high citation impact of U.S.-based scientists. Again, the United States were presented as both a role model and a competitor in the same breath, which has empowered a specific European interpretation of the frontier. Beyond that, one can conclude that implementing the frontier metaphor in the European science policy context was not only aimed at establishing a new research funding agency but also a new and bold political approach of the Commission vis-à-vis national European science policy actors, including science funding agencies. Research undertakings funded by the ERC were meant to expand the frontiers of knowledge, but at the same time the Commission had *actually* expanded the political frontiers by seizing new competences hitherto claimed nationally.

Grand Challenges

The establishment of the ERC as a European funding agency dedicated to basic research was the most conspicuous novelty in the Seventh Framework Programme (2007–2013). The subsequent Eighth Framework Programme (2013–2020) came with a new name, "Horizon 2020," and complemented the goals of "excellent science" and "industrial leadership" with a new rationale that built on the notion of "societal challenges" (European Commission 2011a, b).[17] In concrete terms, this meant that funding within the new Framework Programme would focus on six priority areas broadly circumscribed by the issues of health and demographic change, food supply and agriculture, energy security, transport, climate action and sustainability, and security.[18] In the parlance of the Commission, this "reflects the policy priorities of the Europe 2020 strategy and addresses major concerns shared by citizens in Europe and elsewhere" (European Commission 2011a: 5). The term "societal challenges" in these documents is used mostly synonymously with "grand challenges," a term officially introduced in EU policy in 2007 and 2008 to stipulate a new rationale for an all-encompassing coordination within the promised European Research Area (European Commission 2007, 2008). Shortly after, in the so-called Lund Declaration (Swedish EU Presidency Conference 2009: 40) a large coalition of stakeholders and representatives from science policy, industry, and research organizations proposed that "European research must focus on the Grand Challenges of our time moving beyond current rigid thematic approaches."

As in the case of frontier research, the idea of grand challenges is not European by origin. Rather, the concept first appeared in U.S. science policy contexts of the late 1980s, indicating a need for federal funding in the field of computational sciences, especially with regard to the building of supercomputers (Hicks 2016). The first explicit definition can be found in a 1987 report by the U.S. Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), outlining the High Performance Computing & Communications (HPCC) program: "A grand challenge is a fundamental problem in science or engineering, with broad applications, whose solution would be enabled by the application of the high performance computing resources that could become available in the near future" (OSTP 1987: 3). The definition illustrates that the new term is employed to mediate between basic and applied research, if not to revisit their distinction, and to clarify what is meant by basic/fundamental (problems of great concern) and by application (the promise of broad usability). Evidently, problems and solutions are conceived here in technical terms—that is, the idea of grand challenges is still close to what in the former terminology could have been labeled, for example, as application-oriented basic research. Following this stance, institutions such as the National Research Council (NRC 1988a, b, 1995), and star scientists (Reddy 1988; Wilson 1988, 1989) used the grand challenges concept to articulate their research agendas in the fields of computational sciences and artificial intelligence. Strikingly, throughout the 1990s, the concept was nearly exclusively used in these computing-related communities.[19]

After the millennium, however, definitions became broader. The NRC introduced the concept in new disciplinary contexts, such as environmental sciences (NRC 2001a), physics (NRC 2001b), earthquake engineering (NRC 2004), and biology (NRC 2009). The following statement, for example, shows more flexibility in regard to what kind of disciplinary knowledge is necessary to tackle grand challenges, which are now circumscribed as "major scientific tasks that are compelling for both intellectual and practical reasons, that offer potential for major breakthroughs on the basis of recent developments in science and technology, and that are feasible given current capabilities and a serious infusion of resources" (NRC 2001a: 2). By being translated into ever more different contexts, the notion of grand challenges became increasingly associated not only with technical but also with societal problems. This is no surprise, as one important aspect of the grand challenges discourse is its appeal to a broader public beyond academia. As early as in the 1980s, the first protagonists claimed that grand challenges "capture the imagination of the public" (Reddy 1988: 17). Scientists, policy makers, and other stakeholders in the United States (e.g., NRC 2001b: 147; Kalil 2012) and in Europe (e.g., European Commission 2008: 8; Royal Society 2011: 76) have reiterated these arguments ever since. The appeal to a broader public is particularly visible in the *Grand Challenges in Global Health* initiative, announced by Bill Gates in 2003 (Varmus et al. 2003; Varmus 2009).[20]

