FROM BIOTECHNOLOGY TO BIOECONOMY: POLICY TRANSITION, SPATIAL IMPLICATIONS, AND REGIONAL PATH DEVELOPMENT

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AA	Auswärtiges Amt – Federal Foreign Office
BE	Bioeconomy
BMBF	Bundesministerium für Bildung und Forschung – Federal Ministry of Education and Research
BMEL	Bundesministerium für Ernährung und Landwirtschaft – Federal Ministry of Food and Agriculture
BMU	Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit – Federal Ministry of the Environment, Nature Conservation and Nuclear Safety
BMWi	Bundesministerium für Wirtschaft und Energie – Federal Ministry for Economic Affairs and Energy
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung – Federal Ministry for Economic Cooperation and Development
BT	Biotechnology
CFC	Chlorofluorocarbons
CORDIS	Community Research and Development Information Service
CSR	Corporate Social Responsibility
EAFRD	European Agricultural Fund for Rural Development
EC	European Commission
EEG	Evolutionary Economic Geography
ERDF	European Regional Development Fund
ESF	European Social Fund
EU	European Union
FDI	Foreign Direct Investments
FP7	7th Framework Programmes for Research and Technological Development
FPB	Framework Programme Biotechnology – Rahmenprogramm Biotechnologie
GIS	Global Innovation System
GMO	Genetically Modified Organism
GPT	General Purpose Technology
GRW	Gemeinschaftsaufgabe ‚Verbesserung der regionalen Wirtschaftsstruktur' – Joint Task 'Improvement of the Regional Economic Structure')
GSC	Grand Societal Challenge

ICT	Information and Communication Technology
IPK	Leibniz-Institut für Pflanzengenetik und Kulturpflanzenforschung – Leibniz Institute of Plant Genetics & Crop Plant Research
KBBE	Knowledge-based Bioeconomy
KET	Key Enabling Technology
LPS	Leistungsplansystematik – Benefit Plan Systematics
NFSB	Nationale Forschungsstrategie Bioökonomie 2030 – National Research Strategy Bioeconomy 2030
NIS	National Innovation System
OECD	Organisation for Economic Co-operation and Development
PPP	Public and Private Partnership
PV	Photovoltaic
RIS	Regional Innovation System
SDG	Sustainable Development Goals
SME	Small and Medium Enterprises
TIS	Technological Innovation System
UK	United Kingdom
UN	United Nations
USA	United States of America

'I don't think the primary purpose of […] the entirety of the human race is just to blindly consume, to support a failing economy and a faulty system […] until we run out of every resource […]

I don't think we're supposed to sit by idle, whilst we continue to use a long outdated system, that […] ruins our environment and threatens every aspect of our health […]

I don't think how much military equipment we are selling to other countries, how many hydrocarbons we're burning, how much money is being printed and exchanged, is a good measure of how healthy our society is

But I do think I can speak for everyone when I say
We're sick of this shit!

Time to mobilise, time to open eyes!*'*

Roughton 'Rou' Reynolds [Enter Shikari – Gandhi Mate, Gandhi]

1 INTRODUCTION

The hunger for growth in all areas of economic activity has undoubtedly brought unprecedented prosperity to many parts of the world. At the same time, this sheer insatiable hunger has created a multitude of negative externalities. Anthropogenic climate phenomena, overexploitation of ecosystems, increasing social disparities within and between countries, and humanitarian crises are only a few fragments of the 'dark side' of innovation and growth-oriented thinking (MERTON 1936; MEADOWS 1972; LEE 2011; BIGGI & GIULIANI 2020). As these aspects become increasingly researched, it seems that companies, the society, and politicians are also paying more attention to these insufficiencies. Some companies react (strategically) by putting emphasis on corporate social responsibility (CSR) (PORTER & KRAMER 2006). Parts of society are increasingly raising these issues in pop culture (as in the initial quote from the band Enter Shikari in 2012), books and social media, or in social movements such as Occupy, Fridays for Future, and Extinction Rebellion. The emerging involvement of green parties in parliaments and governments (e.g. in the latest election of the European Parliament 2019 (EP 2019)) also reveals that there is a change in thinking taking place and the 'harder, better, faster, stronger' mentality is gradually losing some of its momentum in industrial nations.

Hence, in order to tackle far-reaching negative externalities, policy measures that were initially aimed purely at economic growth have been altered in line with changing contextual frameworks (KATTEL & MAZZUCATO 2018; SCHOT & STEINMUELLER 2018). For instance, the acknowledgement of Grand Societal Challenges (GSC) in the EU's Horizon 2020 programme in 2014 (EU 2020) and the formulation of 17 Sustainable Development Goals (SDG) by the UN in 2015 (UNITED NATIONS 2015) represent landmarks for supranational authorities to provide a guiding structure.

An approach to change the economic system, which commonly puts the utmost priority on unlimited growth on a finite planet, is its transformation into a bio-based economy (or bioeconomy). First conceptualisations date back to 2004 (PATERMANN & AGUILAR 2018) and, subsequently, concrete endeavours to pursue this goal have been announced by governmental instances (e.g. OECD 2009; BMBF 2010; EC 2012; FORMAS 2012). Compared to alternative economic theories, such as post-growth or sufficiency theories, technological advancement and economic potency remain crucial driving forces in this framework. In fact, technologies are seen as the enabler and foundation of the bioeconomy. In literature, we find a common understanding that a fluid transition of applied policy measures 'from a biotechnology-centric vision to an economic activity that spreads across several key sectors and policy families' (OECD 2018, p. 11) took place (PATERMANN & AGUILAR 2018). HÜSING et al. (2017) already attested a development in the same vein in Germany one year earlier and thus illustrated the early commitment to actions to promote the bioeconomy.

It is precisely this well-documented shift that now offers the opportunity to understand changes in policies and moreover to detect further implications of this development, i.e., many stakeholders have high expectations for the implementation of a bioeconomy and, following the public discourse, suggest that it is the ultimate solution for a wide range of problems. The German Bioeconomy Council, for example, states that the bioeconomy will contribute positively to at least six SDGs (LANG 2018). RONZON & SANJUÁN (2020) provide evidence that the bioeconomy concept might affect twelve SDGs. While further research in social sciences deals with the bioeconomy's scope and depth (e.g. BIRCH & TYFIELD 2013; BUGGE et al. 2016), its degree of sustainability (e.g. SHEPPARD et al. 2011; PFAU et al. 2014), or which strategies have emerged and might work best for implementation (e.g. MCCORMICK & KAUTTO 2013; STAFFAS et al. 2013; BESI & MCCORMICK 2015), there is a lack of analyses regarding the bioeconomy's geographical dimension. Spatial implications that are caused by the change of course in politics and what consequently happened on the regional level are relevant questions that need to be addressed.

In the past, innovation policies were widely known for primarily supporting urban areas with emphasis on high-tech industries, at least in developed countries (ERGAS 1987; LEE & RODRÍGUEZ-POSE 2016). Place-based biotechnology contests such as BioRegio in 1997 and BioProfile in 1999 are prime examples of this kind of policy (DOHSE 2000; DOHSE & STAEHLER 2008). Now there is the presumption that a more inclusive approach will be adopted, induced by the introduction of the bioeconomy scheme. The Federal Ministry of Food and Agriculture (BMEL 2014, p. 20), for instance, claims in its *National Policy Strategy Bioeconomy* that the bio-based economy will contribute by 'securing and creating employment and added value, especially, in rural areas'. Policy measures that aim to include peripheral regions and not only focus on creating, but also diffusing innovations, provide the opportunity to level out regional disparities and differences in living conditions (MCCANN & ORTEGA-ARGILÉS 2013). This means that combining high-tech solutions (i.a. from biotechnology, nanotechnology and digital technologies) with traditional industries situated in rural areas (e.g. agriculture, food industries, pulp and paper industry) is a promising way to shake-up locked-in structures. Thus, a new generation of policy design shows the evolution of the political course, but alongside this it also enables an investigation into whether the resolutions to change the manner in which funding is applied are also reflected in the spatial distribution.

This, naturally, leads to consecutive questions about regional path development, i.e., when the general framework of a national system changes to a certain degree, it presumably causes effects on a regional scale since the concerned actors are embedded in unique environments (FREEMAN 1987; ASHEIM et al. 2011b). At the same time, regional economies underlie incessant path dependent processes that ordinarily do not change significantly in a short time, but rather develop into related industries (MARTIN & SUNLEY 2006; MARTIN 2010; NEFFKE et al. 2011). Against the backdrop of shifting bio-themed policies, central issues on the regional level are of interest – e.g. the role played by existing structures in the development of the bioeconomy, the effect of being or not being promoted and receiving grants due to a biotechnology contest, or which structural characteristics are beneficial within the bioeconomy framework.

In their entirety these deliberations illustrate the multiplicity and complexity of the global societal system. In this case, it shows clearly how anthropogenically generated activities on all tiers worldwide have resulted in a situation whereby, via the intermediary of further instances, regional paths might (and must) finally change in the long-term. In a similar manner, this dissertation addresses research gaps from macro to micro-levels in order to study the described change from biotechnology to bioeconomy and associated research questions in their rich diversity. The reference framework for this exploration is as follows: Germany has been chosen as the observation unit and main subject for three main reasons. First, as previously mentioned, the German innovation policy changed in a way that is ideal for the intended analyses. Secondly, in quantitative research data availability is always a determining factor. The publicly available funding database 'Förderkatalog' of the Federal Ministry of Education and Research (BMBF) allows access to crucial information about the majority of funded projects within the last decades. Thirdly, the author speaks German fluently, which enables him to find and understand relevant documents and data more easily for comprehensive analyses. The observation period comprises the years 1995 to 2015, for the following two reasons: Firstly, the first serious political conceptualisations of the bioeconomy were formed in the late 2000s, ergo they are still quite young. The purpose of this doctoral study is to detect structural differences during and due to the transition. Secondly, the BioRegio contest, announced in 1995, represents a cornerstone in the introduction of new approaches by policy-makers. The intention of the contest was to establish a vibrant biotechnology sector in Germany and it has been object of many scientific investigations to date (cf. DOHSE 2000; EICKELPASCH & FRITSCH 2005; ENGEL et al. 2013; GRAF & BROEKEL 2020). Including this policy programme in the project opens up the possibility to evaluate it from different perspectives. The observation period ends in 2015 for one simple reason: The work for this doctoral thesis started in 2017 and the data suggested that the data entry for the year 2016 was incomplete at that time. Hence, 2015 as the last fully covered year marks the end.

Given this opportunity to understand structural shifts of political leitmotifs and instruments, this dissertation aims to highlight apparent as well as latent implications that are thereby induced. Theoretical considerations from a variety of research fields such as economic geography, politics and economics are tested by using primarily quantitative data and methods. Hence, this dissertation seeks to shed light on different aspects to comprehensively answer the question

> **'How has the transformation from biotechnology to bioeconomy evolved in Germany and what were the fundamental consequences from the point of view of economic geography?'**

In order to address this research question, this doctoral thesis is subdivided into one conceptional study to structure and operationalise the bioeconomy and three studies that cover the following questions:

Study [i]: How has mission-oriented innovation policy changed in the past and in what way are novel priorities implemented? In what way did the change in leitmotif from biotechnology to bioeconomy occur, how pronounced was this shift and what sectors benefitted the most?

Study [ii]: Is the growing bioeconomy a potential avenue for putting a more inclusive innovation policy into practice? Have the funding patterns changed spatially due to the modifications of policy objectives? Do rural regions benefit from the pursuit of a bio-based economy?

Study [iii]: How is the transition from sectoral to holistic funding reflected at the regional level? Which impact have place-based biotechnology contests had on regional development? What types of path development are identifiable and which specific regions have adapted to the new scheme to a particularly high degree?

To get to the bottom of these research questions, this dissertation consists of seven chapters, where the three main studies proceed from the general to the concrete. The structure is as follows and depicted in Fig. 1-1:

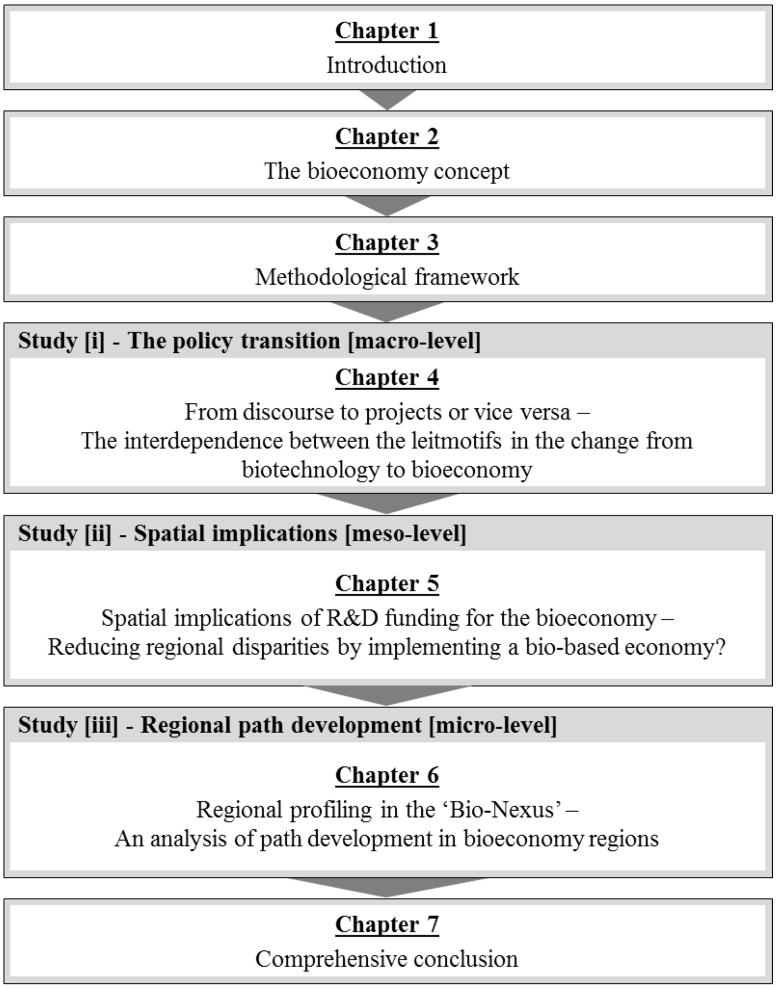


Fig. 1-1: Structure of the dissertation

Firstly, a brief introduction frames the general topic, specifies the research objectives and design, and illustrates which academic gaps can be filled by the thesis.

Chapter 2 provides an overview of how the bioeconomy as a political concept can be defined and which parts of the economy fall into this construct. Since the bioeconomy has no uniform definition and many stakeholders have very differing understandings of this notion, it is still a fuzzy image. For that reason, it is imperative to first clarify the boundaries of the bioeconomy, what it comprises and what sources this view is based on.

In chapter 3, the methodological background is presented. Although additional data have been used in each of the three studies, the funding database 'Förderkatalog' of the BMBF forms the main basis of all analyses carried out in this dissertation. As mentioned, the bioeconomy is a quite vague concept. That leads to the necessity to tailor the data in order to provide a sensible representation of bioeconomy funding in Germany. For the sake of transparency a detailed description of the data-generating process is described in this section.

The fourth chapter contains the first original study in the doctoral thesis. It focuses on the evolutionary character of innovation policies and illustrates how the transition from biotechnology to bioeconomy can be observed at different levels. By taking the example of the growing relevance of the bioeconomy in innovation policy, it is possible to draw inferences about the mechanisms in policy-making processes. Mission-oriented innovation policies have gained momentum in the last decades, but they are still quite controversial because they have a reputation for distorting natural competition. Thus, the emerging mission 'bioeconomy' gives new insights about whether there is a strict top-down process from agenda setting to implementation or if bottom-up flows can also be detected. This study contributes to a better understanding of policy-making processes, which are still a black box for academic research. Moreover, by breaking down this development, the scope, scale and progress of the bioeconomy in Germany also becomes clearer.

In Chapter 5, the geographical dimension is considered in more detail for the first time. The theoretical deliberations are concerned with the inclusiveness of innovation policies. Innovation is mainly seen as the essential driver for economic growth and wealth. However, critical thoughts about the negative aftermath, such as growing regional disparities and environmental issues, are increasingly being expressed. For that reason, this study investigates structural characteristics of the bioeconomy that might lead to a greater involvement of rural and peripheral regions. In order to detect spatial patterns in bioeconomy funding, comparative regressions and cluster analyses are employed. This case draws attention to the role of innovation policy that, for the sake of more equal living conditions, goes beyond merely funding high-tech branches in urban environments. It also investigates which role the bioeconomy is able to play in this regard and how the policy shift is reflected in geographical terms.

Chapter 6, deals with the development of bio-themed funding at the regional level. Evolutionary thinking is currently the principal theorem in economic geography. Drawing on this, this study examines how the biotechnology-bioeconomy-conversion has unfolded in individual regions and aims to compare different types of path development in an exploratory manner. Since it is likely that path-dependent tendencies determine the engagement of regions in the bioeconomy, the participating regions of the two place-based biotechnology contests BioRegio and BioProfile were examined with regard to their further development.

Moreover, cluster analyses are carried out with the intention of identifying regions that specialise to a certain extent within the scope of the bioeconomy. This research aims to enrich the theoretical frameworks of path development literature, which is somewhat lacking in quantitative empirical studies (apart from those looking at path branching). Moreover, the examination of specific regions that have engaged in the bioeconomy delivers insights for regional policy-makers about starting points for the implementation of bioeconomical activities and also what drives regional development.

In chapter 7 the central results of the dissertation are outlined and comprehensively discussed before the research design is critically reviewed and future research avenues are presented.

The framework of this doctoral thesis rests upon the BMBF research project ‘B2BFuture – Von der Biotechnologie zur Bioökonomie – Analyse von öffentlicher Forschungsförderung, technologischen Pfaden und Innovationsdynamiken im Zeitraum zwischen 1995 und 2015 in Deutschland’ (‘From Biotech to Bioeconomy – Analyzing public R&D support, technological paths, and innovation dynamics between 1995 and 2015 in Germany’). The Universities of Bremen and Greifswald jointly executed this project from 2017 to 2020. The project was primarily conceptualised by Muhamed Kudic and Daniel Schiller and carried out by Mariia Shkolnykova and myself. Both sub-projects deal with the transformation from biotechnology to bioeconomy. While Mariia Shkolnykova focussed primarily on network structures of dedicated biotechnology firms in patents, the presented study concentrates on the policy transition and the implications at a higher level.

2 THE BIOECONOMY CONCEPT

When speaking about the bioeconomy, it becomes apparent that the technical term bioeconomy (synonymous with 'bio-based economy') is understood in several different ways and there is neither political consensus about its meaning not consensus amongst individual politicians, economic actors, bioeconomy experts and researchers. Thus, to make the bio-based economy measurable, a solution is required for this issue. In the past, assorted institutions and researchers have attempted to define the bioeconomy using various approaches.

GOLEMBIEWSKI et al. (2015, p. 309) highlight that the origin of any bioeconomy definition lies in 'vision-like publications provided by public and governmental institutions'. While some perceptions of a bio-based economy both from a policy and research perspective mainly focus on biotechnological innovations (cf. THE WHITE HOUSE 2012; WIELD 2013; CARLSON 2016), namely the red biotechnology (i.e. health related biotechnology such as biopharmaceuticals), and do not capture the holistic nature of the concept, most stakeholders acknowledge that the bioeconomy goes beyond this narrowly delineated approach. The German government was one of the earliest national administrations to stipulate a dedicated bioeconomy strategy. It includes goals such as global food security, sustainable agricultural production, production of healthy and safe foodstuffs, industrial utilisation of renewable raw materials and energetic use of biomass and thereby illustrates the broader definition of the subject (BMBF 2010). To achieve these goals a transformation from an oil-based to a bio-based economy is suggested, but the concrete scope of this concept is left open to the reader. In further strategy papers of supranational or national authorities one finds different approaches and very individual perceptions of the bioeconomy.

Some researchers, therefore, have attempted to systematise and standardise the notion of a coherent bioeconomy. One approach to capture the underlying theory of a bio-based economy was phrased by BUGGE et al. (2016), who performed a bibliometric analysis of academic literature in order to identify the components of the bioeconomy. They came up with three key characteristics to distinguish between visions for technology, resources and ecology. However, since this study is mostly driven by literature from natural and engineering sciences, it neglects the involvement of a societal facet. Moreover, these three suggested pillars are rather roughly outlined and do not give much information about the industrial sectors included. Nevertheless, the analysis still provides valuable input for a better understanding of the bioeconomy's scope.

Due to the lack of a uniform and tangible understanding of bioeconomy, it was necessary to find a coherent definition for the bioeconomy notion that was suitable for an empirical analysis. Therefore, we gathered data and conceptions from various actors involved with the bioeconomy concept and systemised their opinions within a breakdown of the bioeconomy along the value chain. Since the bioeconomy is 'largely driven by policy action and the contents of bioeconomy strategies worldwide' (VIAGGI 2016, p. 105), the political vision has naturally determined our definition to a large degree (see Table 2-1)[1]. Thus, the derived definition has a broad range, similar to the German strategy paper NFSB. We propose a breakdown into four pillars: the *input*, *processing* and *output dimensions* as well as a *socio-economic framework*. Hereinafter follows the description of each pillar's elements in detail.

2.1 Input dimension

The production or cultivation/breeding of biomass primarily includes the directly connected sectors agriculture, forestry and fishery. Apart from the production itself, which often occurs in a conventional manner, the ecological and sustainable aspect of the production plays a fundamental role here; i.e. alternative cultivation methods, pest control and fertiliser adapted to the environment or further measures to produce by means of suitable practices. Furthermore, issues linked to more efficient, reliable and responsible cultivation of plants or animal husbandry, which improve the health or general conditions of the generated organic output, belong to this class. In a nutshell, we aggregate the entirety of **agriculture, forestry and fishery** into this class and additionally, all efforts that make these sectors more sustainable, efficient branches that contribute to the implementation of the bioeconomy.

A second facet of the production side is the issue of **climate and environmental protection** to ensure the feasibility of biomass production. This encompasses prevention and acute protection measures. At the same time, it implies research about the impact of specific aspects on the ecosystem and the elaboration of appropriate actions in order to protect the environment or to allow it to recover. Topics that belong in this field are, for instance, coastal management, emission reduction, preservation and support of biodiversity and the prevention of soil degradation.

[1] The list makes no claim to be comprehensive. Its intention is merely to help the reader understand our bioeconomy definition.

Table 2-1: Parts of the bioeconomy considered by policies and academia

Subject & Objectives	Dimensions	Source
Sustainable agriculture & forestry	Input – agriculture & forestry	GBC 2009; OECD 2009; BMBF 2010; EC 2012; FORMAS 2012; KARP et al. 2015; PIETZSCH 2017; WESSELER & BRAUN 2017
Climate & environmental protection	Input – climate & environment	(OECD 2009; EC 2012; MCCORMICK & KAUTTO 2013; BUGGE et al. 2016; HAUSKNOST et al. 2017)
Green biotechnology	Processing – green biotech.	OECD 2009; BMBF 2010; MCCORMICK & KAUTTO 2013; GOLEMBIEWSKI et al. 2015; KARP et al. 2015; LEE 2016; WESSELER & BRAUN 2017
Blue biotechnology	Processing – green biotech.	EC 2012; MCCORMICK & KAUTTO 2013; BMEL 2014; ZINKE et al. 2016
Red biotechnology	Processing – red biotech.	OECD 2009; BMBF 2010; THE WHITE HOUSE 2012; PETERSEN & KRISJANSEN 2015; BUGGE et al. 2016; GBC 2016; WESSELER & BRAUN 2017
White biotechnology	Processing – white biotech.	AGUILAR et al. 2009; OECD 2009; BMBF 2010; EC 2012; SILLANPÄÄ & NCIBI 2017
Food & feed production/refinement	Output – food & feed	GBC 2009; BMBF 2010; EC 2012; BMEL 2014; VIAGGI 2016; SILLANPÄÄ & NCIBI 2017
Chemicals, organic components	Output – products & materials	GBC 2009; BMBF 2010; EC 2012; STAFFAS et al. 2013; GOLEMBIEWSKI et al. 2015; KARP et al. 2015; SILLANPÄÄ & NCIBI 2017; WESSELER & BRAUN 2017
Pulp and paper industries	Output – products & materials	BMBF 2010; EC 2012; PIETZSCH 2017; SILLANPÄÄ & NCIBI 2017; WESSELER & BRAUN 2017; HERMANS 2018; PURKUS et al. 2018
Energy production from biomass	Output – energy & fuels	BMBF 2010; EC 2012; MCCORMICK & KAUTTO 2013; SILLANPÄÄ & NCIBI 2017
Coherent policies & their evaluation	Socio-economic framework	BMBF 2010; EC 2012; MCCORMICK & KAUTTO 2013; BMEL 2014; DIETZ et al. 2018; PHILP 2018
Communication with & sensitisation of the public	Socio-economic framework	BMBF 2010; EC 2012; BMEL 2014; BUGGE et al. 2016; PIETZSCH 2017
Bio-related education & qualification	Socio-economic framework	EC 2012; FORMAS 2012; MCCORMICK & KAUTTO 2013; BMEL 2014; ZINKE et al. 2016; SILLANPÄÄ & NCIBI 2017
Venture capital, financing of bioeconomy firms	Socio-economic framework	EC 2012; ZILBERMAN et al. 2013; BMEL 2014; GBC 2016; VIAGGI 2016
Networking, partnership, knowledge-diffusion	Socio-economic framework	ALBERT 2007; OECD 2009; BMBF 2010; MCCORMICK & KAUTTO 2013; ZILBERMAN et al. 2013; BMEL 2014; MCDONAGH 2014; BUGGE et al. 2016
Ethics (GMO, animal welfare etc.)	Socio-economic framework	PAULA & BIRRER 2006; BENNETT 2007; MCCORMICK & KAUTTO 2013; BUGGE et al. 2016; SILLANPÄÄ & NCIBI 2017
Competitive land use	Cross-cutting	PIETZSCH 2017
Working in cascade, minimising waste, circular economy	Cross-cutting	LEE 2016; PIETZSCH 2017

2.2 Biotechnology

Another component, if not the very origin of the bioeconomy leitmotif, is clearly biotechnology. This segment is often marked as the most important component of the bioeconomy. According to political ideas, biotechnology, stated by the EU as ‘key enabling technology’, is the driving force behind innovative processes in all upstream and downstream industries (OECD 2009; BMBF 2010; EC 2012). It thus functions as a cross-cutting technology that can be applied in all facets of the bioeconomy. Biotechnology is most commonly subdivided into three segments: green, red and white biotechnology.

Green biotechnology is closely connected to agriculture and involves the research and breeding of plants and crops as well as animals and livestock. Controversial procedures such as gene optimisation of plants and genome editing in general are integral features of this branch. Furthermore, **blue biotechnology**, which deals with the processing and utilisation of biological resources from marine habitats such as algae and fish, is defined solely by the aquatic origin of its resources (EC 2012; ZINKE et al. 2016). It shows major structural overlaps with green biotechnology. We therefore we combined these two segments.

Red biotechnology, which is by far the largest and best-researched subdivision, is dedicated to the medical use of organic substances. Since biotechnology has its roots in the health sector and was heavily promoted by the US National Institute of Health (LAZONICK & TULUM 2011), its past and current focus is human medicine. It deals with the development of therapeutic and diagnostic methods and implies areas such as genome, post-genome and proteome research, systems biology and gene therapy. Due to developments in the past and the potential to gain large revenues from R&D of novel pharmaceuticals obtained using biomass the majority of dedicated biotechnology firms operate in this domain (BIOCOM AG 2018).

While the previously illustrated segments of biotechnology can be clearly demarcated and assigned to a specific industrial sector, the understanding of **white biotechnology** (or industrial biotechnology) is rather blurry. The common definition is the utilisation of biological resources within industrial processes and products (OECD 2009). Consequently, its application area is extremely wide and contains, for instance, the creation of innovative processes and technologies to provide biological basic material (e.g. instead of plastic) or to identify, extract and produce substances from or with organic substances within various industries. Another example is the application of microorganisms in sewage treatment plants during the purification process. It becomes clear that the scope of white biotechnology is quite large (BMBF 2010). We also integrated so-called **grey biotechnology** (environmental procedures) into this category (OECD 2009; ZINKE et al. 2016).

2.3 Output dimension

The output pillar is divided into three segments: products and materials, energy and fuels, as well as the food and feed industry.

The production of bio-based **products and materials** is a output mechanism for biomass (BMBF 2010; STAFFAS et al. 2013). Next to its exploitation as an energy source, the second major field of application for crude oil is the use as a raw material for chemical products such as plastic, rubber, lubricants and fertiliser. However, it goes beyond mere substitution of existing products and includes the development of commodities that fulfil new tasks. One prominent example is the biorefinery concept, which analogous to an oil refinery pursues the goal of refining/disaggregating biological resources into multiple substances with the aim to produce minimal waste and create maximum value from the base material. Traditional branches such as the pulp and paper industries also fall into this category (EC 2012; PURKUS et al. 2018).

A further bioeconomy motif is the reduction of dependency on fossil resources. The majority of fossil resources, especially petroleum, are used as **energy** source for industries, transportation **fuels** and heating. In order to tackle the problem of reliance both on finite sources, but also on trading partners, the focus is on electricity and heat generation using biomass and therefore, part of the bioeconomy vision.

One integral objective of the bioeconomy, stated in Germany's research strategy as the paramount target, is to contribute towards securing the global food supply (BMBF 2010). Apart from the mentioned *input dimension* of sustainably producing biomass and novel breeding methods provided by green biotechnology, the **food and feed** industry is another elemental bioeconomy component.

2.4 Socio-economic framework

Most stakeholders agree that for a successful implementation of the bioeconomy approach, apart from all the fields directly related to biological materials and processes, a socio-economic framework is indispensable. In the case of realising a bio-based economy, it encompasses several generic factors like a coherent policy (DIETZ et al. 2018), viable financing for companies within the bioeconomy (VIAGGI 2016), platforms and arrangements for networking (OECD 2009) as well as the creation of novel professions and corresponding qualifications (FORMAS 2012). In addition, bioeconomy-specific determinants are included. These are especially, yet not solely, the sensitisation of the society towards enlightened and conscious thinking/behaviour to trigger sustainable development (PIETZSCH 2017) as well as a debate about ethical justifiability (e.g. concerning genetically modified organisms or animal welfare) (MCCORMICK & KAUTTO 2013). All these features are bundled in the dimension **socio-economic framework**.

This partitioning of the bioeconomy into its components illustrates that the bio-based economy must be understood as a holistic concept with interdependencies between all involved segments and in consequence, cannot be regarded as a clear-cut concept with distinct and independently assigned branches. To delineate the bioeconomy, we suggest the following definition: The bioeconomy includes, on the one hand, all industries that produce, process or refine biomass. On the other hand, it implies both environmental protection and a socio-economic framework that together contribute to the advancement of bio-based-industries. Table 2-2 recaps the elaboration and classification undertaken to structure the bio-based economy.

Table 2-2: Structure of the bioeconomy

	Dimension	Components
Value Chain	**Input dimension** (production)	agriculture & forestry climate & environmental protection
	Biotechnology (processing)	green biotechnology red biotechnology white biotechnology
	Output dimension (material utilisation of biomass)	products & materials energy & fuels food & feed
	Socio-economic framework including immaterial matters such as	coherent policy viable financing for companies within the bioeconomy platforms and arrangements for networking education and qualification sensitisation of the society

[source: own conception]

One objective of this thesis is to trace the transformation from biotechnology towards bioeconomy. Therefore, it is necessary to distinguish between the initial sector-focussed funding, namely the biotechnology sector, and the additional dimensions of bio-related support, which were conceptualised by the bioeconomy strategy. This is why the components of the bioeconomy concept are henceforth categorised and designated as follows (Fig. 2-1):

- **biotechnology nucleus**: green, red, and white biotechnology
- **bioeconomy shell**: input and output dimensions as well as the socio-economic framework

The biotechnology nucleus and the bioeconomy shell jointly represent the bioeconomy concept.

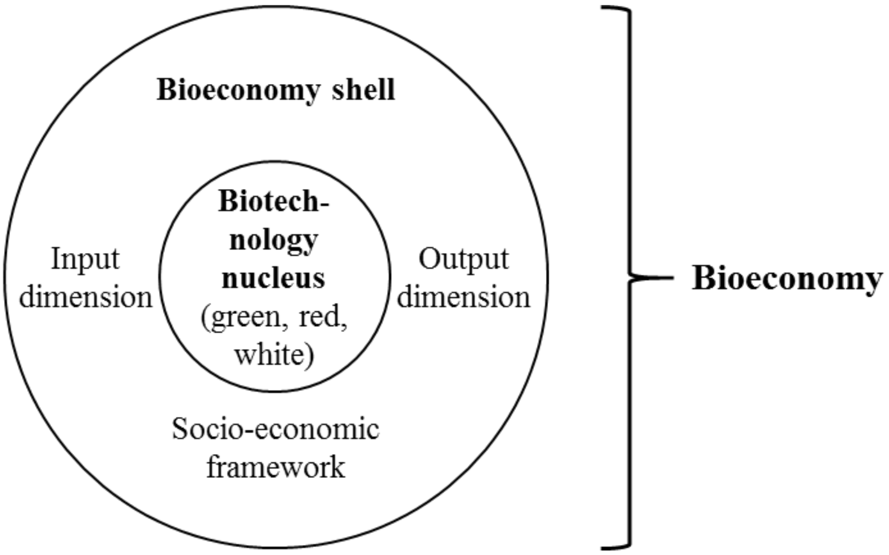


Fig. 2-1: Illustration of the bioeconomy components and structure;
[source: own conception]

3 METHODOLOGICAL FRAMEWORK

3.1 Approaches to measure the bioeconomy

Aside from varying comprehensions of the bioeconomy, a number of institutions and researchers have pursued the measurement of the bioeconomy's scope and economic relevance. In most cases, the superordinate goal was to identify sectors that are directly assigned to the bioeconomy approach. EFKEN et al. (2016) for instance, used the European System of Accounts as a database for calculating the share of each relevant or partially relevant branch and made a distinction in the bioeconomy between primary production, manufacturing, and trade and services. By this estimation, the bio-based economy contributed to approximately six percent of the value added in Germany in 2010. With a similar methodology, based on the NACE classification, and data from Eurostat, PIOTROWSKI et al. (2016) calculated a volume of EUR 2.1 tn. on EU-28 level in 2013. For the United States, CARLSON (2016) estimated the share of a broadly defined biotech-related industry at approximately two percent of US' GDP in 2012 using numerous data from financial reporting and market prices. GOLDEN et al. (2016) used the IMPLAN modelling software with data from US governmental agencies and further literature in order to assess the economic relevance of the bio-based industry (without energy, livestock, food, feed and pharmaceuticals) in the US in 2014. Similar to the previous results, they came to an estimation of approx. 2.2 % of US' GDP in 2014. A collaboration of several institutes in Germany endeavoured to create a design for a self-learning monitoring system, which combines numerous methods to detect and trace the most important streams of biological resources (SYMOBIO 2020). They estimate a bioeconomy share of six to nine percent of Germany's gross value added, depending on modelling (BRINGEZU et al. 2020). On the EU level, the project BioMonitor pursues a similar approach, but has not released any numbers to date (BIOMONITOR 2020).

Common difficulties and measurement issues with regard to the bioeconomy can be found in WESSELER & BRAUN (2017), JANDER & GRUNDMANN (2019) and WYDRA (2020). The presented studies not only exemplify the aforementioned issue of contrasting understandings of bio-based economy, but also visualise the wide range of measurement approaches of researchers.

Evidently, despite all dissimilarities in terms of the bioeconomy perspective or methodological approaches, the common purpose of these examinations is the determination of its scope and magnitude. However, the underlying notion of most dedicated bioeconomy strategies is the knowledge-driven advancement of R&D with biomass to trigger economic development and tackle the EU's 'Grand Societal Challenges' and to reach UN's 'Sustainable Development Goals'. In fact, the increased consideration of the bioeconomy, its rising economic value and prevailing momentum is based on the advance of biotechnological processes and their application, but is not driven by the extensions of biomass production, the unprocessed utilisation of biological resources or a vigorously pushed strategy for sustainability. Particularly the schemes of the OECD, USA, Germany and the EU imply a principal focus on innovative solutions and consequential economic advantages and do not prioritise the sustainability pillar of the leitmotif (HAUSKNOST et al. 2017). Subsequently, besides surveying the actual bioeconomy in its completeness, it is equally interesting to delineate the innovative facet of the bio-based economy.

For this reason, the purpose of this dissertation is not to capture the bio-based economy per se, but to grasp the knowledge-induced bioeconomy that represents the technological and economic instigator of the entire movement. As emphasised in chapter 2, the roots of the bioeconomy lie in a basic idea generated by governmental institutions, for which reason a coherent innovation policy has a considerable impact on the bioeconomy's development. Therefore, we draw on data about public R&D investments in Germany and present a methodology designed to capture all projects relevant to the bioeconomy.

3.2 Data and method

The German government, as most other administrations of developed countries, relies on support strategies in the form of manifold R&D subsidy programmes (CZARNITZKI et al. 2007), with the bioeconomy strategy as an example of these programmes. The expenses for R&D programmes in Germany increased within twelve years from EUR nine bn. in 2005 to EUR 17.2 bn. in 2017 (BMBF 2017d). This development illustrates the importance of German innovation policy on the one hand as well as the purview in which politics try to direct future research objectives on the other.

For the sake of transparency, the BMBF discloses its investments in R&D projects in the German subsidy database 'Förderkatalog' (BMBF 2017b). Now, in order to capture and reflect the funding landscape of the bioeconomy in Germany we made use of the publicly available data. According to a statementby the BMBF, the database contains approximately 95 percent of all R&D projects funded by their ministry (with an increasing tendency). However, it is the responsibility of the other departments (e.g. Federal Ministry of Food and Agriculture, Federal Ministry for Economic Affairs and Energy) to record their projects.

However, the BMBF is not only in charge of implementing the biotechnology and bioeconomy strategies, but also accounts for approximately 58 % of total R&D expenditure in Germany (BMBF 2017a) and therefore, is responsible for the lion's share of all funding. Thus, this database is sufficient in order to make empirical statements about the knowledge-driven bioeconomy funding landscape. By April 2017, the dataset comprised 191,347 projects with valid information, with the earliest entry being from 1968.[2]

The data is structured based on the applied funding measures. This internal BMBF classification is called 'Leistungsplansystematik (LPS) – Benefit plan systematics' and has 22 superordinate topics such as 'A – Health research and health economy', 'D – Food, Agriculture and Consumer Protection' or 'E – Energy research and technologies'. This classification is refined by two further tiers (see Table 3-1 for an excerpt). Eventually, bioeconomy R&D is aggregated in its own category 'B – Bioeconomy'. However, there are two issues which need to be taken into account during the analysis. On the one hand, the segment 'B' includes projects that date from far before the official bioeconomy policy concept was formulated – the first record in this category is dated 1968, whereas the start of the bioeconomy strategy was in 2010. On the other hand, it is apparent that numerous topics or projects within several other classes such as 'EB1920 – Energetic use of biomass', 'GC2060 – Organic electronics' or 'KA1210 – Nanobiotechnology' can clearly be assigned to bioeconomy, but are not covered by this class. Furthermore, there is a certain probability that projects relevant to bioeconomy are grouped in various segments, for instance 'AA0520 – Pharmaceuticals/drug discovery', 'DA0100 – Healthy nutrition, improvement of nutritional behaviour and nutrition information', 'EA6010 – Basic research energy' or 'RB9000 – High-Tech-Strategy'. For that reason we considered it necessary to integrate all these projects that actually operate in the scope of the bioeconomy approach, including projects outside of the category 'B – Bioeconomy'.

The database 'Förderkatalog' is openly accessible and offers valid information about the temporal horizon, the monetary investment, the names of the grantees, as well as the executing organisation along with their respective locations and also information about the collaboration partners in the case of joint projects. We diagnosed two types of information about each undertaking's topic which were most relevant for the identification process. In

[2] It would be interesting not only to analyse the German database exclusively, but also to include information from EU's CORDIS (Community Research and Development Information Service) funding dataset to get a wider scope of public investments. However, apart from excessive matching-issues, the purpose of this analysis is Germany's genuine efforts on the bioeconomy's development. For this cause, the 'Förderkatalog' database constitutes an ample basis for this study.

addition to the BMBF's internal classification (LPS) that elaborates the subject area, the title of the project provides genuine indications about the project's content.

Table 3-1: Excerpt of BMBF's subsidy database 'Förderkatalog' and categorisation ('Division' is manually added by the author)

Funding area	Funding focus	Code	Label	Division
A - Health research and health economy	AA - Health research and health economy	AA0110	Infection	[iii]
		AA0120	Nervous system and psyche	[iii]
		AA0210	Medical genome and post-genome research	[ii]
B - Bio-economy	B - Bio-economy	B00101	Plant research	[i]
		B00102	World food supply	[i]
		B00202	Innovative plant breeding in cultivation system	[i]
		B00601	BioChancePLUS	[i]
		B00604	BioProfile	[i]
C - Civil security research	C - Civil security research	C01010	Scenario-oriented security research	all excluded
		C01020	Technology alliances	
		C01050	International cooperations	
D - Food, Agriculture & Consumer Protection	DA - Nutrition	DA0100	Healthy nutrition, improvement of nutritional behaviour and nutrition information	[ii]
	DB - Sustainable agriculture & rural areas	DB0200	Sustainable agriculture, horticulture, forestry, fisheries and food industry; tapping the potential of renewable raw materials	[i]
		DB0300	Perspectives for rural areas	[iii]

[source: own draft according to BMBF (2017b)]

Given these circumstances and based on the BMBF classification[3], we first categorised the dataset into three divisions on the 1,460 tier 3 level (see Fig. 3-1 and Table 3-1), namely

[i] classes that were ascertained to belong to the bioeconomy,

[ii] classes that only partially belong to the bioeconomy and

[iii] further categories that are unlikely to contain bioeconomy projects[4].

Subsequently, with common text-mining techniques (e.g. removing whitespaces and stop words, converting to lower cases) the project titles were simplified. Considering the main principle of the bioeconomy, namely the involvement of biological materials and processes, it is, in our opinion, an appropriate measure to draw on this basic idea and hence to create a collection of biomass-connected terms and expressions. For that reason, we detected all phrases that belong to biological substances and processes that appeared in at least five

[3] It should be noted that this internal system is constantly reviewed and thus, retroactively changes over time.

[4] We excluded the funding area 'C – Civil security research' entirely, as biological warfare agents are not part of the bioeconomy notion.

project titles and had a unique stem within division [i][5]. The result was a set of 374 terms (see App. 3-A, p. 23). With this array of phrases, we calculated the amount of bioeconomy-relevant terms in each project title to identify relevant projects in [ii] and [iii]. Using these calculations, after gradual refinement of the adjusting parameters, we applied a step by step procedure to select projects relevant to the bioeconomy:

1. Classification of subdivisions from the funding database with regard to their relatedness to the bioeconomy. As a part of this classification, all projects from the subdivision [i] were selected and added to the database.
2. Application of distinct thresholds[6]
    a. Within division [ii], we chose all projects that featured at least two keywords.
    b. Due to certain bio-related projects in unanticipated classes [iii], the counting threshold value was set to four key words per project title.

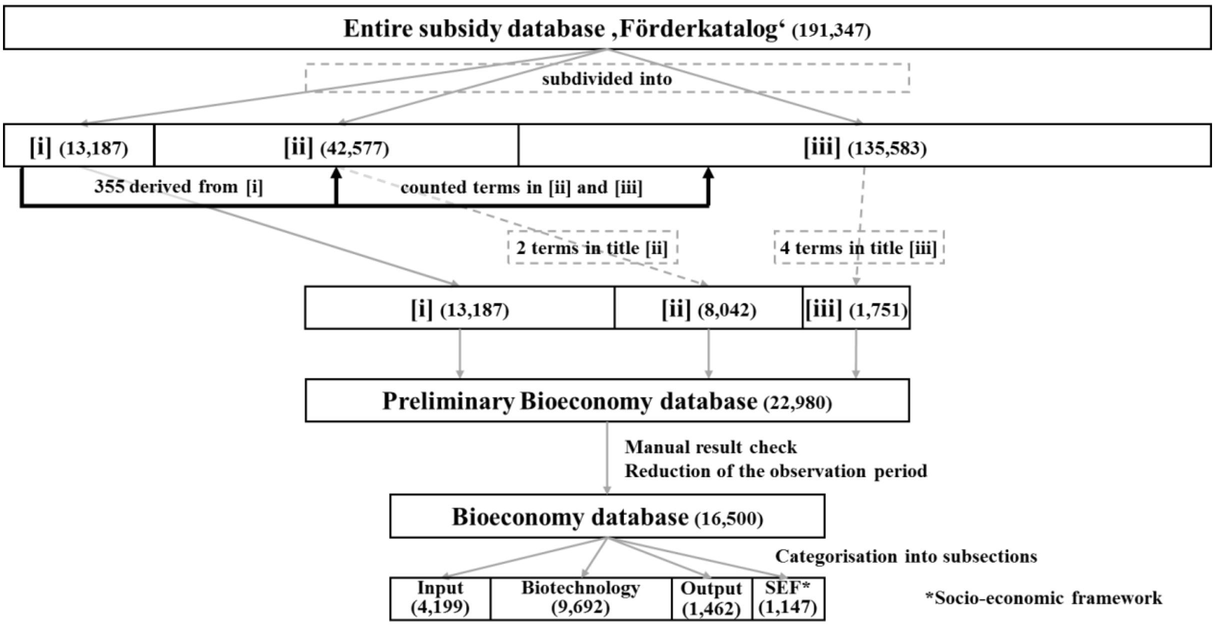


Fig. 3-1: Schematic process of the database derivation (not proportional); [source: own draft]

In order to categorise the bioeconomy projects into the dimensions mentioned above (see Table 2-2, p. 14), we determined groups within BMBF's internal classification (LPS), which

[5] Since some identified terms also lead to the detection of unintended antonyms (e.g. organ* – anorgan*; mikrob* – antimikrob*; bio – bioni[ck] or biometrisch), they had to be subtracted from the count. Moreover, in order to deal with the ambiguity of several words in different contexts (e.g. zelle (as in cell of organism) – brennstoffzelle (as in fuel cell); kultur (as in cell cultures) – kultur (as culture like civilization); the word 'gen' (gene) is component in a great number of bio-unrelated German words), we counted those terms separately (and attributed them a lower value).