In 2009, quite simultaneously with the developments in Europe sketched above, the concept became a key element in the Obama administration's *Strategy for American Innovation,* which proposed to "harness science and technology to address the 'grand challenges' of the 21st century" (White House 2009: 22).[21] In 2012, the Office of Science and Technology Policy (OSTP) convened a conference on Grand Challenges (Dorgelo and Kalil 2012), and until the end of the Obama administration in January 2017, the OSTP displayed on its website a definition and a set of "grand challenges" that were funded by diverse U.S. government institutions, such as the National Institutes of Health (NIH), the Defense Advanced Research Projects Agency (DARPA), the National Science Foundation (NSF), the Department of Education (DOE), the National Aeronautics and Space Administration (NASA), and the U.S. Agency for International Development (USAID).[22] Those funding programs aimed at transforming the identity work of scientists and engineers, particularly in regard to collaborative research: the White House asked for "all hands on deck." The rhetoric employed here is an example for how the grand challenges discourse highlights the necessity of multilateral cooperation and collaboration (Keenan et al. 2012; Kallerud et al. 2013; Hoareau McGrath et al. 2014)—in this respect, the discourse moved clearly beyond older notions of applied research.

Discussing the increasingly prominent role of the grand challenges discourse in U.S. science policy, Diana Hicks (2016: 37) suggests that the new concept may be "a new way of seeing research." At the same time, Hicks stresses that the modernist basic/applied schema always lurks in the background. As a consequence, many actors "see the new language as another way of talking about applied research." Following Hicks, this is particularly the case when "grand challenges" are reworded as "societal challenges," which can then be juxtaposed with "scientific challenges" (Hicks 2016: 38). Indeed, the idea that science can and should be harnessed to address societal goals and problems does not seem new at first glance. As early as in the nineteenth century, the concept of "applied science" was associated not only with technological developments, but also with more general ideas of societal progress (see chapter 1). Furthermore, critical debates in the 1960s and 1970s have resulted in ever newer categories pertaining to knowledge production, such as "mission-oriented research" and "strategic research" (see chapters 2 and 3), as well as in the ideals of "interdisciplinarity" and, later, "transdisciplinarity." A common denominator of these new categories was the alignment of science toward real world problems, not defined by disciplinary developments but by societal demands.

Against this background, several science policy scholars have considered the grand challenges discourse as a reformulation of mission-oriented R&D programs (Gassler, Polt, and Rammer 2008; Cagnin, Amanatidou, and Keenan 2012; Foray, Mowery, and Nelson 2012; Mowery 2012; Amanatidou et al. 2014). In contrast, Hicks (2016) and some other observers avoid equating the grand challenges concept with traditional research categories and instead investigate whether and in what sense grand challenges are more than "old wine in new bottles" (Kallerud et al. 2013: 2; Calvert 2013: 475; Ulnicane 2016; Kaldewey 2017). This perspective is important because if we subsume the new discourse under an established concept, we miss the chance to elicit whether and how the new semantics transform the very categories we used before.