[6] Through repeated experimentation, it became clear that the choice of threshold values of two and four proved to be the most sensible. The reduction to lower thresholds involved too many projects that were not in the bioeconomy scope. When the threshold value was lifted, too many relevant projects were excluded.

are clearly assignable to one of the previously determined bioeconomy sections along the value chain. A significant proportion, however, had to be attributed by hand, which also served as a result review and occasionally led to the identification of projects which did not fit and were subsequently eliminated from the database. The dissertation's appendix (p. 170) displays the entire BMBF classification in which the categorisation of the bioeconomy concept is described in more detail.[7] Furthermore, a schematic visualisation of the dataset building process is depicted in Fig. 3-1. Even though the database covers projects dating back to 1968, the analysis is limited to a time frame from 1995 to 2015. In Germany, the change within bio-themed funding towards the bioeconomy officially begun with the launch of the bioeconomy strategy in 2010. While the historical development of biotechnology funding before 1995 could offer interesting insights, the focus of this study is on more recent trends. By employing this method, 16,500 projects within the observation period could be identified as relevant to the bioeconomy and were included in the final dataset. Table 3-2 lists the basic descriptive statistics of the data.

Table 3-2: Comparative figures of the funding datasets - 1995 – 2015

	Full database	Bioeconomy concept	Biotechnology nucleus	Bioeconomy shell
Number of projects	114,448	16,500	9,692	6,808
Av. funding per proj. in EUR	546,911	426,936	497,838	325,999
Med. fund. per proj. in EUR	208,685	235,916	277,536	176,150
Av. proj. duration (days)	995	1,118	1,144	1,081
Median proj. duration (days)	1,095	1,095	1,095	1,095
Share of joint projects	.59	.72	.77	.64
Share of public organisations	NA	.66	.65	.68

[source: own calculations]

[7] The appendix can be found separately at the end of the thesis due to its massive volume.

Appendix

App. 3-A: Key words and counts for text-mining

Key words for text-mining – counting as 1

actinomy, aeruginosa, agrar, agri, agro, aktinomycet, alga, alge, algi, alkaloid, <allel>, <allele>, allelop, amino, anbau, antig, antikörp, apfelanbau, apheres, apoptos, aptam, arabidopsis, archae, array, assay, astacus, autotroph, baccatin, bacillus, bact, bakt, barley, basidiomycet, baum, bäum, beet, bio, blut, bodenfruchtbarkeit, brassica, breed, canola, carotin, cellulose, cereal, cerevisia, chitin, chitosan, chlorophyll, chloroplast, chromosom, clib, coli, coryne, cuphea, cyto, denitrifikation, derivat, diversitat, dna, drosophila, edelkreb, eiwei, elisa, embryo, endog, enzym, epilyz, epitop, erblich, ernte, erreger, escherichia, esteras, eukary, eutropha, farming, fauna, feedstock, ferkel, ferment, fett, fettsaeur, fettsäur, flachsfaser, flavonoid, fleisch, flora, food, forst, freiland, frucht, frücht, fruecht, fungeos, fungus, fusarium, futter, gartenbau, geflügel, gehirn, <gen>, <gene>, <genen>, gerst, getraenke, getränke, getreid, gewachs, gewächs, gewachshaus, gewaechs, glioblastom, glucos, glutamat, glutamicum, glyc, glyk, golgi, grain, haploid, harnstoff, hefe, hepatozyten, heterotroph, hoelz, holz, hölz, homolog, homozygot, honigbi, hormon, hortinlea, <hsp, human, hydroformyl, hydrolys, inhibitor, insekt, interferon, inulin, ipas, kairomon, kartoffel, kartoffelkreb, kaskad, kautschuk, keim, kiefer, klonal, kohlenhy, koksaghyz, kollag, kolorektal, korn, kultivierung, landrass, landwirtschaft, leben, leber, legehenn, leguminos, lektin, liganden, lignin, ligno, lipas, lipid, lockstoff, lymph, lysin, lyso, maeus, mais, malign, marin, markergestützt, maus, mäus, meliloti, mesenchymal, metabol, methylier, mikroalg, mikroben, mikrobie, milch, milchkuh, miscanthus, mistel, mitochond, mizell, monozyt, morbus, morphism, mrna, mutant, mutation, mykorr, nachwachs, naehr, nahr, nähr, napus, natuer, natür, nematod, neuron, nukleas, nuklease, nuklein, nukleinsäure, nukleinseaure, <oel>, <oil>, okolog, okosys, <öl>, oled, oligom, oligonukleotid, omega, omics, organ, organ, osmose, palmoel, palmöl, papier, pappel, pathog, pcr, pektin, peptid, pferd, pflanz, phaeno, phano, phäno, phanomics, phenom, pheromon, photosynth, phytopathog, pilz, plant, plantag, plasmid, pluripotent, polymerase, polyoma, pradikativ, prädikativ, praedikativ, praparat, prokaryot, proteas, protein, proteom, protoplast, pseudomonas, qtl, raps, rekomb, resistenzg, retikulum, rezeptor, rhizobium, rhizosph, ribosom, <rna>, <rnas>, <rns>, rogg, saat, sacch, samen, schädling, schaedling, schwein, sequenzanalys, serum, sinapin, sirna, snp, solanum, somat, sonnenblum, staphylococcus, staphylokinas, starkevarietat, stärkevarietät, steroid, stofflich, stoffumwandl, stoffwechsel, streptomycet, stroh, subtilis, tannen, taraxacum, tarulin, thaliana, thuringiensis, tierisch, tilling, tissu, transgen, transkriptom, tropi, vakzin, vegeta, vitamin, vitro, vivo, vulgaris, wald, wein, weißstängel, weissstängel, weiz, wheat, wood, wuchsstoff, xylos, zebra, zellkultur, zerocarbfp, zoonos, zucht, zücht, zucker, zuecht, zwitter

Ambigious phrases – counting as 0.5

boden, böden, boeden, cell, erzeug, gen, kultur, laendlich, landlich, ländlich, leben, life, nachhalt, natur, oeko, öko, ressourc, rohstoff, umwelt, wirkstoff, zell

Excluded phrases

anorgan, antibakt, antibio, antimikrob, biografi, biographi, biometrie, biometrisch, biomimetik, biomimetisch, bionic, bionik, bionisch, implant, lagerstätt, oberkiefer, organisa, organiza, transplant, unterkiefer, vorgang

The symbol ‘<’ means that a phrase is only detected when no other letter or symbol is in front of the key word; same applies to ‘>’ for the ending of a key word; e.g. **<gen>** is only counted as one if it stands alone and thus means **‘gene’**; that leads to a search where words such as ‘**gen**ug’ (enough) are not recognised as key word

4 FROM DISCOURSE TO PROJECTS OR VICE VERSA THE INTERDEPENDENCE BETWEEN THE LEITMOTIFS IN THE CHANGE FROM BIOTECHNOLOGY TO BIOECONOMY

Abstract

The design and implementation of innovation policy funding programmes has been the subject of scientific and political debate for decades. Especially the increasingly popular approach of mission-oriented innovation policies is a much discussed subject. The question of how missions arise, what rhetoric accompanies them and how they are eventually implemented has not yet been sufficiently clarified and specification is lacking. Whether mission-oriented innovation policy actually follows a strict top-down logic, or whether the policy-making process rather resembles a certain evolutionary scheme is questioned in this study. On the basis of the change within many policy strategy papers from biotechnology to a much broader bioeconomy, it is shown that, in reality, the transition does not follow a linear sequence. Neither excessive prioritisation nor neglect of a selected sector can be confirmed in this analysis. Within the bioeconomy, however, a clear change can be identified. Biotechnology funding was visibly reduced as part of the change of leitmotif while R&D increased in the agricultural sector in particular. Furthermore, it becomes clear that the issue of missing markets, which is predicted in theoretical studies, can also be confirmed empirically. So far, in terms of public involvement, little effort has been invested in the practical application of bioeconomical knowledge, which is why the intended transition towards bio-based economic activities is lagging behind expectations.

Keywords

Innovation Policy, Policy design, Funding data, Biotechnology, Bioeconomy

4.1 Introduction

The notion of transformative system change and its implementation has been the subject of discussion in various disciplines for some time now. In the context of innovation policy, WEBER & ROHRACHER (2012) illustrated the rationales for governmental interventions in order to initiate sustainable development and turn away from pure growth-thinking. In the past, classical mission-oriented strategies that go beyond a market-fixing mechanism and instead pursue market-shaping strategies have earned their justification. The idea of 'tilting the playing field' in the direction of markets or technologies identified by the government, generated the opportunity and necessity to anticipate and trigger desired technological paths, although they often focused narrowly on technical innovations (e.g. Apollo Project or cleantech industries) (AGHION et al. 2009; MAZZUCATO & PEREZ 2015, p. 245). Yet, the aim of modern innovation policies has progressed over time and adjusted to new conditions and challenges. Thus, increasingly more holistic, fundamental and normative elements of the socio-technical system are being targeted (DAIMER et al. 2012). In fact, KATTEL & MAZZUCATO (2018) portray the evolutionary development of innovation policy and categorise it into three stages. Accordingly, the most recent innovation policy era is characterised by normative principles and distinguishes itself from previous generations by its comprehensive approach that also includes non-technical innovations (KUHLMANN & RIP 2018). A prominent example of such a modern approach, that tackles far-reaching and fundamental shortcomings, is the 'Grand Societal Challenges', which are addressed, for instance, in the EU's mission-oriented framework programme Horizon 2020 (DAIMER et al. 2012). One integral objective within the EU's 'Grand Societal Challenges' as well as in various other sovereign countries is the implementation of a bioeconomy (GBC 2018; EU 2020).

Over the last couple of years, the concept of a bioeconomy has gained momentum due to the urgency to overcome dependence on fossil resources and also as a response to anthropogenic climate change. A wide range of published strategy papers and interest groups, such as environmentalists or dedicated companies, have raised awareness of a bio-based economy as a leitmotif for politics, economy, the public and science. Although making use of the benefits of living organisms dates back to ancient times, the understanding of the bioeconomy only arose quite recently. At the beginning of the new millennium, policy-makers discerned the potential for a transformation from an oil-based to a sustainable bio-based industry. The EU already started to promote the concept of a knowledge-based bioeconomy (KBBE) through a funding programme which was integrated in the 7th Framework Programme for Research and Technological Development (FP7). Subsequently, the German Government resolved to also put a focus on this subject matter. By presenting the 'National Research Strategy Bioeconomy 2030' (NFSB) in 2010, the Federal Ministry of Education and Research (BMBF) emphasised the significance of the bioeconomy. Consequently, this blueprint was supplemented by the 'National Policy Strategy on Bioeconomy' of the Federal Ministry of Food and Agriculture (BMEL) in 2013 and was merged into a mutual strategy in 2020 (BMBF & BMEL 2020). Recently, this advancement in policy has been described as a theme shift 'from a biotechnology-centric vision to an economic activity that spreads across several key sectors and policy families' (OECD 2018, p. 11).

The developments briefly outlined show, on the one hand, that innovation policy missions in general have evolved and, on the other hand, that there has been an actual change from the promotion of biotechnology to the funding of the bioeconomy. However, it is often not clear how a transition of policy goals is defined and consequently pursued.

In light of this fact, it is our aim to assess whether and in what way the shift in political discourse from biotechnology to bioeconomy has been reflected by a transition in both funding programmes and projects. In order to achieve this, we go back to the origin of public bio-themed R&D support at a programmatic level, starting with systemic biotechnology funding, and illustrate the evolution from biotechnology to bioeconomy. At the same time, we trace the implementation at a project level so that we can both assess the actual execution of the stated transition and identify the priorities within the bioeconomy. For this purpose, we built a database consisting of all relevant bioeconomy projects that have been funded by the German government between 1995 and 2015. In the process, we divided the bioeconomy into its components to determine realised funding measures. We chose Germany as the observation unit due to its early commitment to the bioeconomy, as previously described and hence the availability of sufficient data, which allows an examination of the funding patterns and for conclusions to be drawn about the policy change over time.

With this study we are contributing to existing research in two respects. Firstly, by tracing the evolution of thematic shifts at both programmatic and project levels, we gain a better understanding of how political trends emerge, develop and are implemented. There is still a lack of knowledge about evolutionary mechanisms underlying policy-making processes. By addressing the different leitmotifs of biotechnology and bioeconomy support, we are able to shed light on the question whether policy evolution either follows a linear top-down approach or is rather accompanied by bottom-up dynamics and feedback loops. Secondly, social science literature dedicated to the bioeconomy is still rare and based on different opinions about the bioeconomy's scope. We therefore make the bioeconomy tangible by dissecting it and thus illustrate its comprehensive character along several parts of the value chain from raw materials to final products and industrial applications. This allows us to categorise and quantify its publicly funded knowledge-based component.

This article is structured as follows: First we discuss the transformation of innovation policies and outline the topic of mission-oriented strategies more in greater detail. This is succeeded by a discussion of mechanisms in the policy-making process. Subsequently, we embed this discussion in the bioeconomy context, followed by an historical overview of bio-related funding in Germany on a programmatic level. Thereafter, the data at the project level are described, analysed and evaluated. Finally, the results are discussed and conclusions are drawn.

4.2 Innovation policy in a state of change

Within the last two decades increasingly more attention has been paid to the subject of innovation policy (EDLER & FAGERBERG 2017). As EDLER et al. (2016) emphasise, there are manifold innovation policy instruments to attain certain objectives within economies, either through supply- or demand-side policy. This set of policy tools has undergone a persistent progression and can be distinguished according to the corresponding theoretical principles (SCHOT & STEINMUELLER 2018). In the second half of the 20th century, neoclassical thinking has dominated economics. The integration of technological progress as a decisive factor for growth (cf. Solow-Swan model) led to the pursuit of a policy scheme with the primary goal to prevent market-failures such as insufficient R&D spending. Consequently, funding for foundational research or direct support to firm R&D have been the most common and popular instruments in this era (EDLER & FAGERBERG 2017; KATTEL & MAZZUCATO 2018). Further applied mechanisms were regulations and direct subsidies for specific industries like tax treatments (SCHOT & STEINMUELLER 2018). This conception altered considerably in the late 1980s due to the establishment of the innovation system approach amongst others by FREEMAN (1987) and FREEMAN & LUNDVALL (1988) (WEBER & ROHRACHER 2012). By acknowledging failures at the system-level, new policy tools complemented the former market failure-perspective. As a result, cluster policies, network stimulating approaches and the encouragement of agency such as start-up finance and fostering entrepreneurship have been introduced as crucial means (EDLER & FAGERBERG 2017). More recently, increasingly negative social and ecological externalities, partially induced by growth and innovation, required a new political discourse (WEBER & ROHRACHER 2012; BIGGI & GIULIANI 2020). While KATTEL & MAZZUCATO (2018, p. 788) identified a 'normative turn' in modern policy strategies, WEBER & ROHRACHER (2012) as well as SCHOT & STEINMUELLER (2018) point to the necessity of a transformative innovation policy. Climate change, growing income disparities within and between countries, and better access to education are just some examples for comprehensive problems that need to be tackled by governmental authorities. This, again, requires novel practices in policy steering and illustrate the incessant adjustments that are mandatory in order to cope with changing circumstances.

One highly debated aspect in this context is the proactive mission-oriented approach (i. a. MARTIN 1995; AGHION et al. 2009; WEBER & ROHRACHER 2012; KIVIMAA & KERN 2016; MAZZUCATO & SEMIENIUK 2017). Similarly, AGHION et al. (2009) stress the relevance and benefits of overcoming conventional 'neutral' innovation policies. In lieu of subsidising regardless of the technological field, systematic funding that contributes to a selected mission is more likely to shake up existing structures than mere regulation by the market. MAZZUCATO (2014, p. 5) justifies the necessity of state intervention since it is 'providing the vision and the dynamic push to make things happen that otherwise would not have' and implies the government's opportunities to take up structural challenges and shape necessary markets.

In the past, economic incentives such as preventing inferior technical systems, relinquishing industries in a state of negative lock-in or gaining first-mover advantages in novel technologies were main rationales for innovation policy (AGHION et al. 2009). However, the urgency to deal with far-reaching social or environmental problems has become apparent and subsequently received greater attention from political stakeholders. These types of issues or market-failures are mostly characterised by their extensive nature and demand for solutions that cut across industries and technologies (FRENKEN 2017). In general, looking beyond the mere inability of individual firms to solve problems that span multiple sectors, most economic actors have a lack of commercial incentives. For this reason, national or even supranational policies by the public sector are crucial in order to create a coherent, stable and long-term roadmap as well as to compensate for deficient investments in the private sector (MAZZUCATO 2014).

Aside from this, private actors rarely contribute financially to basic and applied research since new developments in emerging sectors are highly uncertain and therefore risky. Private actors thus tend to invest in areas of manageable technological complexity (MAZZUCATO 2014). Accordingly, due to the nature of venture capital, which mainly aims for short-term investments with quick returns, durable long-run financing, which is essential to the investment strategy of firms, is often left to public funding (MAZZUCATO & SEMIENIUK 2017). A lack of patient or long-term investments in more difficult to manage and ambitious paths is a restraining factor for scientific advancement. In order to stimulate technological exploration that would be omitted otherwise, it establishes another rationale for public involvement (AGHION et al. 2009).

In general, the US government has pursued the mission-oriented approach most successfully since the second half of the 20th century, while other economies have struggled either with the persistent pursuit of a coherent funding scheme, a lack of incentives or missing market implementations (ERGAS 1987). For instance, due to their innovation policy the USA were able to pursue visionary technologies and to successfully create industries, for example biotechnology (LAZONICK & TULUM 2011) or advanced information technology (AGHION et al. 2009). Another example is Germany's continuous large scale public subsidies of renewable energy technologies, which established both technology and markets (JACOBSSON & LAUBER 2006).

4.3 Limits to mission-oriented policy intervention

Nonetheless, since it is anything but trivial for a government authority to plan and forecast the economic system (HAYEK 1945) and because of imperfect knowledge (or 'pretence of knowledge' (HAYEK 1975)) there is a risk involved with merely 'picking winners'. The most uncertain and demanding part of policies is to identify or rather anticipate market-failures as a basis for the development of appropriate programme designs (ERGAS 1987). Therefore, a visionary, venturing government that is capable of predicting technological and market developments is required in order to implement and conduct a mission-oriented policy (MARTIN 1995). As a result, only few economies possess the competence, a risk-taking attitude and, at the same time, the critical market size to take the high road of a market-shaping strategy (AGHION et al. 2009). To illustrate the latent underlying risk of this process, HUGHES (2012, p. 39) terms this process as 'choosing races and placing bets'.

The mechanism of identifying a promising and feasible technology is also a very discursive phenomenon. Not only due to changing governments, but also as a result of scientific and technological advancements or the potential of economic success of a selected path, the composition of policy programmes changes over time. CANTNER & PYKA (2001), for example, illustrate how the German government pursued a policy to foster nuclear power on account of a lack of oil resources in the 1970s. Subsequently, along with the nascent controversy concerning the potential hazards of nuclear plants, a movement in favour of renewable energy formed and forced the government to alter the design of public support, which afterwards had a considerable impact on further developments in the German Clean Technology industries (CANTNER & PYKA 2001; JACOBSSON & LAUBER 2006). Nevertheless, with respect to the planning certainty of firms, a long-term strategy is a prerequisite for the successful accomplishment of the targeted mission (MAZZUCATO 2014).

Aside from the possible impact of governmental interventions on technological advancements, BOSCHMA et al. (2017) emphasised the significance of the place- and path-dependent nature of the creation of new trajectories. In other words, since new industries are more likely to develop in countries with related activities already present, i.e. existing knowledge as a driver for new growth paths, not every economy is capable of generating novel technologies (HIDALGO et al. 2007). In an examination of EU-funding efficiency, UHLBACH et al. (2017) highlighted the necessity of appropriate allocation of public R&D funding in terms of the level of relatedness. They found the EU-support was most effective in regions where the level of related knowledge was neither too low nor too high. Apart from that, it is the government's task to ensure that uncertain and expensive investments have a long-lasting economic effect. ERGAS (1987) showed that mission-oriented countries invest and benefit primarily at the initial stages of new trajectories, while diffusion-oriented economies are the driver for specialisations at a later phase of the industry life cycle. Yet, with the advancement of information and communication technology (ICT), the diffusion of new technologies has also changed. Successfully developed sectors, for instance the aforementioned renewable energy technologies received significant funding from the German government and therefore, Germany became one of the biggest manufacturers. Subsequently, German firms were able to maintain a leading position in wind turbine production, but were ousted by Chinese solar photovoltaic (PV) manufacturing. Trying to explain this diverging development, BINZ & TRUFFER (2017) point out the nature of these two different sectors. While PV technology is largely standardised and already in the stage of mass markets, wind power depends mainly on synthetic or so-called 'sticky' knowledge (ASHEIM 2007), which is not ordinarily transferable over space. Ergo, this case indicates the complexity and far-reaching effects of innovation policy and illustrates why governments often act risk-averse and discard mission-oriented strategies.

Notwithstanding the latent risks of the described mission-oriented policy, the necessity and global demand for a technological transition to suit the needs of EU's 'Grand Societal Challenges' (GSC) and UN's 'Sustainable Development Goals' (SDG) are increasing with time. Against this backdrop, numerous governments have responded by adjusting their innovation policy with increased attention being paid to sustainable development. It is precisely these policy changes that KATTEL & MAZZUCATO (2018) and SCHOT & STEINMUELLER (2018) have systemised into different generations and frames respectively, where the current period is characterised by complex socio-economic challenges. Many of these novel objectives are inherently extensive and connote trans-sectoral solutions and thus, require comprehensive endeavours in order to attain defined targets. The concept of a (knowledge-based) bioeconomy, which has been added to the agenda of several policies worldwide, represents one identified approach.

4.4 The character of mission-oriented policy-making processes

A considerable part of the criticism about mission-oriented approaches within innovation policy is provoked by its strict top-down character. In other words, the fact that political decision-makers determine a distinct direction that favours chosen technologies or economic sectors and thereby neglects or weakens other segments of the economy might lead to the distortion of natural competition. Along with this argument, there is also the question of how missions are chosen and how they are implemented. With regard to the depicted principle of mission-oriented innovation policy, we assume a rather linear process (see Fig. 4-1). According to MAZZUCATO (2014), one main argument for the state's intervention is to supply a specific vision or strategy that can be pursued mutually and otherwise would not have been tackled. Therefore, a linear top-down process could be assumed: a goal will be set by the policy and is accompanied by a certain political and public discourse and rhetoric, which will subsequently be expressed in the form of concrete funding programmes. This, in turn, is reflected in changed foci of funded projects that contribute to the stated mission.

However, in political science, over many decades a lively discussion has evolved around the character of the policy-making process (WEIBLE 2014). In the past, this process was often understood as a multipart process that was divided into several stages such as 'Issue Definition', 'Agenda Setting', 'Policy Adoption', 'Implementation' or 'Policy Evaluation'

(DELEON 1999). Initially, LASSWELL (1956) conceptualised the public policy-making as a 7-step linear temporal-sequential process, which built the foundation for more elaborate phase-based concepts. Within this framework, JONES (1970) derived the notion of a policy cycle, which emphasises the evolutionary and self-evaluative nature of public policies, and only comes to an end when a policy is terminated. Subsequently, this theoretical model faced varied criticism, for instance that a classification into a specific sequence is neither a realistic assumption nor empirically verifiable (SABATIER & JENKINS-SMITH 1993). Furthermore, the basic presumption of the top-down character of policies might lead to a bias that oversimplifies the interaction between stages, actors and other policy programmes (SABATIER & JENKINS-SMITH 1993). For that reason, work in contemporary literature rather focusses on specific elements of the policy cycle, integrates theories into the entire policy process or is dissociated from thinking in distinct stages (SABATIER & WEIBLE 2014).

Prioritisation of a leitmotif
political and public discourse & rhetoric ↓ **sets** priorities in programmes ↓ **change** focus of funded projects

Fig. 4-1: Assumption of the linear character of mission-oriented policy-making [source: own draft]

Since there is a clear lack of empirical evidence about the issue of the emergence and development of novel missions or policy strategies, an explorative analysis can help provide a more detailed understanding of this process. Based on these theoretical deliberations about mission-oriented policy on the one hand and the policy-making process on the other, two contrary trajectories of policy formulation and implementation seem possible:

(a) The mission-oriented policy is implemented in a linear, top-down manner. Thus, the policy-makers provide the foresight to steer the process in the direction of a specific mission and subsequently, priorities in policy and the direction of projects change correspondingly.

(b) The development of any policy, from identifying a mission to changing priorities within strategies to actual implementation, is a combination of top-down and bottom-up mechanisms, i.e., it resembles rather a self-renewing and evolutionary process with several interactions between not clearly separated stages.

This empirical study on bioeconomy in Germany, therefore, concentrates on the interplay between the political discourse and the implementation of the priorities determined in the form of enacted programmes and executed projects. That means, two factors are most essential in this context: timing and content. In case (a), the government sets the mission (biotechnology and bioeconomy) and consequently initiates corresponding funding programmes dedicated to this goal shortly after. Consequently, there are measurable rapid changes in quantity and content in publicly-funded R&D projects in the respective field. If (b) applies, we assume that the mission is connected to preceding missions and is in constant evolution due to successes and failures. Funding programmes are also inspired by previous experiences and are adapted to changing circumstances. In consequence, alterations in project content and numbers will rather appear more steadily over a longer time frame.

In order to probe the case, we will initially shed light on the public bioeconomy discourse, before we concentrate on the development of funding programmes for the bioeconomy. Ultimately, analyses at the operative project level will provide insights into the implementation of the bioeconomy discourse.

4.5 The public bioeconomy discourse

Within the last decade, the notion of a bioeconomy replacing the current fossil resource-based economy has become prominent due to the desire to find an instrument to combat anthropogenic climate change, to transform energy systems towards renewable energies or even to deal with world hunger.

While previous support programmes had often focussed on biotechnology, the EU introduced the approach of a knowledge-based bioeconomy (KBBE) within their 'Seventh Framework Programme' in 2004 (GOLEMBIEWSKI et al. 2015). Subsequently, several other countries seized the idea of holistic bio-based systems with different national flavours depending on their idea of bioeconomy (MCCORMICK & KAUTTO 2013). For instance, in 2010, the government in Germany announced a funding programme along with a policy strategy targeting the transition towards an integrated bioeconomy as one of the first countries to do so. This financing scheme is part of the 'Hightech-Strategy' which has been running since 2006 and represents a mission-oriented approach to benefit from the enhancing nature of the strong NIS (BMBF 2017c). Moreover, the funding measure meets the EU's requirements to invest in education and R&D, as stipulated in the Lisbon Strategy (2000) and Europe 2020 (2010) (EP 2000; EC 2018b).

It has become clear that, among others, politicians have high expectations that this approach will contribute to solutions for EU's GSCs and to reach the UN's SDGs. Referring to the success of the IT industry in the USA, MOWERY (2006) and AGHION et al. (2009) propose combining governmental missions (e.g. demand-side policies) and sufficient public funding to achieve underlying market-shaping strategies. Acknowledged by over 50 governments worldwide, an increasing number of countries have implemented either dedicated bioeconomy strategies or incorporated bioeconomy-related strategies into their policy (GBC 2018; OECD 2018). The German government is pursuing the goal of assuming a pioneering role in this development and has therefore designed a mission-oriented programme to gain early mover advantages in anticipated technologies.[8]

Although the situation looks promising at this initial stage, the establishment of a bio-based economy is anything but certain. With all the advantages that come from the holism of the bioeconomy concept, there are some idiosyncrasies which illustrate the differences between previous mission-oriented approaches and the identified bio-based transformation. First and foremost, the most apparent distinction when compared to path-forming policies, which are already occurring and have been evaluated, is the character of the targeted objective. Most preceding policies were aimed at specific technologies, both those which were successfully realised such as biotechnology (LAZONICK & TULUM 2011), NASA's space-projects (MAZZUCATO 2014), cleantech industries (JACOBSSON & LAUBER 2006) or failed attempts such as supersonic aviation (Concorde) (MAZZUCATO 2014) or magnetic levitation trains (Transrapid) (BÜLLINGEN 1997). The bioeconomy, however, endeavours the transformation of the entire oil-based economic system and thus affects different sectors, technologies and knowledge bases. Therefore, in order to attain this objective, solutions are required that go beyond single trajectories. Thus, there is a demand for conjunctions between multiple, previously only loosely linked, paths (TÖDTLING & TRIPPL 2018). Moreover, since the imperative of the identified economy is derived predominantly from negative externalities, many markets still need to emerge in the first place. In essence, past technology policies

[8] One needs to take into consideration that dissimilarities between conceptions of bioeconomy ideals and the multi-facetted nature of bio-based economies result in differing foci of programme designs. For instance, the interpretation of the German NFSB, originating from the biotechnology funding scheme, is an integral component of the 'Hightech-Strategy' and points to a pronounced technology-driven conception of the bio-based economy and might overlook the ecological limitations of the concept (HAUSKNOST et al. 2017).

were based on clearly defined and pegged technological targets with previously known markets and, in many cases, with the state itself as the biggest customer. In contrast, GSCs in general and the bioeconomy in particular are characterised by their complexity as well as a lack of both precise targets and consumers (FRENKEN 2017; SCHOT & STEINMUELLER 2018).

In addition, history has proven that the transition of energy regimes has invariably been an arduous and slow process (PHILP 2018). While FRENKEN (2017) states that mission-oriented strategies ordinarily take 5-10 years, the relevant policy strategies cover even longer time frames, i.e. 20 years. In order to achieve the self-imposed targets it is imperative that the mission will not suffer in terms of its implementation or even be terminated after changes of government. At present, the bioeconomy is still gaining momentum on a global scale, nevertheless a long-term commitment is not invariably made due to (geo)political developments. In contrast, as mentioned above, innovation policy aspirations often underlie a discursive process and, as a result, require broad public acceptance (CANTNER & PYKA 2001). In this respect, the bioeconomy seems to have difficulties with public relations. The broad population, save for a small set of professionally affected communities, is not aware of the politically-induced leitmotif. However, the bio-based industry has the basic prerequisites to involve the entire economic system, i.e. producers and consumers in all aspects, and therefore, it demands communication with and the sensitisation of the public (DIETZ et al. 2018).

Another crucial aspect for the bioeconomy's success and a frequently raised objection is the feasibility of strategy implementation in terms of capacity limits. In other words, is it viable to substitute fossil resources with renewables, develop novel products consisting of biomass and, at the same time, meet the paramount goal of securing the food supply for the increasing global population without exploiting and irreversibly damaging the ecosystem (PRIEFER et al. 2017)? On the basis of this issue, the underlying argument about the government's 'pretence of knowledge' (HAYEK 1975) becomes clear and calls into question the identified future system. That is to say, any identified strategy not only carries the risk of not being the most efficient solution, but rather entails the danger of aggravating the current market-failure. For instance, the advancement of genetically modified organisms (GMOs) is eminently contested. There are numerous severe concerns about the intensification of this technology, which is why the EU, among others, has rigid restrictions against genetically modified foodstuffs (cf. precautionary principle). There is a possibility that a new trajectory is created which exacerbates prevalent problems or generates novel ones (e.g. lead in fuel or

CFC in refrigerators). Another example is the increasing production and processing of biological substances, which could lead to rebound effects caused by overcapacity and, eventually, intensify conflicts over land use. As a consequence, serious concerns have been raised about whether the bioeconomy is the optimal solution for the current problems or if, eventually, the market will develop the most efficient solution by itself (e.g. utilisation of hydrogen or the like) (FRIEDMAN 1982[1962]).

4.6 Political interventions to foster bioeconomy in Germany at the programme level

By looking at the previously depicted development of the bioeconomy, it becomes clear that the discourse surrounding biological research has changed substantially in the last 20 years. Before the turn of the millennium, both nationally and globally, biotechnology was one focus of mission-oriented policies. However, a trend towards the bioeconomy has been established in the political dialogue since 2004 (PATERMANN & AGUILAR 2018). This acknowledged shift of approaches offers the opportunity to get insights into recent mission-oriented policy-making and allows to track the evolution of a current strategy that gets increasing recognition globally. Future research is encouraged to check whether the bioeconomy is an atypical case with an evolutionary structure or whether other mission-oriented strategies (e.g. the Quantum Technology Strategy or the most recent Hydrogen Strategy) follow a similar pattern. For this reason, we now provide a brief historical background of past and present bio-themed funding programmes in Germany.

Pioneering endeavours in Germany to promote biotechnology date back to the period around 1970 (WARMUTH 1991; BMBF 2011; SCHÜLER 2016). Most funding in biotechnology largely favoured basic research by public institutions and was aimed at the generation of scientific knowledge (WARMUTH 1991). By establishing the innovation system approach in policies, the first systematic, regional funding strategy to commercialise biotechnological procedures was launched in 1995 (COOKE 2008; MCCANN & ORTEGA-ARGILÉS 2013). As one of the earliest examples, the BioRegio contest was carried out by the German BMBF from 1997 to 2005 and supported the biotechnology sector in the four winning regions (STAEHLER et al. 2006). This political programme aimed to initiate a cold start in order to lift the lagging biotechnology sector in Germany and make it competitive and eventually, to have the leading biotechnology industry within Europe (DOHSE 2000).

Subsequently, further programmes (i. a. BioProfile, BioChance, BioFuture) were addeded in order to continue this mission-oriented place-based[9] approach (EICKELPASCH & FRITSCH 2005; COOKE 2007; BMBF 2017e). In 2001, the BMBF introduced another funding measure ('Rahmenprogramm Biotechnologie' – 'Framework Programme Biotechnology' (FPB)) to not only foster biotechnology independent of the location (in contrast to BioRegio and BioProfile), but also biosciences in general. Eventually, starting in 2010, this programme merged into the 'Nationale Forschungsstrategie Bioökonomie 2030' – 'National Research Strategy Bioeconomy 2030' (NFSB), which is carried out by six Federal Ministries[10] who jointly promote and fund the holistic bioeconomy concept (HÜSING et al. 2017). Afterwards, this scheme resulted in additional specific programmes, e.g. the 'Roadmap Bio-refinery' in 2012, and the 'National Policy Strategy on Bioeconomy' of the BMEL in 2013. Moreover, the coalition agreement of 2018 determined that the bioeconomy vision called 'Von der Biologie zur Innovation' – 'From biology to innovation' ('Bio-Agenda') would be pursued further instead of specific biotechnology support (BUNDESREGIERUNG 2018b; BMBF 2020). In 2020, the Research and Policy Strategies were bundled to form an overall strategy (BMBF & BMEL 2020). For an overview of the dedicated bio-related strategies, see Table 4-1. Evidently, the German policy has altered over time from a focus on a specific technology towards a scheme aimed at tackling GSCs (HÜSING et al. 2017). Yet, this policy development pattern did not take place exclusively in Germany; it was rather a global process (OECD 2018).

The foci of the drafted programmes differed significantly. For instance, BioRegio aimed at the emergence of dedicated biotechnology firms and contained predominantly start-up financing of private companies to initiate a cluster building process. BioProfile's measures, however, targeted public institutions in order to broadly fund biotechnology-related basic research in the regions' respective profile areas (STAEHLER et al. 2006; DOHSE & STAEHLER 2008). The subsequent FPB targeted a wider range of grantees within the biosciences, whereby the primary focus was still biotechnology. This framework supported R&D in

[9] BioProfile was a contest between regions that could apply with a special profile for biotechnological procedures (STAEHLER et al. 2006). The three winning regions were the network of Brunswick, Göttingen & Hanover, the network of Berlin & Potsdam and the network of Stuttgart, Tübingen, Esslingen, Reutlingen & Neckar-Alb. BioChance and BioFuture did not have a focus on specific regions.

[10] Under the leadership of the BMBF, the following federal ministries are responsible for implementation: Ministry of Economic Affairs and Energy (BMWi), Ministry of Food and Agriculture (BMEL), Ministry of Environment, Nature Conservation and Nuclear Safety (BMU), Ministry of Economic Cooperation and Development (BMZ) and the Federal Foreign Office (AA).

public institutions and private projects almost equally with 44 % and 38 % of the overall promotion fund respectively (BMBF 2011).

The bioeconomy strategy instruments, however, cover an extensive spectrum of technologies, sciences and industries due to the holistic character. The actual number of funding lines increased with the implementation of the NFSB and a wider spectrum of topics were covered. For instance, because the government aspired to include several industries, it introduced the measure 'Bioeconomy as societal change' to address the underlying socio-economic challenges such as the systematic monitoring of bioeconomic processes or communication with the public (PTJ 2020). Other suitable measures to achieve the intended linking of sectors are the governmental incentives 'Innovation spaces Bioeconomy' which does not have any specific core branch and 'Agrarian systems for the future', which approaches the issue of agriculture as a whole (PTJ 2020).

Table 4-1: Milestones of bio-themed funding in Germany

Leit-motif	Time-period	Funding Programme	Purpose & Implementation
Biotechnology	1979-1983	'Benefit plan Biotechnology 1979-1983'	1st programme to foster narrowly defined biotechnology
	1985-1988	'Applied Biology and Biotechnology'	Mainly basic research in biotechnology
	1997-2005	'BioRegio'	Fostering biotechnology in four regions
	1999-2007	'BioProfile'	Fostering biotechnology 'profiles' in three regions
	2001-2010 (into NFSB)	'Framework Programme Biotechnology'	Fostering Biotechnology and related biosciences
⇩	since 2006 (continued 2014)	'Hightech-Strategy'	Prioritisation of innovations; including non-technical solutions since 2014
Bioeconomy	2010-2020	'National Research Strategy Bioeconomy' connected to the Hightech-Strategy	Conceptualisation of a bioeconomy in Germany
	2013-2020	'National Policy Strategy Bioeconomy'	Connecting multiple policy areas in the bioeconomy framework
	since 2019	'Innovation spaces Bioeconomy'	Fostering four selected regions within the bioeconomy scope
	since 2020	'National Bioeconomy Strategy' – Bundling Research and Policy Strategy	Pursuit of a mutual 'Bio-Agenda'

[source: own draft according to BT 1990; WARMUTH 1991; STAEHLER et al. 2006; BMBF 2011; SCHÜLER 2016]

The German cabinet identified and determined five fields of action within the NFSB, in which a sustainable economy oriented towards the natural cycle of materials was to be established (BMBF 2010). HÜSING et al. (2017) illustrated the differing priorities of the strategy in an in-depth evaluation of the measures undertaken within the programme. They found that the field of action 'Industrial utilisation of renewable resources' in particular has the greatest significance within this scheme. Less attention is paid to the following three fields of action: 'Securing global food supplies', 'Sustainable agricultural production' and 'Production of healthy and safe food'. The promotion of the core issue 'Biomass-based energy sources' is almost negligible. Further funding measures favour the development of cross-sectional technologies or the assistance of SMEs and the formation of companies (HÜSING et al. 2017). It is apparent that the origin of the strategy, which lies in biotechnology, remains an essential pillar and reflects the claim of the German government that it conducts technology-oriented and innovative R&D. In fact, twelve out of the 36 evaluated funding measures were initially a component of the former FPB (HÜSING et al. 2017). This is not extraordinary since biotechnology, labelled by the EU as 'key enabling technology' is presumed to be a driving force behind innovative processes in all upstream and downstream parts of the bioeconomy according to political thinking and thus, functions as an interdisciplinary technology that can be applied in the entire bioeconomy (BMBF 2010; EC 2012).

While the advancement of biotechnological solutions seems to be paramount considering the past and current governmental strategy for action, one key issue is the lack of diffusion of new knowledge into marketable products (HÜSING et al. 2017). Apart from extensive SME subsidisation and start-up financing, the policy seldom aims to achieve this crucial element, which simultaneously highlights the problematic nature of missing markets.

Moreover, the aspect of ecological sustainability seems to be only implicitly addressed by technological advances at various levels. In fact, no explicit environmental protection measures were integrated into the framework of public funds. The same applies with regard to the matter of insufficient (governmental) demand for bio-based solutions.

In conclusion, it can be said that the innovation policy strategy has developed dynamically on paper. Initially, the focus was exclusively on biotechnology. This thematic focus, however, expanded gradually due to altered preconditions, became increasingly extensive, and eventually led to the bioeconomy concept. Thus, there was no distinct event that terminated the biotechnology funding and afterwards launched the bioeconomy strategy. This process resembles an evolution, in which the focal point biotechnology remained constant and policy changes happened as a consequence of changed circumstances.

Considering this development, we also aim to evaluate, at project level, the actual implementation of the strategies. To be able to conduct this analysis, a clear understanding of the bioeconomy concept as well as a meaningful dataset are necessary. After delineating the structure and definition of the bioeconomy for the analysis, the data provenance and preparation will be described in the following chapters.

4.7 Results: Public funding of the bioeconomy at project level

In the following, the prepared project data (see chapter 3) will be analysed. Initially, we will give an overview of both the general development of the bioeconomy and the overall funded R&D projects. Subsequently, the structural change within the bioeconomy will be presented before the individual subclasses are examined more closely.

As has been established, the issue of the bioeconomy is increasingly attracting attention in political agendas on a global scale. While it is evident that there is a rise in bio-related strategies at a programmatic level as well as a thematic expansion, this change is less clearly evident in terms of distinct bioeconomy projects.[11] Although the number of projects related to the bioeconomy more than quadrupled from 316 in 1995 to 1.374 in 2015, the proportion in relation to the overall amount of projects only increased slightly (see Fig. 4-2). The share oscillated between approximately 12 and 13 percent during the initial years of the BioRegio funding until 2003. After two steep rises to almost 20 percent of all funded R&D projects in 2004 and 2007 respectively, it has levelled off at 14 to 15 percent in recent years. Notably, there was no detectable growth in the share of bio-related R&D with the introduction of the bioeconomy strategy and the connected funding measures in 2010.

However, due to the depicted structural changes in bio-related innovation policy accompanied by the successive inclusion of a broader scope of decisive sectors, we find there was a shift within the funding of the bioeconomy. Therefore, we split the dataset into biotechnology core and bioeconomy shell (see Fig. 4-3). In the first years of our observation period, three quarters of all bio-related research was in biotechnology, dominated by **red biotechnology**. Until 2006, the general development was characterised by fluctuations without a persistent trend. From that point on, we found a significant increase of R&D beyond solely biotechnology. Eventually, in 2012, in the third year after the introduction of the bioeconomy strategy (NFSB), the number of projects in the biotechnology core was for

[11] A project is only counted in the year of its beginning. As such, each project is considered once in the following analyses.

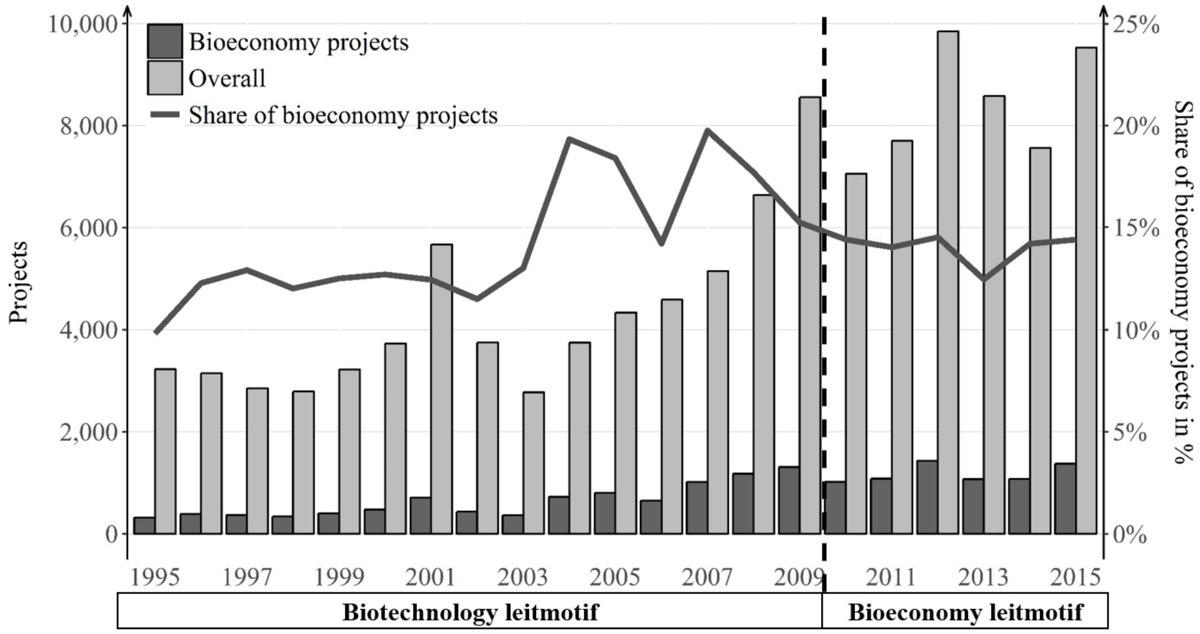


Fig. 4-2: Funded projects in Germany 1995 - 2015
[source: own calculations]

the first time smaller than in the bioeconomy shell. Hence, the data suggest a transition of funding associated with the alteration of strategy at a programmatic level. Nevertheless, two aspects must be taken into account in this context. Firstly, while we find a clear structural transformation within bio-related support, as previously stated the proportional share of all the projects funded in Germany did not increase significantly. Secondly, the tangible change towards a biotechnology-transcending scheme at project level started roughly in 2007, possibly even in 2001, whereas the NFSB was not established until 2010. Thus, the trend towards more general bioeconomy funding was already implicitly addressed by several other funding measures (mostly driven by grants for sustainable **agriculture & forestry** as well as R&D in biomass-based **energy & fuels**). However, a great leap in favour of bioeconomy R&D activities as a consequence of the NFSB did occur in 2012. This somewhat delayed response can be explained by two facts. First, the transition from a biotechnology strategy towards a bioeconomy strategy proceeded fluidly, in which one third of all funding measures originated from the former scheme. Secondly, each step of the process, from the announcement of the strategy to the preparation of specific funding programmes, the submission of project applications, revisions etc. up to the final project start, takes months or sometimes years.