What, then, distinguishes the grand challenges concept from older categories of applied research and from those concepts that mediated between basic and applied research, as, for example, Stokes's (1997) notion of "use-inspired basic research"? The main difference is that grand challenges are no research category in the narrow sense, but rather represent a discourse about the role and future mission of the scientific community. In most definitions, grand challenges are conceptualized as long-term and large-scale research goals, determined by heterogeneous societal stakeholders. Thus, they enable actors to construct alternative objectives of science and science policy vis-à-vis the twentieth-century ideal of "technological innovation." Many observers therefore associate the grand challenges idea with new conceptions of innovation, such as "social innovation," "green innovation," or "responsible innovation."[23] Ideally, this means a democratization of priority-setting that would make science more independent of economic interests.[24] Furthermore, the idea that grand and global challenges have to be addressed by close cooperation between different actors and beyond national borders is obviously related to the idea of a social contract between science and society[25]—yet quite a different one, if compared to the contract idea we know from twentieth-century science policy. Jane Calvert (2013: 475), for example, suggests that introducing grand challenges indicates a "political renegotiation of the value of science." If grand challenges are understood as "publicly stated priorities," then they "could be seen as part of an attempt to establish a new contract for the public funding of science."

However, such analytical definitions of grand challenges do not explain the relevance of the discourse for present-day transformations of the identity work in science and science policy. To assess whether the grand challenges concept really is able to replace the "tired categories" (Hicks 2016: 39) of twentieth-century science policy, one has to take a closer look at the history and performativity of the concept, its tacit presuppositions, and the deep structure of the discourse in which it is embedded (Kaldewey 2017). Historical semantics teach us that language in general and contested concepts in particular are both "indicators" and "factors" of social and political change (Koselleck 2004: 251; see also Olsen 2012: 171). To understand whether and how the grand challenges discourse can actually be interpreted as a driving force in the history of science policy, it is necessary to trace its origin, its changing meaning, and how it has diffused and proliferated in various contexts within and beyond academia.

In plain English, both the noun "challenge" and the adjective "grand" convey a meaning that evolved independently of any scientific or science policy context. The term "challenge" has its origin in Middle English, where it was used in the sense of "accusation" (as a noun) or "to accuse" (as a verb). Being confronted with a challenge implied a demand to stand up against an accusation. The most salient form of such a challenge was the duel as an arranged combat between two individuals, traditionally noblemen. Following etymological dictionaries, this accusatory connotation died out in the seventeenth century. What remains today is the notion of someone participating "in a competitive situation or fight to decide who is superior in terms of ability or strength."[26] Since the nineteenth century, the term "challenge" has been particularly associated with the sphere of sports. In various disciplines, "challenge cups" have been institutionalized as specific forms of competition, and the event of a "world title challenge" evokes the older meaning of challenging an individual to a duel. There is also evidence that the phrase "grand challenge," which has never been common in everyday speech, has its origin in sports. In 1839, the "Grand Challenge Cup," a men's eight-crew rowing competition, was initiated and institutionalized as the most prestigious event of the annual Henley Royal Regatta on the River Thames; with few exceptions, that competition has continued through to the present under the same name.

It is not until the 1980s that "grand challenges" disseminate beyond the sphere of sports and appear in those peculiar U.S. computational science and science policy contexts described above. Unsurprisingly, during the formative phase of the grand challenges discourse from the late 1980s to the early 2000s, several examples point to the coupling of science and technology developments with the logic of sports. A first example for using sports-like challenges in the sphere of science and technology is the annual international RoboCup competition, which took place for the first time in 1997 in Nagoya, Japan. Some years before, the main figure behind the RoboCup, computer scientist Hiroaki Kitano, had copublished a paper with scientists from the United States, Japan, and Germany, outlining "Grand Challenge AI Applications" and referring explicitly to the grand challenges definition of the American HPCC program (Kitano et al. 1993). Two years later, Kitano and his Japanese colleagues presented the idea of using a "Robot World Cup" as a new "standard problem" for AI and robotics research, from which "a lot of interesting research issues will arise" (Kitano et al. 1995: 1). In short, they considered it a "grand-challenge project" (Kitano et al. 1997: 73).

A second example brings us back to U.S. science policy contexts. In 2003, DARPA announced the plan of a "Grand Challenge for autonomous robotic ground vehicles," intended to spur technological development for military applications.[27] Teams of professionals and amateurs were invited to develop autonomous vehicles able to navigate an off-road course in the desert between Los Angeles and Las Vegas, with the winner being promised prize money of $1.0 million. While the inaugural challenge in March 2004, in which no team completed the course, was reported by *Popular Science* magazine as "DARPA's debacle in the desert" (Hooper 2004),[28] the agency itself was enthusiastic:

> All across the nation, from garages to high schools, from universities to corporate laboratories, hundreds—perhaps thousands—of people worked on solving a problem important to the DoD. We had hoped that the Grand Challenge would excite many people, but it grew into something much, much bigger than anyone had imagined. The Congressionally authorized prize authority inspired many smart people who would not ordinarily work on a problem important to DoD, dedicating long days, nights and weekends toward finding a solution. (Tether 2005: 8)

Immediately after the event, DARPA's director, Tony Tether, stated in a press release that "we learned a tremendous amount today about autonomous ground vehicle technology" and that even those vehicles that did not come very far "made it to the Challenge."[29] In other words, not only did Tether highlight the scientific relevance of the Challenge, but also its character as a sports-like event, which was held a value in itself, as in the Olympic Games, in which "the important thing is not winning but taking part."[30] Consequently, the DARPA Grand Challenge was repeated in October 2005, with the prize doubled to $2.0 million, and this time five of twenty-three vehicles completed the course. The winning team was led by Sebastian Thrun, then the head of Stanford's Artificial Intelligence Laboratory (SAIL) and later responsible for Google's driverless-car program. The event, the team, and the winning car, which was named Stanley, received media coverage (e.g., Davis 2006) and were successful in terms of scientific reputation. The *Journal of Field Robotics* published a highly cited paper with the title "Stanley: The Robot that Won the DARPA Grand Challenge" (Thrun et al. 2006).

The two examples indicate that the meaning enshrined in the grand challenges discourse tacitly introduces aspects of the logic of sports into the science system (Kaldewey 2017). This is particularly noteworthy when we compare the grand challenges discourse to more traditional conceptions of research (as shown in the other chapters of this volume): "pure science" had, at least in the U.S. context, a religious and moral connotation; "applied research" mostly refers to industry and business; and "problem-oriented research," "interdisciplinarity," and "transdisciplinarity" have a decidedly political tone. All of these concepts translate the logic of specific societal spheres (religion, the economy, politics) to make sense of the practices and goals of scientific research. The grand challenges discourse now discloses a new reference point for how we talk and think about science, technology, and their social embeddedness: the logic of sports and competition, leading to self-mobilization and, ultimately, to self-optimization of the participating scientists and engineers.

The structural potency of a concept—that is, its capacity to become a factor of historical change—depends on how successfully it is institutionalized both in discourses and social structures. For example, one reason for the success of the concepts of basic and applied research was their embeddedness as categories in international R&D statistics (Godin 2005). As a result, they were the key to formulating science policies around the world until today. As for the grand challenges concept, it is probably too early to assess whether it will become stabilized as a "social fact" in a way comparable to the linear model of innovation (Godin 2006). There are, however, several indicators pointing to successful processes of institutionalization.

First, as discussed above, the grand challenges concept has become a key rationale for science policy in various contexts, most prominently in the United States and in Europe, but partly also in other cultural contexts, such as India or China (Hoareau McGrath et al. 2014). Second, the concept was picked up in a variety of contexts beyond science policy in the narrow sense. It has been included in the Organisation for Economic Co-operation and Development's (OECD 2010, 2012) innovation strategies, influenced the practices of new philanthropic organizations (Brooks et al. 2009), and was taken up by private think tanks (e.g., Pamlin and Armstrong 2015). Third, the concept is increasingly translated into specific transdisciplinary curricula at renowned universities. For example, in 2007, Princeton University established a "Grand Challenges Program" focusing on issues of climate and energy, development, and health. A glossy pamphlet asks the reader to "imagine a world in which the brightest minds work together to solve humanity's most pressing environmental problems, a transformative world that expands classroom learning beyond traditional academic and national boundaries."[31] More radically, Michael Crow, president of Arizona State University, aimed to achieve a comprehensive reconceptualization of research and teaching, "to seek solutions to the grand challenges associated with sustainability," the result of which would be the "New American University" (Crow 2010). Finally, and this is perhaps the most interesting point, the grand challenges discourse also impacts scientific communication and research practices. There is some evidence that normal scientific publications increasingly refer to grand challenges (as indicated, for example, in figure 9.5). Furthermore, prominent new journals are no longer organized around specific research fields or disciplines; instead, they focus on challenges such as climate change (e.g., *Nature Climate Change,* since October 2010) or energy security (e.g., *Nature Energy,* since January 2016). As publishing is crucial for every scientist, we may assume that a journal expecting its authors to address grand challenges in their research may significantly influence their choice of problem and research trajectories.