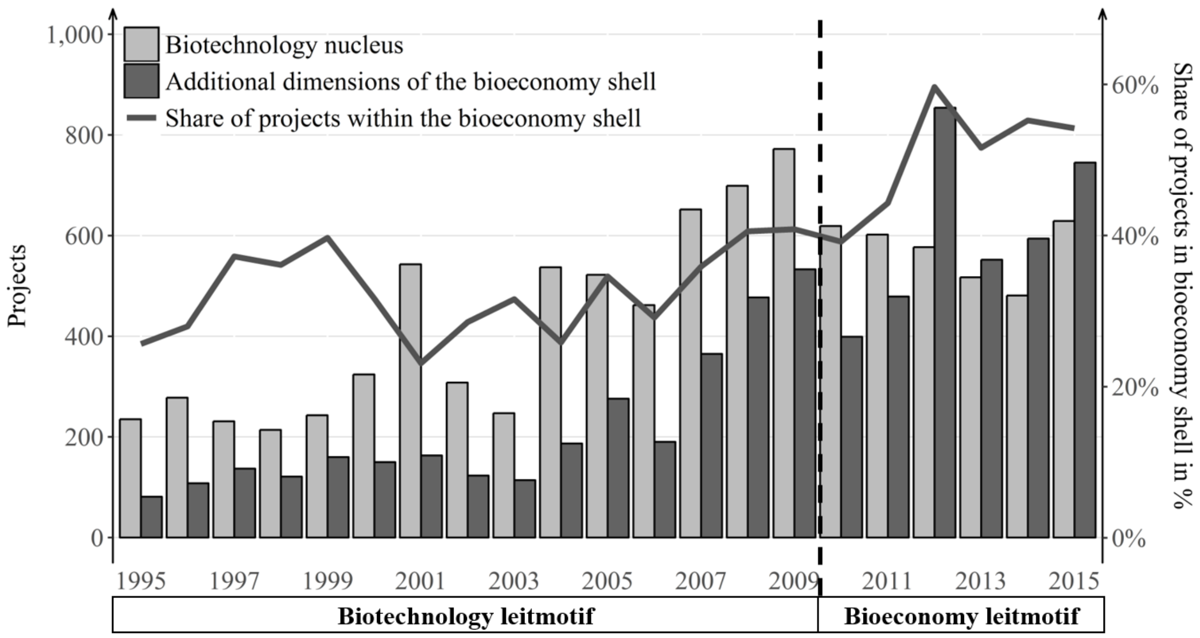


Fig. 4-3: Comparison between bioeconomy and biotechnology funding 1995 - 2015 [source: own calculations]

As the structural changes within the bioeconomy sectors reveal more detailed information about the transition than the mere number of funded projects, a breakdown of these developments is illustrated in Table 4-2. The most obvious structural change to the bioeconomy funding is the steady increase of **agriculture & forestry** funding. At the same time, the share of support for **red biotechnology** dropped noticeably by 19 percentage points between the start and end of the observation period. The sector **agriculture & forestry** ultimately became the most funded area within the bio-based economy (based on the project count). The main driver for the conspicuous growth in significance is the involvement of the BMEL. From 2002 on (except 2005), the BMEL funded the majority of the R&D projects within **agriculture & forestry**. The BMBF is by far the most relevant funding source in most other areas (with the exception of **energy & fuels**). This illustrates the character of the bioeconomy, in which different departments are planned to deal with this subject. Two broadly defined categories were responsible for the steep increase: Between the years 2002 and 2011 the majority of projects in this sector were financed in the field ‘Sustainable agriculture, horticulture, forestry, fisheries and food industry; development of the potential of renewable raw materials’. Since 2012, the main driver has been ‘Studies on the emergence of wood and agricultural biomass, on the mobilisation of utilisation and production reserves and on increasing the use of wood and agricultural raw materials, including new production processes and products’. The BMBF had only one funding line in **agriculture & forestry** that featured somewhat greater aspirations: ‘Research for a future-oriented forestry’.

Table 4-2: Public R&D projects within the bioeconomy in Germany, 1995 - 2015 (number of projects)

Bioeconomy dimension	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015
Input	**∑16%**	**15%**	**11%**	**18%**	**27%**	**30%**	**37%**
Agriculture & Forestry	1%	3%	5%	12%	22%	24%	28%
Climate & Environment	15%	12%	6%	6%	5%	6%	9%
Processing	**∑69%**	**65%**	**73%**	**70%**	**61%**	**50%**	**46%**
Green biotechnology	8%	12%	9%	9%	9%	8%	3%
Red biotechnology	45%	36%	42%	42%	37%	28%	26%
White biotechnology	16%	17%	22%	19%	15%	14%	17%
Output	**∑ 4%**	**11%**	**10%**	**9%**	**9%**	**9%**	**9%**
Products & Materials	3%	8%	4%	3%	1%	1%	2%
Energy & Fuels	0%	1%	1%	3%	7%	6%	5%
Food & Feed	1%	2%	5%	3%	1%	2%	2%
Socio-economic framew.	**∑10%**	**9%**	**6%**	**4%**	**4%**	**9%**	**9%**
Total (absolute numb.)	**1,070**	**1,212**	**1,498**	**2,174**	**3,498**	**3,530**	**3,518**

[source: own calculations]

The second subclass of the *input dimension*, **climate & environmental protection**, was one of the most frequently considered pillars and after losing some relevance during the 2000s, it has been focussed on incrementally more since 2010. This funding, however, stems from various measures and, unlike **agriculture & forestry**, does not concentrate on a specific support line.

Over time, the funding share of biotechnological projects, as previously established, has become much less significant. **Green and white biotechnology** have remained quite stable at about ten percent (except for 3.4 % in 2013 - 2015) and between 15 and 20 percent respectively. In contrast, only roughly half of the projects in **red biotechnology** were financed in the latest time period compared to previous funding. In **green biotechnology**, most R&D-projects were promoted with a focus on plant research. Naturally, in **white biotechnology** many undertakings are related to industry and are found within LPS such as ‘BioIndustry 2021’, ‘Biotechnology 2020+’ or specifically in ‘Optical technologies for lighting and environmental protection’ or ‘Analytics – Sensors, measurement methods and models’. Analogous to this, R&D in health dominates funding in **red biotechnology**. First and foremost, projects in the field ‘Systems biology’ have the biggest share throughout the whole observation period. More recently, funding of SMEs and thereby a bigger focus on specific market solutions can be perceived. One needs to bear in mind that the overall amount did not decline (on the contrary, project numbers in the **red biotechnology** almost doubled from 483 to 916 between the first and last time period shown), but other bioeconomy sectors have recorded more significant increases in terms of the number of projects.

The subclasses of the output dimensions generally fluctuated at a low base level except for energy-related projects. This outcome reflects and confirms HÜSING et al.'s (2017) and FRENKEN'S (2017) findings that there is a lack of clear markets and customers for bioeconomy products. Projects to develop **bio-based products or materials** have had some peaks, resulting from temporary funding measures such as ‘Identification and investigation of marine natural substances’ or ‘Integrated environmental protection in the timber and furniture industries’, but did not receive persistent research grants. Interestingly, **energy & fuels** from biomass is the only segment of all classes in the output pillar that shows a slightly positive development in terms of the project count. Contradictory to HÜSING et al. (2017), who identified the field of action 'Biomass-based energy sources’ as being neglected in terms of public R&D, we find a rise from zero projects in 1995 - 1997 to around 200 each in the last three time periods. As mentioned before, this segment differs slightly from the others, as more than half of the R&D funding are derived from the Federal Ministry for Economic Affairs and Energy. ‘Energetic use of biomass’ and ‘Basic energy research’ are the categories with the most undertakings within this category. R&D in **food & feed** industries only had a very limited share of the bioeconomy funding in the past. Even the topic ‘Global food supply’, which is mentioned in the NFSB as being a principal goal of all those stated in the NFSB, only had 14 and 42 projects financed in 2012 and 2013 respectively and funding stopped in the following years.

Although measuring the **socio-economic framework** has never been done in previous attempts to assess the scope of the bioeconomy, we identified a not insignificant allotment of funded projects in this pillar. Between 1996 and 2000, this was mainly driven by the BioRegio contest, in which e.g. network activities were fostered between firms and institutions. After a loss in relevance from 2001 to 2011, inter alia, investments in international cooperation and further exchange opportunities for scientists (via scholarships) have received considerable support, indicating the significance attributed to this issue. Subjects like animal welfare, general infrastructure or social-ecological research still appear less frequently, but have become more apparent in recent years.

To gain a more complete or differentiated understanding of the bioeconomy funding in Germany, the monetary dimension has to be considered as well. In Table 4-3, it can be seen that the overall development follows the same trend as the project count, yet in different magnitudes, i.e., R&D projects to promote biotechnological processes receive more financial support on average than projects in the *input, output dimensions* and also more than those in the *socio-economic framework*. While this can generally be explained by the cost-intensive equipment used in biotechnology, we also find that **red biotechnology** is the predominant driver for this issue. It is only within the more recent time intervals that **green and white biotechnology** were issued more funding than projects in relative terms. Apart from that, it is interesting that R&D projects in **climate & environment** have a bigger monetary share than their share by the project count. In every other category at almost any other time period, the project number is equal to or higher than its financial stake.

Table 4-3: Public R&D funds within the bioeconomy in Germany, 1995 - 2015

Bioeconomy dimension	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015
Input	**∑18%**	**20%**	**14%**	**14%**	**16%**	**22%**	**28%**
Agriculture & Forestry	3%	4%	3%	7%	11%	13%	18%
Climate & Environment	15%	16%	11%	7%	5%	9%	10%
Processing	**∑71%**	**62%**	**73%**	**78%**	**73%**	**67%**	**59%**
Green biotechnology	6%	12%	7%	7%	8%	9%	4%
Red biotechnology	52%	40%	48%	53%	47%	40%	35%
White biotechnology	13%	10%	18%	18%	18%	18%	20%
Output	**∑ 3%**	**8%**	**9%**	**5%**	**7%**	**8%**	**11%**
Products & Materials	2%	5%	3%	2%	1%	1%	3%
Energy & Fuels	0%	1%	2%	2%	6%	6%	4%
Food & Feed	1%	2%	4%	1%	0%	1%	4%
Socio-economic framew.	**∑ 7%**	**11%**	**5%**	**2%**	**3%**	**3%**	**4%**
Total (in million EUR)	**515**	**696**	**692**	**916**	**1,557**	**1,438**	**1,230**

[source: own calculations]

In essence, public funding of bio-related R&D projects co-evolved gradually with programmatic changes. A rise in projects related to the bioeconomy shell became visible well before the introduction of the NFSB in 2010. This gradual change started already around 2001 and a further marked rise of funding in the bioeconomy shell occurred in 2012 with a delay of two years after the introduction of the NFSB. The significant decline of projects in **red biotechnology** since 2010 in favour of R&D in **agriculture & forestry**, mainly driven by the involvement of the BMEL, as well as investments in undertakings related to the **socio-economic framework** of the bioeconomy, has been most apparent. Most pillars do not follow a consistent trend and fluctuate around a certain value, whereas much less attention has been paid to the *output dimension*. The biotechnology core still plays a very important role, which can be traced back to the funding history in Germany and the special role attributed to biotechnology as key enabling technology (KET).

4.8 Discussion

In the analysis, we used a broad definition of the bioeconomy, which made it possible to supplement preceding bioeconomy research and to overcome existing drawbacks regarding both a detailed definition and meaningful data (cf. e.g. BUGGE et al. 2016; PIETZSCH 2017; WESSELER & BRAUN 2017). These data revealed a steady increase from 316 funded projects in 1995 to 1,374 in 2015. However, in the same time period the growth in the overall amount of funded projects advanced at almost the same rate, which is why it is not possible to speak of a clear prioritisation of bio-related R&D. The argument that priorities and, accordingly, public governance are shifting to an extent that one sector or branch is massively promoted or neglected cannot be confirmed here. Nevertheless, we found a considerable structural change within the bioeconomy R&D funding at the expense of **red biotechnology**, which was, among others, a focus area of the previously pursued funding schemes. The *biotechnology segment* was, proportionally, by far the most heeded pillar between 1995 and 1997. Due to the shift at the programmatic level and BMEL's growing engagement, biotechnology lost in relative significance in governmentally funded R&D projects. In spite of this, biotechnological processes still enjoy the most attention in funding programmes and make clear the vision of the Federal Government, whose procedural model consists of solving emerging issues mainly via technological innovations (HAUSKNOST et al. 2017; BUNDESREGIERUNG 2018a).

Against the backdrop of the debate about new innovation policy approaches, KATTEL & MAZZUCATO (2018) highlight how non-technological innovations have gained value in the third generation of the innovation policy. Apart from technological innovation, one can distinguish between a great variety of innovations within organisations (DAMANPOUR 1991) as well as other concepts such as social innovations (EC 2013). While GRIMM et al. (2013) emphasise the great potential of social innovations as a policy tool, MCCANN & ORTEGA-ARGILÉS (2015, p. 1299) stress attention to the 'adaption, adoption and diffusion' of existing innovations as an appropriate measure to implement technologies like biotechnology in practice. In view of the relatively recent implementation of such approaches in innovation policy (since 2014 in the German Hightech-Strategy), an evaluation with regard to an adequate quantity and effectiveness is still somewhat premature (KUHLMANN & RIP 2018).

However, the data also reveal that the share of the biotechnology sector diminished over time, which might be an indication of the acknowledgement of facets apart from technological R&D. The biggest beneficiary of this development is the **agriculture &**

forestry sector. At the same time, the *output dimension's* stake as a whole has not significantly increased, which highlights the frequently mentioned issue of missing markets (HÜSING et al. 2017; FRENKEN 2017). In fact, it turns out that the **energy & fuel** section is most frequently promoted within the *output dimension* in the later phases. The energetic use of biomass, in contrast, is often regarded as the last stage of cascade utilisation with the lowest added value. The debate on the prioritisation of the respective bioeconomy fields is justified at this point (e.g. food or fuel).

Another concern raised is the feasibility in terms of ecological sustainability and capacity limits respectively. While there are objections about the general practicability of a bioeconomy, no dedicated funding measures concentrate exclusively on the substantial issue of **climate & environmental protection**. Additionally, in the data one can find evidence that this pillar lost significance over long periods and only recently regained attention. This could be explained by the lack of prioritisation, but also because the topic is implicitly addressed in other funding measures assigned to different segments as well as due to its cross-sectional character. The same applies to some aspects of the **socio-economic framework** such as the sensitisation of the broad population and the entire societal discourse on the subject. With regard to this issue one does not find an explicit line of support, because it is included more as a cross-sectional field of action in both major strategies of the Federal Ministries (BMBF 2010; BMEL 2014).

Looking at the development at both programmatic and project level, we argue that, in this instance, an innovation policy with a rigid and linear top-down character, in which policy-makers determine the direction of R&D funding in empty space, does not apply. By considering the content and time dimension in political discourse, funding programmes and approved R&D projects, it is more likely that other mechanisms can be assumed. It shows that funding measures are based on previous and existing strategies, which thereby have an impact on further schemes in future. In other words, the assumption that the policy-making process is self-enforcing and evolutionary with several evaluation loops between phases, which are not clearly separated, is more likely to be the case than a strictly government-driven process independent of other determinants. One consequence would be the expectation that the long-term aim of establishing a vibrant and innovative biotechnology landscape in Germany has led to an early commitment to a dedicated bioeconomy strategy, in which the cross-cutting biotechnology still plays a fundamental role. Hence, the current priority which favours the bioeconomy concept will prospectively also influence forthcoming innovation policies (see Fig. 4-4).

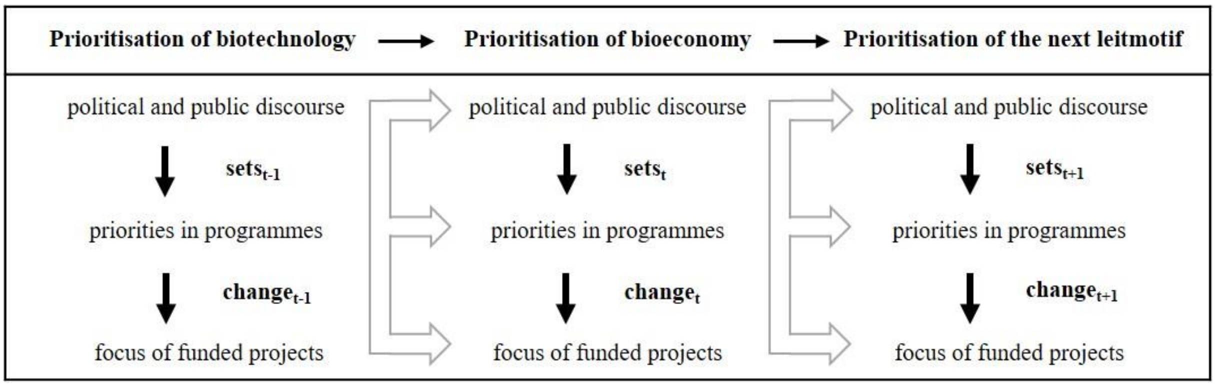


Fig. 4-4: Hypothetical interdependencies during the evolution of bio-based innovation policy

[source: own draft]

In conclusion, the criticism of the top-down character of mission-oriented innovation policy might be justified to some extent, but due to the illustrated implementation of a strategy such criticism does not seem to be so well-founded. The data suggest that the implementation resembles an evolutionary process successively driven by a diversity of actors from business, research and other stakeholders (e.g. civil society) who continuously influence the mission or strategy. The advantage of using this approach is that a certain continuity can be achieved, which is conducive to planning and the long-term visions of all concerned actors. However, the question as to whether the 'race chosen and bet placed' was the most efficient choice remains. Moreover, this self-enhancing path-dependent process might eventually lead to a lock-in situation in which a specialisation is achieved that is difficult to overcome.

4.9 Concluding remarks and future research

In the context of this study we have focussed on the multi-faceted subject matter of the changing character of innovation policies as well as the emergence and development of state-selected missions. The applied innovation policy tools have been adapted in line with the zeitgeist and indicate the increasing relevance of holistic perspectives in modern times. However, how missions surface and are subsequently realised in tangible programmes and projects has largely not been elaborated on. Therefore, the aim was to shed light on the efforts and transformation of bio-themed innovation policy in Germany. Due to the diagnosed shift from a mere technology policy towards a trans-sectoral approach, the expounded case allows the reproduction of the sequence of political actions. To capture the dimension of the underlying changeover, we analysed the development in two stages. First, we traced back political interventions at the programmatic level, which aimed at the construction of a leading biotechnology sector and the implementation of a bio-based economy. Secondly, we built a database containing all publicly funded bio-related R&D projects to identify the development of the measures undertaken.

Overall, it is not possible to draw any final conclusion as to whether and to what extent a critical mass of projects or monetary incentives must be provided in order to assure the realisation of a bioeconomy. Furthermore, it is debatable whether the specification of a direction is necessary or whether other paths induced by the market would guarantee a more efficient and meaningful solution to the EU's GSCs or the UN's SDGs. Nevertheless, past research has shown that a mission-oriented policy has its raison d'être. Particularly in the case of the bioeconomy, it is apparent that economic reasons have not been the sole driver for the innovation policy as was the case for most previous interventions. Instead, ecological imbalances and capacity limits require the commitment of governments to steer and pave future paths.

Through this analysis, we have responded to two deficiencies in the existing literature. Firstly, we are able to show in which way innovation policies occur and develop as well as whether and how those policies are implemented through concrete projects. Secondly, while most studies deal with the technological facet of the bioeconomy, topics covering its socio-economic component are still quite rare. By proposing a classification along the value chain, we acknowledge the comprehensive character of the bioeconomy and suggest a model, in which novel components can be added. Hence, our contribution is a better understanding of the concept and an overview of the general evolution of bio-themed R&D funding in Germany.

The case outlined is an individual case study. It is therefore conceivable that the rule may in reality be characterised by strict top-down planning (e.g. for developing countries). Nevertheless, there are good arguments that this process is to some extent similar in other contexts as well. That means, path dependencies might play a key role in other fields of innovation policy as well. Due to a lack of capacities, it is impossible for a single country to specialise in all kinds of technologies and pathways and therefore a certain focus is necessary (SCHOT & STEINMUELLER 2018). It ist expected that existing structures and knowledge are decisive for future endeavours and that mechanisms of relatedness and branching occur in this respect. In this case it would have been unlikely to foster the bioeconomy concept at a very early stage without the biotechnology efforts of previous decades. The same is also conceivable for strategies in other fields of innovation, which remains a topic for future research. However, the findings must be embedded in the general shift of innovation policies within the last two decades. Since mission-oriented innovation policies and the emergence of bioeconomy promotion took place simultaneously and possibly mutually influenced each other, it would be too early to postulate a strictly causal relationship.

In this study, we one-sidedly examined the input dimension of innovation in terms of R&D projects in the bioeconomy. Other mechanisms, such as market shaping approaches, have been installed by politics to realise the bioeconomy mission, but are not examined here. Also, further research about actual output is required to get a better grasp of the scope, volume and sustainability of the intended knowledge-based bioeconomy. Furthermore, distinct impact studies to evaluate public endeavours are crucial to assess its ramifications and hence, legitimise the political engagement in anticipated and not yet established fields such as the bio-based economy.

Although we were able to present a more comprehensive image of the R&D projects that foster the realisation of a bioeconomy in Germany than previous research, there are still concerns that need to be considered. First, the database we used for the keyword search only provided us information about the title of the project. More detailed information about the objective of the individual projects would have created a better foundation for the identification of bioeconomy projects. In addition, it should be noted that by categorising the projects into different parts of the bioeconomy, we are able to provide a new perspective in terms of content. Yet some projects cannot be attributed in a clear-cut way. For instance, **agriculture & forestry** may be closely related to **green biotechnology** or **food & feed industries**. Cross-cutting subjects such as **climate & environment** and the **socio-economic framework** may also be found jointly in projects that have their core objective in other areas.

While this work addresses the interaction between political rhetoric and the actual translation into corresponding programmes and projects, neither downstream research subjects such as the adoption and evaluation of undertaken policy nor qualitative insights into the individual features were part of the contents of this examination. With our findings, we are able to conclude that there is not a simple linear direction from political discourse that introduces or adjusts programmes and has consequently altered the priorities in projects. However, it is still a matter for further research to determine which factors set which processes in motion or influence them (see Fig. 4-4) and remains the focus of future (qualitative) research. In these regards, additional studies are required to understand the mechanisms of the policy-making process in general and innovation policy in particular.

5 SPATIAL IMPLICATIONS OF R&D FUNDING FOR THE BIOECONOMY REDUCING REGIONAL DISPARITIES BY IMPLEMENTING A BIO-BASED ECONOMY?