Beyond the Dichotomy: From Boundary Work to Identity Work

Science policy discourses in Europe and elsewhere have seen the arrival and adoption of new concepts that leave behind the twentieth-century basic/applied distinction and challenge the linear model of innovation, as well as the ideas of differentiation, orderliness, and contractual relations associated with it. The two concepts discussed in this chapter—frontier research and grand challenges—make visible different trajectories and ideologies of science policy and research planning in the twenty-first century. At the same time, they are comparable in their character as "travelling concepts" (Bal 2002),[32] not so much in the sense of the original epistemological call for letting "concepts" travel between disciplines for the sake of seizing common understandings (Bal 2002: 24) but in their traceable journey across time, regions, and different social contexts (Hyvärinen 2013: 17)—most noteworthy from the United States to Europe, and from popularized to professional contexts of science policy expertise.

The "frontier" was made prominent in North America as a metaphor conveying liberalist ideas—that is, portraying bold individuals who were unleashed from Europeanist intellectualism and national political regulation to venture out into the unknown and to ultimately bring about prosperity for society. In defiance of its initial intra-academic contestation—Turner's hypothesis of an American exceptionalism triggered a *Historikerstreit*—the frontier became very popular among the public. For decades, U.S. presidents and other prominent decision-makers used the concept to justify spending on risk-taking endeavors in the field of science and technology. The appeal of this U.S. concept for EU science policymaking was not so much due to an allusion to the glorious achievements of U.S. science and its allegedly stupendous funding, but to circumnavigate the distinction between basic and applied research and thus be able to establish a European Research Council. Before, European research policy had been more strictly differentiated between national, transnational, and supranational policies, with the latter being restricted to financing near-market R&D activities. Frontier research, again, was a rhetorical substitute for basic research, but more than this: the ERC's mission is to stimulate scientific individualism and a risk-oriented attitude as opposed to the hitherto integrative—that is, collaborative—research. Thereby, the EU's geostrategy, in which the ERC is embedded, is to battle the alleged preeminence of the U.S. knowledge-based economy. Borrowing a science policy concept from another country to fuel its underlying rivalry is not actually ironic, but reflects the ambivalent position of EU political actors toward the United States, with the latter being a rival as well as a role model (Majone 2006).

In a similar vein, the grand challenges narrative traveled a long journey from its origin in the sphere of sport in the nineteenth century, to the problems of U.S. federal funding of computer sciences in the 1980s, to grand challenge competitions in artificial intelligence and engineering that addressed a broader public, before finally being standardized as a new rationale for science policy around the globe. While "grand challenges" thus journeyed back and forth with regard to the national und supranational political contexts of the United States and Europe, they are at the same time conceived as "global challenges," referring to pressing issues that lie beyond political borders. They call not for national policies, but for the global community and various stakeholders from politics, science, and the economy to take action. Moreover, similar to the properties of the frontier, the concept of grand challenges instantaneously intertwines failure and success in the face of an immediate or foreseeable struggle; it is not by accident that its semantics are related to and rooted in sports challenges. Recalling the notion of a social contract, the concept offers the bridging of a gap between science and society by embracing potentially all actors, public and private (sometimes philanthropic) ones, to invest great efforts and to coordinate with each other in solving a concrete problem.

What the two concepts avoid are the kind of dichotomies we know from former science policy discourses that built, not least, on the basic/applied distinction. Particularly if seen from the perspective of science policy, these new concepts are not supposed to be negated: funding agencies do usually not support scientists working on problems that are interpreted as petty.

In a similar vein, science policy is increasingly oriented at ultimate solutions, innovations, and impact for society. Hence, there can neither be "small challenges" nor alternatives to the frontier, which is by definition "endless." As a consequence, however, these new concepts are all-encompassing and sticky *because* they have no clear ambit.

This is, after all, how the new science policy discourses axiomatically diverge from older descriptions pertaining to the linear model of innovation. Building on the basic/applied dichotomy, science policy in the twentieth century oscillated between strategies of *boundary work* and strategies of *identity work*: on the one hand, scientists and research organizations could demarcate their work as distinct and autonomous activities; on the other hand, they could also conceive of themselves as being part of a more comprehensive whole. They could creatively "cross the distinction" (Spencer Brown 1969), moving from one side to the other and assigning positive and negative values, depending on context-dependent necessities. In contrast, science policy in the twenty-first century seems to opt out of these oscillations. From now on, *boundary work* is no longer politically correct. Instead, the *identity work* of scientists and research organizations is aligned toward those goals that are associated with the frontiers of knowledge and the grand challenges of world society. In contrast to conflict-laden boundary disputes, the new narratives proclaim the existence of general values and goals toward which the whole research enterprise has to be oriented. The open question is whether it has become more difficult in the twenty-first century for the scientific community to step back—that is, to suspend solving the big problems of humanity in order to conduct "normal science."

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In his book *Wahrheit und Nützlichkeit* (2013), he explored discourses on the goals and values of science in a long-durée perspective. Recent publications in *Minerva* (2017), *Research Policy* (2018, with Tim Flink), and *Science and Public Policy* (2017, with Désirée Schauz) deal with the changing relationship of science and politics, particularly with the contemporary pluralization of science policy discourses and how they transform the identity work of scholars, scientists, and policy makers.

Notes

1. The *Web of Science* core collection includes the Science Citation Index, the Social Science Citation Index, and the Arts & Humanities Citation Index.
2. Quite similar to the linear model of innovation, it seems not to matter that economic theories of public goods are contested (Coase 1974; Callon 1994; Nelson and Romer 1996; Bozeman 2000; Foray 2000). There is a mutually stabilizing correspondence between the linear model and public good theory in how they tell a story of functional differentiation: while the glory days of a caretaking welfare state were not deemed over yet (Esping-Andersen 1990), neither were those whose enterprises had been doing basic research themselves, now that there was market competition that would hardly allow for these activities, while returns on R&D investments dwindled down. Against this background, the state was appealed to provide scientific knowledge as a public good (Scharpf 1999: 36), particularly via basic research, but also through applied research. Enterprises within a nation-state (or within other political realms, such as the European Union) could then take advantage of this public supply, especially in order to remain competitive on international markets. This "market-failure paradigm" (Bozeman 2000) also extends to state regulations—for example, legal frameworks for technology transfer activities, patent law, standardizations, and public procurement.
3. As regards the relationship of narrative and identity, see Somers 1994. This approach, however, is very much focused on individuals and groups. We propose to broaden the perspective and conceive of "identity work" in regard to epistemic communities, and, ultimately, in regard to science in general. To do so, we combine methods from conceptual history and cognitive metaphorical analysis, as outlined in Flink and Kaldewey 2018 and Flink and Peter 2018.
4. After World War II, the United States had become an international role model for science policy. The concept of "basic research," in particular, can be regarded as an extremely successful science policy export product (see the introduction to and chapter 3 of this volume). What we show in this chapter is that the influence of the United States regarding the global language of science policy goes far beyond this single concept.
5. As regards these concepts, see Benoît Godin, "X-innovation: A Story of Appropriation and Contestation" (unpublished manuscript). For an analysis of "responsible research and innovation" (RRI) see Flink and Kaldewey 2018.