Abstract

The previous chapter described the change in course of innovation policy towards the bioeconomy. However, this development has not only consequences in terms of its content, but also affects the spatial distribution of R&D funding. Against the background of existing polarisation tendencies and the growing acknowledgement of inclusive innovation policy approaches, this study examines the importance the bioeconomy can assume in the reduction of regional disparities. On the basis of a database containing all publicly funded R&D bioeconomy projects in Germany and further data characterising regional features, comparative regressions are conducted in order to identify different funding patterns. The statistics demonstrate differing funding mechanisms in the individual areas of the bioeconomy. The transformation from a biotechnology focus to the bioeconomy results in the inclusion of more traditional industries, which thus leads to greater participation of peripheral and rural regions. Complementary cluster analyses also reveal that over time more regions have adopted the bioeconomy theme. These findings indicate that the pursuit of a bioeconomy strategy has the potential to generate and exploit synergetic effects between agglomerations and their rural periphery in order to prevent a further aggravation of divergent living conditions.

Keywords

Regional disparities, Inclusive Innovation Policy, Funding data, Regional analyses, Biotechnology, Bioeconomy

5.1 Introduction

Recently, two studies assessed that an increasing geographical polarisation in Germany led to different development in the regions in terms of their infrastructure, living conditions and economic performance (IWH 2019; KOMMISSION 'GLEICHWERTIGE LEBENSVERHÄLTNISSE' 2019). Next to a west-east divide with historical causes, one finding is that there is also a clear negative south-north progression. Although it was previously known, the most publicly communicated and alarming conclusion is the steadily growing gap between agglomerations and rural regions (KOMMISSION 'GLEICHWERTIGE LEBENSVERHÄLTNISSE' 2019). Since the occurrence of diverging economic activities is not a new discovery and numerous prior studies came to similar conclusions, whether it was on a national or sub-national level, several measures have been implemented to address this issue of regional disparities, for instance, by both the German government and the European Union (EU). Classical regional policies on the EU level that aim to at least reduce these regional differences are the *Cohesion Policy* and manifold structural funds, namely e.g. the European Agricultural Fund for Rural Development (EAFRD), European Regional Development Fund (ERDF) and European Social Fund (ESF). On the national level, Germany deploys the instrument Bund-Länder-Gemeinschaftsaufgabe ‘Verbesserung der regionalen Wirtschaftsstruktur (GRW) (Joint Task ‘Improvement of the Regional Economic Structure’) to support and promote weaker regions with the intention of achieving an equivalent spatial development in economic and social terms. This goal is mainly pursued, among other things, by investing in the region’s business-related infrastructure or subsidising economic activities (e.g. expansion of production capacities) of resident small and medium enterprises (SME).

However, the underlying approaches in regional policy have gradually changed. In particular, the importance of innovation-based growth, especially in peripheral regions, has grown significantly in recent decades (OECD 2011). Classical innovation policy has successively moved away from sectoral and geographical growth pole approaches and thus, increasingly stressed the value of the spatial dimension as well as the significance of the ‘region’ as an actor (KOSCHATZKY 2005). Therefore, to allocate the limited resources most efficiently as well as to take account of the varying regional endowments and capacities, one-size-fits-all strategies have been renounced in both literature and policies (TÖDTLING & TRIPPL 2005; OECD 2011).

One example is the emergence of the bioeconomy in innovation policy. According to the official Research Strategy on Bioeconomy in Germany (NFSB) published in 2010, innovation and diffusion should not only be driven by urban centres, but should rather develop collectively in all regions. The bioeconomy strategy itself evolved out of previous biotechnology funding, merged with regional and agricultural innovation approaches and replaced them. While past competitions culminating in the systematic subsidisation of biotechnology locations predominantly led to funding for development in agglomerations (e.g. BioRegio & BioProfile), the bioeconomy concept is also applied in peripheral regions. For this reason we analysed the biotechnology and bioeconomy funding histories from 1995 to 2015 as an example of a current case of a more modern approach to innovation policy in Germany (BMBF 2017c). Due to the nature of bioeconomy and its focus on natural resources, whose production is often tied to less developed and rural regions, the potential for lagging areas with rather low innovation capabilities to participate in more applicatory projects is expected to be greater than in basic research. In other words, we want to research whether the shift which has occurred in bio-themed innovation policies has actually led to a more balanced spatial distribution of R&D projects and thus proactively counteracted increasing regional disparities.

This examination contributes to the literature in two main respects. On the one hand, research in the context of (innovation) policy that goes beyond the notion and sole motivation of economic growth is still quite sparse. The inclusiveness of policy measures and the consideration of how welfare is distributed individually and spatially has mostly been a secondary priority amongst economists and economic geographers. Hence, a raised awareness of potential approaches to reduce disparities and derived policy implications will help to better understand which policy practices are suitable when facing polarisation tendencies. On the other hand, the bioeconomy design is rather intangible and needs more in-depth analysis to get a grasp of its scope and depth. There has not been much elaboration of which components of the bioeconomy are situated in which geographical areas. Particularly the shift in leitmotif from biotechnology to bioeconomy, thus, delivers the opportunity to identify differences between the two and to gain valuable insights about the potential for regions to benefit from this change.

This elaboration is organised as follows: In section two, we first collect the deliberations on inclusive (innovation) policy, which illustrate the urgency to look beyond viewing economic growth as the main objective for good governance. Thereafter, in section three we point out empirical evidence about the impact of innovation policy on technologies and regional (peripheral) development before we introduce and demonstrate in section four how the leitmotif transition in innovation policy from biotechnology to bioeconomy developed. In section five, the idiosyncrasies of bioeconomy as well as their expected potential for regional development are illustrated. Subsequently, we describe the data and method we used for our empirical analysis and display our results based on descriptive analysis, regression models and cluster analyses. Finally, a discussion of the results and methods follows before the paper ends with a brief conclusion.

5.2 Inclusive innovation policy

Politicians, mainly in developed countries, frequently pursue an approach of subsidising high-tech industries as they have the reputation of consequently triggering innovation and economic development (ERGAS 1987; LEE & RODRÍGUEZ-POSE 2016; MAZZUCATO & SEMIENIUK 2017). For instance, the US' 'Strategy for American Innovation', the 'Hightech-Strategy' of the German government, South Korea's 'Creative Economy Strategy', illustrate the clear focus on solutions within high technology industries (OECD 2014b; THE WHITE HOUSE 2015; BMBF 2017c). Complementary studies have shown that particularly employment in those sectors enables the generation of further jobs and raises wage levels in the respective country or region (e.g. ECHEVERRI-CARROLL & AYALA 2009; MORETTI 2010; MORETTI & WILSON 2014; GOOS et al. 2018). In consequence, policy tools concentrated mostly on agglomerations, since actors in high-tech industries tend to be located in an urban environment and that is where the overall effect is expected to be at a maximum due to the nature of interactive learning and spatially-bound knowledge spillovers (CAPELLO 1999; AUDRETSCH & FELDMANN 2004). Specific examples in Germany are the BioRegio and BioPofile contests that were introduced in 1997 and 1999 with the intention of establishing biotechnology in seven selected urban regions (see chapter 6.4, p. 97ff. for more details).

Theoretical deliberations and empirical evidence thus show that in most cases, on the one hand, high-tech industries possess the greatest efficacy in terms of job creation and wage increases and, on the other hand, this works best in agglomerations.[12] However, as described in the outline, globally but also within nations we find an increasing trend towards inequality (WEI 2015). This development raises the issue relating to the inclusiveness of policy measures. Over time, some concerns and criticism have been voiced that view the mechanisms of growth and innovation less euphorically (BARTIK 1991; BREAU et al. 2014; LEE & RODRÍGUEZ-POSE 2016; SASSEN 2019; BIGGI & GIULIANI 2020). In fact, the 'dark

[12] In fact, SHEARMUR (2019) points to the issue of a systemic bias in favour of urban regions in both theory and empirical research.

side' of innovation is increasingly the subject of debate in academic literature as well as in governmental organisations. Next to environmental issues and established negative externalities (pollution, overburdened infrastructure, housing prices etc.) in agglomerations, the topic of diverging living standards within countries is widely discussed due to the increasing inequality of wealth distribution (ATKINSON 2015). Against this backdrop, institutions and governments such as the OECD (2014a) and the EC (2010) acknowledge the fact that mere economic growth is not sufficient as an objective for policy measures.

Therefore, it is essential to address the structural and spatial distribution of the benefits generated in order to do justice to the goal of a balanced and healthy social structure (TUROK 2011). Cities are critical in this concern, since disparities are growing between urban and peripheral regions. High-tech firms and employment, for instance, are usually located in an urban environment due to the economic advantages of agglomerations and the proximity to universities (JAFFE 1989; PORTER 1996; GLAESER et al. 1992). Labour migration is, for example, an essential driver of the concentration of human capital in certain areas. FLORIDA (2002) illustrated that the *creative class*, which is an indicator for innovation and growth, tends to be concentrated in a few major cities. As a consequence, this generates inter-regional disparities.

In conclusion, the policy's focus on economic growth and innovation with the accompanying attention paid to high-tech industries, which are primarily located in urban agglomerations, is arguably too short-sighted. Therefore, an inclusive innovation policy to achieve more equivalent conditions is called for. Although some strategy papers recognised the value of policies that aim to reduce the disparities within and between regions, many innovation or industrial policy measures still concentrate on high-tech industries in agglomerations.

To alter this narrow view, foundational economists call for increased focus on basic industries that are not at the centre of R&D funding, for instance the construction or the agri-food sector (BENTHAM et al. 2013; BOECK et al. 2019). Some argue the foundational economy, that employs 40 % of the whole labour force, receives hardly any R&D funding (BENTHAM et al. 2013). Thus, they propose directing more R&D subsidies towards foundational industries in order to rebalance this status. With regard to the geographies of inequalities, lagging regions do not just need more financial support, but also an adequate strategy adjusted to their specific context in order to catch up (OECD 2014a). A better and more efficient diffusion of innovation is a prominent approach to effectively generate opportunities for job creation (e.g. entrepreneurship) and economic prosperity (MCCANN &

ORTEGA-ARGILÉS 2013). In light of the unequal spatial distribution of the economy and living standards, as well as the growing discrepancy between high-tech and low-tech salaries, the question of whether a job created in rural areas has the same societal value as one in an agglomeration arises. In general, the 'dark side' of innovation should be acknowledged and discussed more in the academic and political context instead of subordinating everything to the idea of innovation generation (BIGGI & GIULIANI 2020).

That means a systemic readjustment of the focus of innovation and industrial policy is required if politicians genuinely wish to achieve a convergence of living conditions. Therefore, in the following, the mechanisms of the policy's influence on regional development will be addressed before the possible importance of the implementation of a bio-based economy is discussed.

5.3 The impact of innovation policy on regional development

While there are few empirical studies on the impact of regionalised innovation policies, one can find several analyses on the effects of innovation policy in general. Prominently, MAZZUCATO (2014) showed that the long-term vision of governmental support is inherently underestimated, since investments are made in risky research and technologies that would have been avoided by private actors. Eventually, this predominantly leads to the advancement of technologies and thus, to the welfare of companies. Although there are cases which show failures or wrongly chosen paths, thus illustrating the difficile nature of innovation policy, we find diverse scholars that vindicate the policy-driven economy approach.

Some studies on particular innovations or branches, furthermore, illustrate the extent of policy-driven approaches. E.g. LAZONICK & TULUM (2011) showed that ground-breaking innovations in biotechnology were initiated and supported by government funds. Additionally, using examples of basic innovations of 'Apple' products, MAZZUCATO (2014) demonstrated that most of the innovative components originated from publicly funded technologies. In another example, she traced the development of certain pharmaceutical drugs, which were often shown to be induced by R&D subsidies. ARNOLD (2012) concluded in his research that there were measurable long-term effects of multiple funding programmes stimulating several individual fields (e.g. brain research, O_3 research) or whole industrial branches (e.g. the automotive industry, information and communications technology (ICT)). AGHION et al. (2011) justified state intervention by providing evidence that, on the one hand, incessant laissez-faire would lead to environmental failures and, on the other hand, sectoral policy has positive effects when appropriately applied. For instance, policy measures have greater impact if they are applied in a decentralised way and complemented with further instruments, such as taxes for industries that inadvertently produce negative externalities. UHLBACH et al. (2017) inferred similar results and stressed the necessity of appropriate allocation of public R&D subsidies in terms of the relatedness level. They found the EU-support was most effective in regions where the extent of related knowledge was neither too low nor too high.

Moreover, there are indications that cooperative public R&D is particularly beneficial at both the microeconomic and the macroeconomic level. CZARNITZKI & FIER (2003) as well as CZARNITZKI et al. (2007) focussed on the firm level and found statistical affirmation that R&D networks are more likely to generate patents than individual R&D. In addition, networks with financial support perform better than collaborations without governmental aid. A study on Japanese research consortia lead to comparable results, which concentrated on firms' outcomes such as research productivity (BRANSTETTER & SAKAKIBARA 1998). Particularly the aspect of increased knowledge spillovers within the networks illustrates the importance of collective learning. On the macro-economic scale, regions with low innovation capacity are more likely to take advantage of subsidised R&D projects, notably in partnership with external research institutions (BROEKEL 2015).

Most empirical analyses indicate that, on the whole, there is a positive impact of governmental-led initiatives to foster specific technologies, industries or regions. However, the policy design needs to fit the targets set. That means, the one-size-fits-all perspective, in which one top-down approach is applied regardless of the region's characteristics, is obsolete, and policies should be more differentiated and adapted to certain conditions (TÖDTLING & TRIPPL 2005).

In order to support peripheral regions and trigger their innovation potential, empirical studies indicate that the policy interventions applied have to build on existing endowments (AGHION et al. 2011; MARROCU et al. 2013; CARVALHO & VALE 2018). Some studies go one step further and point out that peripheral regions offer advantages over agglomerations in many areas. For instance, lower negative externalities (e.g. negative spillovers) and strong in-house capabilities might be important determinants that lead to faster growth outside of agglomerations (GRILLITSCH & NILSSON 2017). Other factors such as employee loyalty in addition to lower salaries, close relationships to local institutions and the affinity for the location can play a vital role for the company's progress (EDER & TRIPPL 2019). Those characteristics and mechanisms are very valuable for private players and the quality of innovation, and thereby constitute promising components for inclusive policy designs.

As mentioned at the outset, the transition from biotechnology to bioeconomy might be an example that meets the objectives of an inclusive innovation policy. Subsequently the changes in the leitmotif are portrayed to give a quick overview about the bio-related R&D landscape in Germany.

5.4 The transition from biotechnology to bioeconomy in the German innovation policy

The first official global appearance of the idea of a bio-based economy was in 2004 when the OECD released the document ‘Biotechnology for sustainable growth and development’ (PATERMANN & AGUILAR 2018). As such, this vision of ‘a concept that uses renewable bioresources, efficient bioprocesses and eco-industrial clusters to produce sustainable bioproducts, jobs and income’ (OECD 2004, p. 4) was first mentioned in a report about biotechnology. Subsequently, many countries altered their innovation policy in the form of a transition from biotechnology to bioeconomy.

This subject, which is increasingly present in global (OECD 2009), supranational (EC 2010) and national (BMBF 2010; THE WHITE HOUSE 2012; MEAE 2014; UK GOVERNMENT 2018; BMBF & BMEL 2020) funding schemes, aims at the promotion of R&D related to biological resources. In the holistic bioeconomy concept, next to the trans-sectoral technologies of the biotechnology sector, upstream industries such as agriculture and forestry as well as downstream sectors, for instance energy production from biomass or the food industry, should also be engaged in and benefit from the bioeconomy concept (BMBF 2010; EC 2012; BMBF & BMEL 2020). The past bio-themed funding measures in Germany are briefly presented below in order to illustrate the underlying transition from biotechnology to bioeconomy (see also Table 4-1, p. 39 and chapter 4).

Pioneering endeavours in Germany to promote biotechnology date back to the period around 1970 (WARMUTH 1991; BMBF 2011; SCHÜLER 2016). Most funding in biotechnology largely favoured basic research by public institutions and was aimed at the generation of scientific knowledge (WARMUTH 1991). However, with regard to bio-related funding in Germany, the initial systemic approach to commercialise biotechnological procedures was proposed in 1995 in the form of the BioRegio contest. Subsequently, further programmes (i. a. BioProfile, BioChance, BioFuture) were added in order to continue this strict sector-based approach. In 2001, the German Federal Ministry of Education and Research (BMBF) introduced another funding measure ('Framework Programme Biotechnology' (FPB)) to not only foster biotechnology independent of the location (in contrast to BioRegio and BioProfile), but also bio-sciences in general and thus, somewhat broadened the narrow interpretation. Eventually, starting in 2010, this programme merged into the 'National Research Strategy Bioeconomy 2030' (NFSB), which was carried out by six Federal Ministries[13] that jointly promote and fund the holistic bioeconomy concept (HÜSING et al. 2017). Subsequently, this scheme has resulted in additional specific programmes, e.g. the 'Roadmap Bio-refinery' in 2012, and the 'National Policy Strategy on Bioeconomy' of the BMEL in 2013 (BMEL 2014), which also interfaces with other political schemes such as 'Action plans for the material and energetic use of renewable raw materials' (2009/10) or the 'Forest strategy 2020' (2011). In 2020, the Research and Policy Strategies were bundled to form an overall strategy (BMBF & BMEL 2020). It can therefore be stated that there is clear evidence in Germany of a theme shift 'from a biotechnology-centric vision to an economic activity that spreads across several key sectors and policy families' (OECD 2018, p. 11).

The policy course outlined above might play a vital role in proactively countering regional disparities by improving the rural region's economic performance. The reasons why the promotion of a bioeconomy in particular has the potential to be an auspicious example of an inclusive innovation policy will be examined in more detail next.

5.5 The bioeconomy's capabilities to reduce regional disparities

The bioeconomy concept possesses the potential to involve rural and peripheral regions due to its extensive nature with a focus on new production mechanisms using biological resources or novel procedures in traditional branches such as the food and feed industry or pulp and paper industry. Germany's policy tools mentioned in the outline and the EU's *Cohesion policy* are more general endeavours to balance inter-regional inequalities. However, the two respective bioeconomy strategies also integrate the development of peripheral regions. While the EU's strategy states that it is intended 'to support local bioeconomy development (rural, coastal, urban)' (EC 2018a, p. 18), the BMEL (2014, p. 20)

[13] Under the leadership of the BMBF, the following federal ministries are responsible for the implementation: Ministry of Economic Affairs and Energy (BMWi), Ministry of Food and Agriculture (BMEL), Ministry of Environment, Nature Conversation and Nuclear Safety (BMU), Ministry of Economic Cooperation and Development (BMZ) and the Federal Foreign Office (AA).

places emphasis on ‘securing and creating employment and added value, especially in rural areas’.

By implication, the issue of a concrete and comprehensive implementation of this political intention comes to the fore. The most apparent fact, initially, is that the majority of the upstream industries involved in the production of biological raw materials, such as agriculture and forestry, are located in rural areas. The same applies to some downstream industries, notably food and feed, the chemical industry, textiles, as well as the production of energy using biomass. These sectors are often characterised by their rather low technological requirements. Modern policy has recognised the unfeasibility and inefficiency of trying to create strong high-tech sectors in any location whatsoever and hence, underscores the need to transmit knowledge from the core into structurally weak regions, according to the precept of ‘adoption, adaption and diffusion’ (MCCANN & ORTEGA-ARGILÉS 2015, p. 1299) of (external) knowledge. Thus, the aspiration is, as BALLAND et al. (2019, p. 1) phrase it, not ‘to leverage existing strengths, [but instead] to identify hidden opportunities and to generate novel platforms upon which regions can build competitive advantage in high value-added activities’. In other words, instead of specialising in already existing dominant industries, endeavours should rather be made to diversify the prevailing structural conditions.

From a theoretical perspective, HASSINK (2010b) conceptualises the risk of a strong specialisation as a perilous dependence on one or few industries, which results from an absence of renewal tendencies. Subsequently, there is a decreasing innovation potential along one or a small number of technological paths, which increases the susceptibility to external shocks and might result in a lock-in, which ultimately leads to path exhaustion (ISAKSEN 2015). To avoid these scenarios, current policies pursuing the bioeconomy concept aim at a diversification of incumbent trajectories and path renewal, respectively. MCCANN & ORTEGA-ARGILÉS (2015, p. 1296) clarify ‘that very few regions make fundamental structural or sectoral shifts in the short- to medium-term’ and thereby illustrate the relevance of regional branching. In the context of bioeconomy this means that in rural and peripheral areas existing endowments in low technology sectors possess the potential to enrich the local capabilities with exogenously developed general purpose technologies (GPT), particularly biotechnology. Moreover, these very GPT, connoted as ‘analytical knowledge’ due to their knowledge bases, are predestined for implementation in geographically distant industries (ASHEIM et al. 2011a). The possibility to codify and formalise the biotechnological knowledge provides the opportunity for traditional branches to transfer extant expertise over long distances, to employ them in new ways and through this, renew or even create regional trajectories. Especially for structurally weak regions, which are often characterised by small and medium size enterprises (SMEs) without or with only few own R&D establishments, external and public knowledge are particularly viable (SOETE & TER WEEL 1999; ISAKSEN 2015). In the context of forest-related strategies, ALBERT (2007, p. 65f.) stresses the need for rural areas 'to perfect their 'outside-in' thinking skills, relating information about development in the external world to what is going on internally'. This maxime underlines the beneficial nature of the complementarity between exogenous and endogenous from several other facets of bioeconomy (BUGGE et al. 2016).

CARVALHO & VALE (2018) propose that peripheral regions diversify current structures by 'bricolage', which focusses on agency and available local resources. In general, bricolage 'connote[s] resourcefulness and improvisation on the part of involved actors' GARUD & KARNØE (2003, p. 278) and was founded on the development of the wind turbine path in Denmark. In fact, the core assumptions of the bricolage conception are similar to some basic notions of bioeconomy strategies. Namely, local actors who maintain knowledge about their site, resources, institutions, or markets, as well as linkages to other relevant actors, play a crucial role in allocating the available resources efficiently. Natural resources themselves also have a great significance. As decisive elements within the bioeconomy, rural regions produce most of the biomass to be processed. Furthermore, the Danish wind turbine sector was financially supported by the government in order to foster the new path development (GARUD & KARNØE 2003). The same applies to the case made by ISAKSEN (2015) and, of course, the bioeconomy, which is increasingly being promoted. The fact that the developers of the wind turbines were not necessarily the same individuals who utilised the technology for commercial reasons, emphasises the potential to apply externally generated knowledge adapted to the regional environment and capabilities, for example, to steadily improve low-tech industries. This type of diversification, based on SCHUMPETER'S (2005[1942]) considerations on recombining existing resources, also reflects the deliberation on 'self-discovery' (HAUSMANN & RODRIK 2003, p. 605). This notion stresses the necessity 'to allow for experimentalism in order to discover what works in what context' (MCCANN & ORTEGA-ARGILÉS 2013, p. 208) and to move 'beyond […] natural-resource based products' (HAUSMANN & RODRIK 2003, p. 605), which is particularly crucial for rural and structurally weak regions. In general, innovation opportunities for peripheral regions have successively improved due to the availability of external knowledge (via modern ICT), growing negative externalities in agglomerations as well as local agency and internal knowledge about the respective sites (GRILLITSCH & NILSSON 2017). In other words, regions that are often perceived and labelled as providers of natural resources and as locations for space-intensive industries might have a better chance of moving beyond this stigma and becoming stronger economic actors themselves under the bioeconomy leitmotif.