6. Though rarely documented (e.g., Nature News 1968; King 1968), there were various plans or de facto realizations of what could count as today's ERC—e.g., the Royal Society's European Scientific Exchange Program, plans to establish a European Medical Research Council, the Cooperation for Science and Technology (COST, founded in 1971), a European Scientific Research Council (planned in 1972), and the creation of the actual European Science Foundation (ESF) in 1974.
7. The Royal Society first assailed the Commission (Nature Editorial 1995), followed by molecular biologists, about the prestigious European Molecular Biology Organization (EMBO) (Abbott 1995; Gannon 2000, 2001, 2002; Breithaupt 2003), with the latter teaming up with the Federation of European Biochemistry (FEBS) to streamline and widen their efforts of what would become the *Initiative for Science in Europe.* Other national and transnational R&D actors joined the cause of this epistemic community more or less overtly. This movement was reinforced by prestigious scientific journals, such as *Nature* and *Science* (Flink 2016). The ERC became a salient issue for EU research policy and, at the latest stage of agenda setting, it lobbied for prominent conferences organized under the auspices of the Swedish, Danish, and Irish EU presidencies from 2001 to 2004.
8. There are Frontier cafés and cinemas, Frontier Airlines headquartered in Denver, and various other business enterprises carrying the name, such as the primary Frontier School of Innovation in Kansas City, as well as the Energy Frontier Research Centers, established by the Office of Basic Energy Sciences in the U.S. Department of Energy's Office of Science, to provide just a few examples.
9. Turner—until his presentation a nobody among historians—became immediately famous due to his presentation in Chicago, as the Historical Association convened openly during the World's Columbian Exposition, and its speeches, especially those celebrating U.S. achievements since 1492, attracted large extramural audiences.
10. While Turner could not present any clear definition of the frontier whatsoever, his thinking and metaphorical writings borrowed greatly from evolutionary human geography and biology. It conjectured that people entering the American society would turn into "new men." These were called "germs" that become part of a "social organism," thriving and prospering even and especially in the face of adverse conditions (Coleman 1966: 24–26).
11. Again, Turner distinguished his ideal brave and experimental scientists from the image of a traditional and conservative scholar restrained by deep contemplation.
12. Hoover took up Turner's idea of a frontier of science in his book *American Individualism,* which he wrote in 1922 as secretary of commerce. In Herbert Hoover's presidency (1929–1933), the Great Depression gave him an incredibly hard time, and he still adhered to the same metaphor in trying to deliver messages of hope for a suffering society (Hart 2010).
13. Notably, most science policy-related references to this report circumvent discussing the concept of the frontier, while focusing on its relevance pertaining to the linear model of innovation, whereby basic research is usually emphasized. This lack of scholarly attention is criticized by Ceccarelli (2013: 43–45).

14. "Mission." *About ERC.* European Research Council website. European Commission. Retrieved 27 May 2016 from https://erc.europa.eu/about-erc/mission.
15. "Frontier Research." *Glossary.* European Research Council website. European Commission. Retrieved 27 May 2016 from https://erc.europa.eu/glossary/term/267.
16. According to Servan-Schreiber, Europe was outclassed by the United States in management and technology development and suffered from heavy brain-drain of top-talented workforce.
17. This alleged newness should not hide the fact that the political predefinition of thematic priorities concerning the tackling of societal issues has been a strong rationale as of the Third Framework Programme, most notably with respect to health, energy, and environment (Kuhlmann and Reger 1995; Abels 2003). However, the Framework Programmes have been set up primarily to boost the technology and innovative capacities of business enterprises, and, therefore, societal issues were hitherto subordinated.
18. From the estimated total budget of 77 billion euros, 29.7 billion euros—that is, on average, 4.2 billion euros per year—have been dedicated to this new rationale (European Commission 2013). The distribution of the money explains something about real priorities: (1.) "Health, demographic change and wellbeing"—7.4 billion euros; (2.) "Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the Bioeconomy"—3.9 billion euros; (3.) "Secure, clean and efficient energy"—5.9 billion euros; (4.) "Smart, green and integrated transport"—6.3 billion euros; (5.) "Climate action, environment resource efficiency and raw materials"—3.1 billion euros; (6.) "Europe in a changing world—Inclusive, innovative and reflective societies"—1.3 billion euros; (7.) "Secure societies—Protecting freedom and security of Europe and its citizens"—1.7 billion euros.
19. There are, however, some early references to grand challenges in the field of environmental research (Brown 1994), in ocean and polar sciences (Hempel 1996; Prandle 1997), in geophysical research (Lyons 1998; Raeder et al. 1998), and in regard to educational problems (Ehrmann 1999).
20. Notably, Nobel Prize winner Harold Varmus, who chaired the international board of scientists that was responsible for the program, himself became world famous for his earnest attempts to make research, especially in medicine, accessible for scientists and practitioners of developing countries, which, among other initiatives, led to the creation of the Public Library of Science (PLoS) and boosted the open access movement.
21. In the following years, two updated versions of this report were published (White House 2011, 2015). During that time, the strategy evolved from simple to-do lists to a new and ambitious policy tool (Hicks 2016: 31–34).
22. See "21st Century Grand Challenges" on the archived Office of Science and Technology Policy website, retrieved 27 July 2017 from https://obamawhitehouse.archives.gov/administration/eop/ostp/grand-challenges.
23. The "Responsible Research and Innovation" framework of the European Com-

mission, for example, is intimately connected to the goal of tackling societal challenges. See, for example, the leaflet entitled "Responsible Research and Innovation: Europe's ability to respond to societal challenges," retrieved 3 August 2017 from https://ec.europa.eu/research/swafs/pdf/pub_public_engagement/responsible-research-and-innovation-leaflet_en.pdf.

24. Several authors formulated this hope, however, at the same time they criticized the idea of grand challenges for remaining stuck within the logic of capitalism or neoliberalism (Brooks et al. 2009; Vostal, Silvaggi, and Vasilaki 2011; Cech 2012; Calvert 2013).
25. An example for a close coupling between the reference to grand challenges and the idea of a new contract is the 2011 report from the German Advisory Council on Global Change (WBGU 2011).
26. "Challenge." *Oxford Dictionary of English,* current online version, retrieved 27 July 2017 from https://en.oxforddictionaries.com/definition/challenge.
27. "DARPA Plans Grand Challenge for Robotic Ground Vehicles," press release, 2 January 2003, retrieved 15 June 2016 from http://archive.darpa.mil/grandchallenge04/media/announcement.pdf; "DARPA Outlines Plans for Grand Challenge at Competitors' Conference," press release, 22 February 2003, retrieved 15 June 2016 from http://archive.darpa.mil/grandchallenge04/media/comp_conf_rel.pdf.
28. The playing field was set with 142 miles and a time limit of ten hours. None of the fifteen vehicles actually making it over the scratch line reached the goal, and the four most successful teams only managed five to seven miles before their vehicles dropped out.
29. "American Innovators Take Robotic Technology into the Field during Saturday's Inaugural DARPA Grand Challenge," press release, 13 March 2004, retrieved 15 June 2016 from http://archive.darpa.mil/grandchallenge04/media/innovators.pdf.
30. This famous phrase was part of a speech given in London in 1908 by Pierre de Coubertin, founder of the International Olympic Committee.
31. "Grand Challenges Program," Princeton University website, retrieved 19 August 2015 from http://www.princeton.edu/grandchallenges/about/progress-report/gc_pamphlet.pdf.
32. The term "traveling" is metaphorical by itself and certainly does not suggest that concepts desert their semantic provenance. The concept might be still meaningful within the social world it arose from, while it now also appears somewhere far away from its very origination to convey cognate ideas.

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