It can therefore be concluded that the bioeconomy might be a chance to foster or revitalise regional development, especially for economically lagging regions. We will evaluate whether the structure of the underlying innovation policy and distribution of funding also changed and if it thereby benefits those regions. This leads to the following research question:

> **Are rural, peripheries and structurally weak regions with a traditional and less knowledge-intensive sectoral basis favoured by the funding shift from biotechnology to the broader bioeconomy concept?**

5.6 Data and method

The data lineage for the empirical part of this study is the BMBF's subsidy database, as described in chapter 3. Derived from this unique data, we calculate the project count and project funding of each bioeconomy dimension at any given time on any regional level. For this study, we work on the level of labour market regions, administered by the BBSR (2017). There were two key reasons for this choice. First, labour market regions have the advantage that pronounced linkages between districts ('*Kreise*') are taken into account and thus they provide a better view of the economic reality (e.g. commuting flows, urban-rural-relations) than administrative borders based on history. Secondly, spatial autocorrelation becomes a problem with most models on a district level, which eventually leads to incorrect estimates.

Based on these data, we are able to conduct two different analyses in order to get insights into the spatial implications of the policy shift from a sectoral biotechnology-centred funding to a holistic bioeconomy concept.

5.6.1 Comparative Regressions

In order to test the elaborated hypothesis we conduct four comparative regressions with varying dependent variables,

(i) overall project count,
(ii) number of bioeconomy projects,
(iii) biotechnology projects and finally,

(iv) count of projects within the bioeconomy shell.

For the purpose of tracking the transformation of applied regional innovation policies, analyses are performed taking into account different time intervals, i.e., first we estimate which regional and structural parameters were vital for the acquisition of projects in 1995 - 2001, corresponding to the era of predominantly biotechnology funding. Second, based on the same variables, comparative examinations are performed with data from the most recent time interval, which mainly falls within the period after the introduction of the bioeconomy strategy, from 2009 - 2015. Since the significance of previous biotechnology knowledge and the specialisation of the region is an integral component for the evaluation of path dependency, the share of biotechnology projects obtained as a proportion of the total number of projects in the preceding period of seven years is included into the model ($\boldsymbol{BT_{t-1}}$). Further regressors contain the regional data from the last year of each period, namely 2001 and 2015 respectively. [14]

Various regional data from the Regional database Germany (‘*Regionaldatenbank Deutschland*’) provided by STATISTISCHE ÄMTER DES BUNDES UND DER LÄNDER (2019) are employed as explanatory variables to capture characteristics of the observation units. We include the following regional determinants as independent variables for the econometrical model:

- Number of people employed (EMP)
- Gross domestic product per employee (GDP)
- Unemployed people per capita (UNEMP)
- Population density (POPDENS)
- Employees in knowledge-intensive industries (KNOW)[15]

Furthermore, we add a dichotomous variable called EAST to control the bias in funding which favours Eastern German territories due to the intention to accelerate the catching-up process and also to prevent spatial autocorrelation that can be caused by structural dissimilarities between the regions of the former GDR and West-Germany.

[14] Due to the lack of data regarding the working population in knowledge-intensive industries, we used the earliest available data from 2009.

[15] This variable is constructed based on the definition of the INKAR database (BBSR), suggesting that the industrial sectors 62-64, 66, 69 & 70–74 in the WZ 2008 classification of the Federal Statistical Office of Germany are characterised as knowledge-intensive industries and services.

As is apparent, any dependent variable whatsoever represents count data. This implies that the error term of the regression will not be normally distributed. For that reason, we employ generalised linear models. Since overdispersion occurs in any model, we neglect the Poisson Regression Model and employ Negative Binomial Models for all estimations (ZEILEIS et al. 2008).

5.6.2 Cluster Analysis

In addition to the regression models, complementary cluster analyses provide a more profound understanding of the structural differences between certain groups. For that reason we perform clustering for three determinants and for three periods, analogous to the regression analyses – 1995 - 2001, 2002 - 2008, and 2009 - 2015, using the k-means algorithm. The defining variables for each period are

(i) the total number of projects in the biotechnology core,
(ii) the total number of projects in the bioeconomy shell, and
(iii) the share of the bioeconomy projects.

Both the total number of projects in the biotechnology core and in the bioeconomy shell are integrated to estimate which regions profited the most from public R&D funding. Additionally, a differentiation between these two components is necessary in order to detect patterns. The proportion of bioeconomy projects in the region has been integrated for two reasons. It shows, on the one hand, how well the bioeconomy is represented in one region and provides continuity in a methodological sense, on the other. The latter is important to detect patterns over the different time periods.

Again, the unit used for the analysis is labour market regions. Common tests and figures (Elbow/Scree plot; silhouette plot) mostly suggest a differentiation between four clusters. Since we are comparing different time periods, this proposal is deemed the most sensible choice, having also trialled separation into either more or less than four clusters.

For a more detailed comparison of the resulting clusters, we use the same regional data as in the comparative regressions to get a grasp of the categorisation of the computed groups. Moreover, we add some variables to detect similarities within groups and distinctions between the clusters. We append the share of agricultural and forest area (which is regional data from the Regional database Germany) as a further indicator of the degree of the ruralness. From the derived '*Förderkatalog*' data (subsidy database), we also calculated the amount of joint projects that had a collaboration partner within the same labour market region. The same was done for extra-regional linkages. With both numbers the aim is to test whether there are apparent differences between regions and whether or to what extent they utilise and benefit from their extant endowments or seek knowledge from distant places. And finally, the percentage proportion of R&D projects being run by private business is another key figure which is worth contrasting.

5.7 Results

A number of the depicted statistics about the various datasets in Table 3-2 (p. 22) indicate underlying differences between mere biotechnology funding and the bioeconomy shell. Within the observation period, we find a considerable disparity between the average and median subsidisation. While the average grant in biotechnology is more than 150,000 EUR higher than for projects in the bioeconomy shell, the gap between the median projects is nevertheless still quite large at 100,000 EUR. Furthermore, the number of joint projects is noticeably higher in the biotechnology sector and in either of bioeconomy components it is also higher than for other projects in the database. One basic notion of bioeconomy is the implementation of biotechnological procedures into traditional branches as well as knowledge diffusion in general, which should most likely occur in the context of collaborations between various actors. Hence, a greater number of joint projects might indicate that this approach is being applied in reality.

If one looks at the spatial distribution of the projects (Fig. 5-1), it is notable that, for one thing, regions in the north of Germany and, furthermore, the outskirts of some agglomerations (e.g. around Berlin, Hamburg, and Munich) have received more attention since the introduction of the NFSB, especially in the bioeconomy shell. The funding of the bioeconomy shell seems to generally be more evenly distributed than that of biotechnology. Complementary to the visual differences, the GINI coefficient, which measures the inequality of any distribution, shows some distinctions between the bioeconomy components (Table 5-1). While the distribution of all projects funded by the German government is more even than the projects in the bioeconomy, we find that biotechnology, both in the beginning as well as at the end of the observation period, is highly localised. The bioeconomy shell, however, developed differently, and the GINI value decreased from 0.82 in 1995 - 2001 to 0.74 in 2009 - 2015, and depicts a more inclusive nature.

These simple comparisons of different datasets reveal some structural dissimilarities, which require econometrical analyses to identify and verify the underlying regional implications induced by the policy transition from sectoral to systemic innovation policies. Table 5-2 summarises descriptive statistics about the variables used in the models.

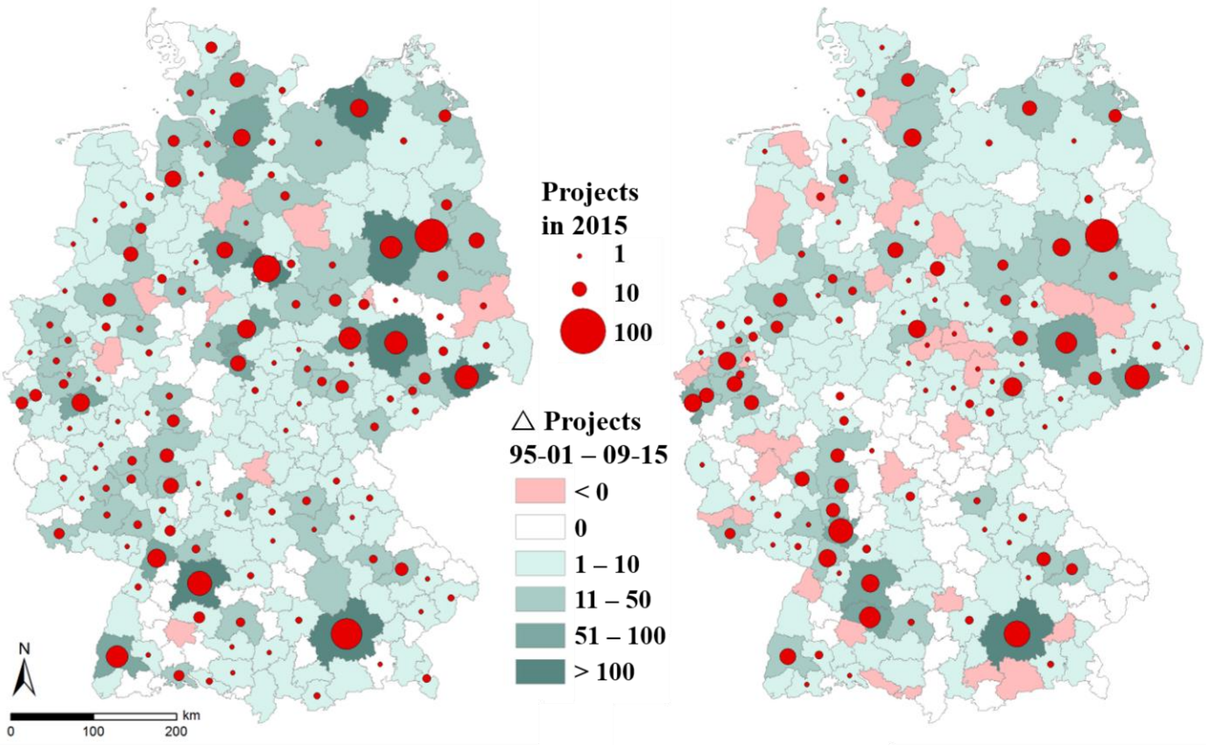


Fig. 5-1: Development of the funding within the bioeconomy shell (left) and the biotechnology nucleus (right)

[source: own calculations]

Table 5-1: Regional distribution of projects; GINI-Index

	Overall Projects	Bioeconomy concept	Biotechnology nucleus	Bioeconomy shell
1995 - 2001	.76	.82	.84	.82
2002 - 2008	.74	.78	.81	.78
2009 - 2015	.68	.76	.81	.74
1995 - 2015	**.71**	**.77**	**.81**	**.75**

[source: own calculations]

Table 5-2: Descriptive statistics of the variables

	Mean		Standard Deviation		Minimum		Maximum		No. of Obser-vations
	1995-2001	2009-2015	1995-2001	2009-2015	1995-2001	2009-2015	1995-2001	2009-2015	
Dependent var. (projects)									
All projects	95.83	228.96	224.79	463.86	0	7	1897	4391	257
Bioeconomy concept	11.63	32.50	30.50	71.06	0	0	273	598	257
Biotechnology nucleus	8.05	16.33	23.08	40.33	0	0	222	353	257
Bioeconomy shell	3.58	16.17	8.34	33.56	0	0	71	245	257
Explanatory variables									
EMP in 1,000 ppl.	154.90	167.58	218.99	246.25	26.70	27.30	1,595.60	1,845.60	257
UNEMP	14.10	9.39	10.77	7.29	3.20	2.10	61.50	46.40	257
GDP p. emp. in 1,000 €	49.17	64.78	8.32	8.91	33.24	49.04	87.75	106.70	257
POP per km²	299	294	428	426	44	36	3,800	3,948	257
KNOW	7.34	7.75	2.87	3.34	3.30	3.20	22.94	22.51	257
BT_{t-1}	.08	.09	.13	.12	0	0	.82	.80	257

[source: own calculations]

5.7.1 Results of the comparative regressions

The regression models contain all the key data for all 257 labour market regions in Germany. Table 5-3 shows the estimations for the first period, which are calculated on the basis of the data from 1995 - 2001, the years from the beginning of the BioRegio contest and the following years. The coefficients were standardised due to their differing scales of measurement. As mentioned before, spatial autocorrelation is a severe issue that occurs in most estimated models on the district level. By aggregating the data to the labour market region level, the independence of the observation regions is given in all models except for the models that looked at all funded R&D projects ('Overall Projects') within the region. Nevertheless, we have also included those results in order to achieve a better comparability between the estimates.

It is hardly surprising that there is evidence that the number of people employed in a region is positively related to the quantity of projects, irrespective of which kind. This illustrates the typical size effect and reflects the advantages of agglomerations, i.e., independent of the field of R&D, a workforce is required to execute any undertakings. Interestingly, unemployment does not play any role in most models, yet projects in the bioeconomy shell seem to be funded more often in regions with a higher unemployment rate. The wealth of a region, measured by the GDP per employed person, is not connected to the number of projects at any point in the period between 1995 and 2001. When it comes to the relevance of the population density, we find no determining indication of a connection, neither within the bioeconomy concept as a whole, nor in the biotechnology nucleus. Yet, it is striking that there is a significant negative correlation in the bioeconomy shell model on a five percentage level. That means, the assumption that less densely populated regions are more often recipients of R&D projects within the added dimensions of the bioeconomy is affirmed, despite the non-existence of a dedicated bioeconomy strategy in the first observation period. Together with the positive link between unemployment and the number of projects, this may point to a more inclusive policy. The impact of the share of people employed in knowledge-intensive sectors is positive and significant in all calculations. This result highlights the pertinence of knowledge as a resource and main driver for economic activities. The expectation that low-tech industries also take part in R&D projects in the bioeconomy shell more often than in the biotechnology sector is not met in the observations here.

Table 5-3: Results of the Negative Binomial Regression, 1995 - 2001 – Labour Market Regions

	Overall Projects†	Bioeconomy concept	Biotechnology nucleus	Bioeconomy shell
Intercept	.218	-2.192**	-3.167***	-2.121*
EMP	.003***	.017***	.021***	.055***
UNEMP	.000	.008	-.002	.069*
GDP	.000	-.002	.003	-.033.
POPDENS	.000	-.002	.002	-.028*
KNOW	.004***	.035***	.046***	.134***
BT_{t-1}	.000	.019***	.033***	.036**
EAST	.002*	.006	.017.	-.012
N	257	257	257	257
AIC	2440.4	1349	1142.6	927.1

Significance levels: > .1 ( ); <= .05 (.); <= .05 (*); <= .01 (**); <= .001 (***)

† Absence of spatial autocorrelation not declinable

[source: own calculations]

The share of previous projects in the biotechnology nucleus is crucial for the development of a region that is pursuing a strategy linked to research in the bioeconomy. There is a clear positive and significant sign in this respect for all models, with the exception of the model with the entire database. In general, in the first observation period after the implementation of biotechnology contests the estimations of the bioeconomy as a whole and the mere biotechnology nucleus do not vary greatly. This can be explained by the fact that the share of biotechnology represents up to 68 % of the entire bioeconomy. The bioeconomy shell displays some minor contrasts to the other models, even at this early stage.

The estimates of the second observation period, which comprises all projects from 2009 to 2015 and therefore represents mainly the time after the implementation of the bioeconomy strategy NFSB, show the actual change of the policy transition (see Table 5-4). The decisive regional characteristics in the model with all projects as well as the model comprising projects of the biotechnology nucleus have mostly not changed. The variable EAST becomes significant and positive at the 0.01 level, but the remaining significant regressors KNOW and BT_{t-1} match with the first observation period with somewhat differing smaller coefficients due to larger numbers of the regressand.

Table 5-4: Results of the Negative Binomial Regression, 2009 - 2015 – Labour Market Regions

	Overall Projects†	Bioeconomy concept	Biotechnology nucleus	Bioeconomy shell
Intercept	2.844***	.855	-1.060	.816
EMP	.001***	.009***	.016***	.018***
UNEMP	.000.	.002.	.001	.008*
GDP	-.000	-.003*	-.003	-.007*
POPDENS	-.000	-.003*	-.001	-.010***
KNOW	.002***	.012***	.024***	.023***
BT_{t-1}	.000	.007***	.019***	.009***
EAST	.000.	.003*	.009**	.005.
N	257	257	257	257
AIC	2955.5	1917.8	1474.2	1657.3

Significance levels: > .1 ( ); <= .05 (.); <= .05 (*); <= .01 (**); <= .001 (***)

† Absence of spatial autocorrelation not declinable

[source: own calculations]

However, since the share of the bioeconomy shell rose up to an equilibrate level of 50 % of the entire bioeconomy, we find varying estimates when analysing the entire bioeconomy concept. In line with the results from the bioeconomy shell in the first interval, the population density is negatively related to the number of projects of all bioeconomy projects at a 0.05 level. The same applies to the bioeconomy shell at a 0.001 level and confirms the initial finding that the bioeconomy projects more frequently take place in rural regions. Unlike the regression analyses from the first stretch, both projects in the bioeconomy and the bioeconomy shell are negatively associated with the GDP per employed person. That is a compelling outcome that endorses the fundamental differences between biotechnology nucleus and the bioeconomy shell and shows which influence the policy change has. Hence, not only more peripheral and rural regions, but also less affluent areas are more frequently involved in projects of the bioeconomy and bioeconomy shell respectively. This might indicate a shift in the policy design from one that favours a certain sector and follows a ‘strengthen the strong’ approach towards a regionalised innovation policy that aims at balancing the regional economic structure. It must be stated that nearly all coefficients declined – most likely due to the massive gain in importance in terms of the project count, namely from 2,727 R&D projects between 1995 and 2001 to 7,755 undertakings from 2009 to 2015 (the same applies to the amount of projects in general, irrespective of the field – from 22,732 to 54,452).

In Table 5-5, we ran the same regression models with data from the entire observation period as a robustness check. Overall, the results suggest approximately the same findings when looking at the individual time frames. Due to the prevalence of the biotechnology in the first part and the bioeconomy shell only emerging later, the population density is only significant on a 0.1 level. Nevertheless, all the other explanatory variables behave the same as in the period from 2009 - 2015. In these estimations, spatial autocorrelation is still an issue for the model with all projects and also for the biotechnology nucleus. However, derived from the previous results, one can see what regional features affect the specific dimensions and that, in general, the bioeconomy shell has the potential to serve as an instrument for a more inclusive innovation policy approach.

Table 5-5: Results of the Negative Binomial Regression, 1995 - 2015 – Labour Market Regions

	Overall Projects†	Bioeconomy concept	Biotechnology nucleus†	Bioeconomy shell
Intercept	3.201***	1.107.	-.727	1.032
EMP	.001***	.004***	.007***	.011***
UNEMP	.000.	.002**	.001	.006***
GDP	-.000	-.001*	-.001	-.004*
POPDENS	-.000	-.001.	.000	-.006***
KNOW	.001***	.005***	.008***	.014***
BT_{t-1}	.000**	.005***	.012***	.007***
EAST	.000**	.001.	.003**	.002
N	257	257	257	257
AIC	3257.7	2175.1	1754.6	1867.3

Significance levels: > .1 ( ); <= .05 (.); <= .05 (*); <= .01 (**); <= .001 (***)
† Absence of spatial autocorrelation not declinable

[source: own calculations]

In order to control for the monetary distribution instead of the project number, we performed additional analyses on the funding amount. Since the response variable does not represent count data, but still does not follow a normal distribution, we needed to logarithmise the respective variable and omit regions without a project in the analysed period. Thus, it did not make sense to execute a test for spatial autocorrelation. This procedure meant that the question was slightly different to the previous analyses and answered the question as to which regions received more funding than others – in contrast to the question of whether and how many projects a region carried out. The findings are to some extent similar, but not as pronounced as in the negative binomial regressions utilising the count data (see App. 5-A, p. 81 & App. 5-B, p. 81).

The combination of a decreasing biotechnology nucleus share, along with an increasing focus on the entire bioeconomy in contrast, reflects the relevance of the regional significance. The results of the cluster analyses now give an indication of the degree to which funding has changed in spatial and structural terms.

5.7.2 Results of the cluster analyses

By performing one cluster analysis for each period of time, it is possible to gauge whether and to which extent the policy change had an impact on certain regions. We built four clusters for each period to trace the development and ascertained that the structure of the clusters is quite similar over time. That means, the basic structure and regional characteristics remain almost the same with only some minor changes for all four of the identified groups in all three periods.[16] Table 5-6 lists the results, how clusters were categorised und labelled. The first, and by a great margin, the biggest group is the labour market regions that have no marked activities in the field of the bioeconomy. Not even every tenth project is connected to bio-related R&D. Due to its size of 180 to 196 regions, overall it represents the average German labour market region and has regional statistics that correspond approximately to the mean value or slightly below (compare with Table 5-2, p. 69). The number of projects per region per period increased from 48 projects to 122, while the bioeconomy projects only rose from four to ten. Interestingly, the size of the cluster decreases over time, by 16 regions in total. A growing number of regions are closer to another group in terms of their development, mainly the second cluster, which we named ‘Rural bioeconomy regions’.

The second cluster has the lowest project count in each period. However, the proportion of bioeconomy projects is higher than in any other group with over 40 % in 1995 - 2008 and 28 % in 2009 - 2015. Looking at the distribution between the biotechnology nucleus and the bioeconomy shell, we find the elaborated transition from biotechnology to bioeconomy. While the focus was initially specifically on biotechnology funding (28 %), its share decreases over time to ten percent. A share of 13 % of all projects operating in the bioeconomy shell in 1995 - 2001 suggests less significance than in the following years.

[16] The displayed regional data GDP, population density, employed in knowledge-intensive sectors and agricultural and forest area correspond to the data from 2015 in order to simplify a comparison between regions and years.

Table 5-6: Region-specific key data of the estimated clusters

Year	N	Projects	BE-Projects	% Bio-economy	% Bio-Tech.	% BE-Shell	GDP per Empl.	Pop.-density	% Empl. Know.	% Agri. & Forestry	% Intra. Joint-Projects	% Inter. Joint-Projects	% Proj. Private
1 - No or few bioeconomy projects													
1995 - 2001	196	48	4	.06	.03	.02	64,470	269	7.23	.081	.23	.47	.42
2002 - 2008	190	61	7	.09	.06	.04	64,631	279	7.32	.081	.37	.68	.42
2009 - 2015	180	122	10	.07	.03	.04	65,000	288	7.32	.081	.37	.77	.46
2 - Rural bioeconomy regions													
1995 - 2001	37	25	8	.41	.28	.13	61,998	201	6.71	.082	.21	.47	.47
2002 - 2008	42	25	11	.46	.23	.22	61,984	174	6.32	.084	.29	.58	.60
2009 - 2015	51	93	24	.28	.10	.18	60,431	140	6.21	.084	.34	.74	.41
3 - Urban (bioeconomy) regions													
1995 - 2001	22	490	67	.16	.11	.05	70,647	494	13.24	.076	.29	.44	.27
2002 - 2008	23	601	112	.20	.14	.07	69,613	465	13.01	.077	.41	.62	.27
2009 - 2015	24	1018	175	.19	.10	.09	70,930	501	13.44	.076	.42	.70	.24
4 - (Bioeconomy) hubs / powerhouse													
1995 - 2001	2	1857	267	.14	.11	.03	81,853	2,265	18.37	.050	.38	.44	.26
2002 - 2008	2	2242	392	.18	.13	.05	81,853	2,265	18.37	.050	.51	.64	.32
2009 - 2015	2	3853	567	.15	.09	.06	81,853	2,265	18.37	.050	.46	.67	.21

N: Cluster size; **Projects:** average number of projects; **BE-Projects:** average number of bioeconomy projects; **% Bioeconomy:** average share of bioeconomy projects; **% Bio-Tech.:** average share of biotechnology projects; **% BE-Shell:** average share of bioeconomy shell projects; **GDP per Empl.:** average GDP per employed person; **Pop.-density:** average population per km²; **% Empl. Know.:** average share of people employed in knowledge-intensive industries (see fn. 5); **% Agri. & Forestry:** average share of agricultural and forest area per total area; **Intra. Joint-Projects:** average share of joint bioeconomy projects with the project partner within the same region; **Inter. Joint-Projects:** average share of joint bioeconomy projects with the project partner located in another region; **% Proj. Private:** average share of bioeconomy projects executed by private business

[source: own calculations]

Eventually, in the most recent time frame, almost twice as many projects were in the broad field of the bioeconomy shell than in the biotechnology nucleus. The regional parameters impressively show that those regions are on average rural and tend to be structurally weak. Even though they are already the lowest of all the groups, the group's GDP, population density and also the rate of people employed in knowledge-intensive industries all decline along with the expansion of the group size, whereas the share of the agricultural and forest area increases.

The two remaining computed clusters represent the urban, diverse agglomerations that engage with the bioeconomy at a certain level. The third cluster, which we called urban (bioeconomy) regions, has 18 out of 24 regions consistently assigned to it and it thus shows minimal fluctuation (see App. 5-C, p. 81 for a full list of the regions assigned to each cluster). Seen collectively, these regions acquired on average substantially more projects both in general, as well as in the bioeconomy. Whether or not the bioeconomy is gaining importance is not conclusive. The policy shift is not yet identifiable, since biotechnology is still a bigger component than the bioeconomy, although the latter is continually rising. Examining and comparing the regional data, the reason for these fairly big differences becomes apparent. Here again, the cluster's key figures are much higher in comparison to the classes we looked at before, except for the agricultural and forestry area. These agglomerations have renowned advantages and capacities which enable them to attract funding and execute projects on a larger scale.

The same goes for cluster four, consisting of the large agglomerations Berlin and Munich. These two regions symbolise the biggest and most diverse labour market regions in Germany. Interestingly, Hamburg as the second biggest city or its respective labour market region is not assigned to this category at any time, although it has similar regional statistics. This illustrates that the profiles of both Berlin and Munich, which are predominantly committed to the biotechnology, are more linked to the bioeconomy (15 % of all projects in the most recent observation period) than other bigger agglomerations that possess comparable capacities such as Hamburg. Nevertheless, the rather low and slowly increasing share of the bioeconomy shell suggests that the centre of the R&D was initially, and still is, biotechnology.

The juxtaposition of the local and extra-regional collaborations reveals an expected distribution. Size effects of the regions are mainly responsible for this aspect. If the cluster type without a greater connection to bioeconomy serves as the mean of all German labour market regions, the remaining classes can be easily compared. The rural bioeconomy regions have a somewhat lower rate of intra-regional cooperation, but have a similar share of partnerships with associates from other places. This shows that the local endowments in those regions are lower, thus requiring knowledge from outside. More diverse regions or agglomerations (both other cluster types) have greater opportunities to collaborate with actors on site and thus have a bigger share of intra-regional joint projects. Inter-regional connections, however, are to some extent less frequently necessary, but still the most common kind of joint projects.

The same goes for the percentage of private business involved in bioeconomy projects. The average region, as well as the more peripheral bioeconomy regions, have a considerably higher proportion of projects carried out privately than the agglomerations. Big research institutes and especially universities, which are both major players in bioeconomy research, are prevailingly situated in cities and regions with a certain standard of infrastructure.

5.8 Discussion and critical appraisal

The research question as to whether the shift from biotechnology to bioeconomy might contribute to a reduction in regional disparities is tested with multiple approaches and methods. An inclusive innovation policy that keeps a watching brief over low-tech industries and economically lagging regions is one essential method to counter polarising trends. Our findings, derived from the data of the BMBF, demonstrate in which ways the endeavour to establish a bio-based economy concurrently leads to a more comprehensive spatial distribution of innovative activities. An altered policy approach and the opportunities for traditional industries in peripheral regions to benefit from the implementation of external biotechnological knowledge seem likely to trigger a catch-up process.

We found that particularly the increasing project numbers of the bioeconomy shell are driving the more even allocation of R&D undertakings, which is reflected in the GINI-coefficient. By conducting negative binomial regressions over several periods of time, the different parameters that are decisive for the acquisition of projects reveal structural differences between the respective data. They show that the new dimensions of the bioeconomy shell in particular have been gaining more political attention at the latest since the introduction of the bioeconomy strategy and they involve more sparsely populated and less wealthy regions. This progress underlines, in consequence, the significance of this pillar for the sustainable development and success of the whole bioeconomy concept. Finally, the cluster analyses emphasise the preceding results. Those that profit from the leitmotif change are, amongst others, rural regions with less people employed in knowledge-intensive branches. Again, the progress over time shows a growing number of observation units which specialise in the bioeconomy in general and the bioeconomy shell in particular. As studies on foundational economies suggest, more R&D in so-called 'low-tech' branches is necessary in order to support lagging regions. Subsequently, this commitment might induce a catching-up process and ultimately lead to more equal living conditions. The cluster characteristics show that rural bioeconomy regions with high stakes in traditional bio-related up- and downstream business in the bioeconomy shell therefore seek extra-regional collaborations to implement novel and innovative ideas, due to a lack of available on-site knowledge. The close connection to cross-sectional biotechnology might be useful as an instigator for future schemes.

Notwithstanding all these results, we find some overall developments that signal a more inclusive and less localised innovation policy in general. For instance, within the same period of time the GINI index for all projects decreased at the same rate from an already lower starting point of 0.76 to 0.68 in the most recent observation period. Furthermore, if one takes a look at the development of the cluster we called 'Rural bioeconomy regions', the simultaneous rise in all projects in the last period is obvious. It appears that innovation policy in Germany is evolving in a direction, in which more regions can participate in and profit from publicly funded projects. This is in line with the EU Smart Specialisation approach that aims to build on the existing capabilities of rural regions.

All in all, the findings highlight the potential to contribute to a reduction in regional disparities by distributing funding more comprehensively in sectoral and spatial terms. High-tech branches are vital for the purposes of innovation, but especially new combinations of knowledge from different, but related work fields, are evidently most fruitful.

Although we find some convincing data that support our deliberations about a transition in policy measures towards those that increasingly favour regions with a low R&D intensity, some shortcomings have to be taken into account. The subsidy database, on which all our findings are based, only provides information on the general research field and the topic of the project through the project title and the internal classification system of the BMBF. Further data, such as a more detailed project description or an abstract, would have offered the opportunity to employ a more sound procedure for the identification of projects, e.g. more sophisticated text-mining methods complemented with machine learning techniques. The project titles are in some cases quite specific and serve as a sufficient definition of the undertaking, but some titles are acronyms and give little insight into the actual project topic. This might lead to undetected bioeconomy projects. Furthermore, since the categorisation into our system (*input, processing, output, socio-economic framework*) of each of the 16,500 projects is too time-intensive, we partially rely on the BMBF'S classification system, which differentiates between several main subjects and subclasses, i.e., we translated some of the BMBF's subclasses to our logic where they were unambiguous. Whether, in reality, all projects correspond to our definition and understanding of the distinct bioeconomy components is dependent on the quality of BMBF's classification. Another issue with the database is that all departments have to register their funding projects themselves. Ministries that do not enter the projects they are funding are underrepresented in this study. Overall, although there are some limitations with the data, we still assume they give a representative image of the funding landscape in Germany.

The variables that are most decisive for our estimations are derived from the funding database. That means, we model how much and what kind of funding a region receives. However, we cannot quantify the actual impact of public funding on regional development. Whether more projects or funding for a region trigger innovation in the bioeconomy would be a starting point for another study. Moreover, contrasting different effectiveness numbers between bioeconomy and non-bioeconomy regions or urban and rural regions might yield new insights for policy-makers. In our analyses, we primarily focus on the distribution of project numbers. Calculations with the funding amount were used as a robustness check for our models. They support some core findings but cannot fully validate the results. This might be due to varying sample sizes and the different modelling approach, but it is also possible that more projects, but smaller funding amounts are distributed to rural regions and that the main share does not differ structurally from other funding.

We also use data from the national level and neglect other public strategies to foster the bioeconomy, e.g. by the EU or at the state level. In order to compare the region's involvement in the bioeconomy, it would be helpful to integrate all R&D funding into the model. However, to gather and process all the data is, of course, time-consuming and does not contribute to the question of the direct implications of the governmentally-lead strategy to implement a bio-based economy.

5.9 Conclusion

This article explored the relationship between the change of the leitmotif from biotechnology to bioeconomy and the spatial distribution of bio-related R&D projects in Germany. Diverse bioeconomy strategies emphasise the chances for peripheral regions to be a determining factor in the implementation of the bioeconomy and also the necessity for this to be the case. One policy approach to improve the regional development in rural areas is the support of local actors. In other words, a less urban-centred sectoral distribution of publicly funded R&D projects can provide an opportunity to revitalise branches that are more often situated in densely populated areas. The former focus on biotechnology that favoured specific agglomerations represented a rather growth-oriented policy and excluded certain regions that also require governmental support, maybe even those that need it the most. The concept of a bioeconomy, however, has by its definition a more comprehensive and inclusive character. However, the question as to whether and to what extent the emerging bioeconomy scheme is able to contribute to its intended objectives is highly controversial (BIRCH 2017; FRENKEN 2017) and requires research on micro and macro levels. In order to estimate the implications of the illustrated policy change, we investigated whether the spatial distribution of publicly funded R&D projects changed in reality.

Therefore, in the elaboration we proposed a disaggregation of the bioeconomy into four main pillars, which are oriented at the value chain of the integral component of a bio-based economy, namely the biological resources. By means of text-mining methods, we were able to detect a consistent database that also includes segments that were neglected in preceding studies, e.g. the socio-economic framework. However, the data does not cover the actual bioeconomy in practice and only serves as an indicator for the regional R&D intensity. The notion of the implementation of exogenous knowledge sources into bio-themed industries, both in upstream and downstream industries, promises innovative solutions in order to diversify the extant economy either into related or unrelated branches, for instance along an existing trajectory or via bricolage and self-discovery adjusted to local capabilities and resources. Thus, this study showed that the R&D in the new dimensions of the bioeconomy shell, namely the *input* and *output dimension* as well as the *socio-economic framework*, were in contrast to biotechnology activities already located in less densely populated regions with a higher unemployment rate, even before the explicit bioeconomy strategy was introduced. In the most recent observation period, those results were affirmed and intensified. It shows a negatively related link between GDP and projects in the bioeconomy. Moreover, the bioeconomy concept as a whole shows similar estimates due to the policy shift.

The three cluster analyses, which identified four groups for each period, illustrate both the policy transition and the increasing number of bioeconomy regions. The analyses show that the categorised bioeconomy regions initially had a greater stake in biotechnology and, over time, developed a specialisation towards the bioeconomy shell. At the same time, even more rural regions with a lower proportion of employees in knowledge-intensive sectors were assigned to this group.

In respect to the structural change within the bioeconomy the increasing attention paid to the bioeconomy shell is having a substantial impact on regional development at the expense of biotechnology funding. The opportunity to innovate off the beaten track, i.e. outside core regions as well as without a focus on high-tech sectors, corresponds with the theoretical considerations on modern innovation policies. These very policies stress the importance of diversifying the economic status quo, which aims at viable and long-lasting solutions by fostering linkages to create synergies between actors and sectors to prevent lock-ins and to counter regional disparities.

The role of the cross-cutting biotechnology, however, should not be underestimated, since it is supposed to be the initiator of innovations in all the industries concerned. Hence, the diffusion and knowledge transfer into both geographically and technologically distant sectors is essential for the utilisation of available bio-related innovation potential in any region. Because of its formalised and codified character, biotechnology is particularly suited to meet this requirement. It should also not be forgotten that although the share of biotechnology in the total number of projects has declined, the monetary distribution is still clearly dominated by biotechnology projects for various reasons. The estimations presented validate the crucial function of biotechnology to attract further public R&D support and emphasise the path- and place-dependency. Whether and to what extent collaboration between actors in the biotechnology and the bioeconomy shell exist and are fruitful, is a starting point for further research.

Beyond that, it is vital and necessary to estimate the impact of the policy interventions undertaken. In this paper, only the input dimension in the form of publicly funded R&D projects was considered. Studies that aim to determine the actual and quantifiable significance of mission-oriented public efforts to create new markets and paths are crucial for the evaluation of policy measures and the rationale to go beyond market-fixing approaches. Therefore, a possible approach for research to be conducted at this level would be to include an output dimension, such as patent data.

Appendix

App. 5-A: Results of the OLS-Regression, 1995 - 2001 – logarithmised dependent variable

	Overall Projects	Bioeconomy concept	Biotechnology nucleus	Bioeconomy shell
Intercept	11090***	11551***	10346***	13044***
EMP	.228**	.271**	.243**	.219.
UNEMP	.122	.066	.041	-.076
GDP	.110	-.063	.026	-.135
POPDENS	.071	-.041	.041	-.109
KNOW	.410***	.493***	.458***	.565***
BT_{t-1}	-.019	.209***	.267***	.037
EAST	.172	.119	.090	.222*
N	256	177	150	124
Adj. R^2	0.46	0.41	0.45	0.31

Significance levels: > .1 ( ); <= .05 (.); <= .05 (*); <= .01 (**); <= .001 (***)

[source: own calculations]

App. 5-B: Results of the OLS-Regression, 2009 - 2009 – logarithmised dependent variable

	Overall Projects	Bioeconomy concept	Biotechnology nucleus	Bioeconomy shell
Intercept	13356***	12446***	11431***	13288***
EMP	.228***	.287***	.190*	.371***
UNEMP	.136*	.106	.084	.102
GDP	.015	-.112.	-.102	-.186*
POPDENS	-.020	-.109.	-.048	-.167*
KNOW	.561***	.520***	.618***	.484***
BT_{t-1}	.032	.271***	.289***	.157**
EAST	.132*	.137*	.122.	.129.
N	257	234	193	218
Adj. R^2	0.54	0.49	0.52	0.41

Significance levels: > .1 ( ); <= .05 (.); <= .05 (*); <= .01 (**); <= .001 (***)

[source: own calculations]

App. 5-C: Cluster transformation of labour market regions over time

1 - Labour market regions with no or few bioeconomy projects in every period

Aalen, Altenburg, Altenkirchen, Alzey-Worms, Ansbach, Arnstadt, Aschaffenburg, Augsburg, Bad Tölz, Bamberg, Bautzen, Bayreuth, Biberach, Bielefeld, Bochum, Borken, Bremerhaven, Burghausen, Calw, Cham, Chemnitz, Coburg, Cochem, Cottbus, Daun, Deggendorf, Dessau-Roßlau, Dingolfing, Donauwörth-Nördlingen, Dortmund, Duisburg, Eggenfelden/Pfarrkirchen, Eisenach, Emden, Erbach, Erfurt, Erlangen, Erzgebirgskreis, Essen, Euskirchen, Flensburg, Freudenstadt, Freyung, Friedrichshafen, Fulda, Gelsenkirchen, Gera, Germersheim, Göppingen, Görlitz, Goslar, Gummersbach, Günzburg, Gütersloh, Hagen, Hameln, Hanau, Haßfurt, Heidenheim, Heilbronn, Heinsberg, Hersfeld, Hildesheim, Hof, Homburg/Saar, Ingolstadt, Kaiserslautern, Kassel, Kaufbeuren, Kempten, Kitzingen, Koblenz, Konstanz, Korbach, Krefeld, Kronach, Landsberg, Landshut, Lauterbach, Leer, Lichtenfels, Limburg, Lindau, Lingen, Lohr am Main, Lörrach, Lübeck, Lüdenscheid, Lüneburg, Mannheim, Marktredwitz, Mecklenburgische Seenplatte, Meiningen, Memmingen, Merzig, Meschede, Minden, Mittelsachsen (Central Saxony), Mönchengladbach, Montabaur, Mosbach, Neumarkt, Neuwied, Nienburg, Nordenham, Nordvorpommern (Northern Hither Pomerania), Nuremberg, Offenburg, Olpe, Oranienburg, Osnabrück, Paderborn, Passau, Pforzheim, Pirmasens, Pößneck, Ratzeburg, Ravensburg, Regen-Zwiesel, Remscheid, Rosenheim, Rottweil, Saarbrücken, Salzgitter, Schwäbisch Hall, Schwalm-Eder, Schweinfurt, Schwelm, Schwerin, Siegen, Sigmaringen, Soest, Sonneberg, Steinfurt, Suhl, Sulingen, Tauberbischofsheim, Traunstein, Trier, Tuttlingen, Ulm, Viersen, Villingen-Schwenningen, Waldshut, Weiden, Weimar, Weißenburg-Gunzenhausen, Wetzlar, Wilhelmshaven, Wolfsburg, Wuppertal, Zwickau

2 - Rural bioeconomy regions in every period

Anhalt-Bitterfeld, Bad Reichenhall, Celle, Eberswalde, Eichsfeld, Einbeck, Eschwege, Holzminden, Kelheim-Mainburg, Kulmbach, Ludwigshafen, Nordhausen, Salzlandkreis, Uelzen

3 - Urban (bioeconomy) region in every period

Bonn, Brunswick, Cologne, Dresden, Frankfurt/Main, Freiburg, Göttingen/Osterode, Halle, Hamburg, Heidelberg, Jena, Karlsruhe, Kiel, Leipzig, Potsdam-Brandenburg, Reutlingen/Tübingen, Rostock, Stuttgart

4 - (Bioeconomy) hubs

Berlin, Munich

Labour market region	1995-2001	2002-2008	2009-2015	Labour market region	1995-2001	2002-2008	2009-2015
Ahrweiler	1	1	2	Perleberg	1	2	2
Bad Kissingen	1	1	2	Prenzlau	1	2	2
Burgenlandkreis	1	1	2	Straubing	1	2	2
Frankfurt/Oder	1	1	2	Verden	1	2	2
Gotha	1	1	2	Magdeburg	1	3	1
Heide	1	1	2	Aachen	1	3	3
Mansfeld-Südharz	1	1	2	Darmstadt	1	3	3
Marburg	1	1	2	Hanover	1	3	3
Meißen	1	1	2	Baden-Baden	2	1	1
Neuruppin	1	1	2	Dillingen	2	1	1
Regensburg	1	1	2	Husum	2	1	1
Saalfeld	1	1	2	Landau	2	1	1
Sondershausen	1	1	2	Mühldorf	2	1	1
Stade	1	1	2	Nordhorn	2	1	1
Stendal	1	1	2	Oldenburg	2	1	1
Vogtlandkreis	1	1	2	Salzwedel	2	1	1
Wiesbaden	1	1	2	Soltau	2	1	1
Münster	1	1	3	Stadthagen	2	1	1
Bad Neustadt/Saale	1	2	1	Weilheim	2	1	1
Bitburg	1	2	1	Finsterwalde	2	1	2
Idar-Oberstein	1	2	1	Gießen	2	1	2
Itzehoe	1	2	1	Neustadt/Aisch	2	1	2
Kleve	1	2	1	Südvorpommern (South. Hither Pomerania)	2	1	2
Schwandorf	1	2	1	Vechta	2	1	2
Westerstede	1	2	1	Würzburg	2	1	2
Wittenberg	1	2	1	Balingen	2	2	1
Zeven	1	2	1	Cloppenburg	2	2	1
Amberg	1	2	2	Höxter	2	2	1

Bad Kreuznach	1	2	2	Leverkusen	2	2	1
Bernkastel-Wittlich	1	2	2	Simmern	2	2	1
Detmold	1	2	2	St. Wendel	2	2	1
Garmisch-Partenk.	1	2	2	Düren	3	1	2
Harz	1	2	2	Düsseldorf	3	1	3
Helmstedt	1	2	2	Mainz	3	1	3
Luckenwalde	1	2	2	Bremen	3	3	1
Mühlhausen	1	2	2	Itzehoe	1	2	1

[source: own calculations]

6 REGIONAL PROFILING IN THE 'BIO-NEXUS' AN ANALYSIS OF PATH DEVELOPMENT IN BIOECONOMY REGIONS

Abstract

In the preceding chapters, two main aspects were established. Firstly, a thematic change in innovation policy took place with the focus shifting from biotechnology towards bioeconomy. Secondly, this alteration was accompanied by a different spatial distribution of public R&D projects. An increasing number of regions and particularly structurally weak areas are benefiting from this amendment. In this exploratory section of the thesis, we highlight the development of certain regions in the context of the bioeconomy discourse. Hence, by merging insights about thematic orientation with quantitative numbers in a longitudinal manner, we can illustrate a more detailed picture of how the shifting schemes are reflected on a regional level. Two different approaches have been chosen in order to identify interesting cases. First, by comparing the winners and other contestants in place-based biotechnology competitions (BioRegio and BioProfile), structural differences between these groups can be detected. Second, cluster analyses are applied to identify regions that tend to specialise in any field of the bioeconomy. In 'organisationally thick' regions, depending on the involvement of private actors, specialisation and regional branching can be observed. Supplementing the results from chapter 5, it is found that, for rural regions, the bioeconomy can be an appropriate tool for regional development, since other industries are often not present.

Keywords

Regional development, Path-dependency, Biotechnology, Bioeconomy, BioRegio, BioProfile

6.1 Introduction

In the past, many scholars have dealt with the nature of path dependence in an economic context (NELSON & WINTER 1982; DAVID 1985; TEECE et al. 1997; MARTIN & SUNLEY 2006). But path-dependency occurs in many areas, not only in a technological sense or concerning regional development (DAVID 2007). Previous experiences, successes and failures, momentous decisions, or maybe even acquaintances might impact the future development on different levels. As a result, a certain path will be established, modified or newly created. The path committed to will in turn probably influence the further direction. This continuous process applies to individuals, who pursue a particular path by e.g. studying medicine and eventually becoming a medic. Or, for a company that e.g. has been acquired by a foreign company and later has to cope with new rules, institutions and markets. Yet, this mechanism also applies to entire nations and regions, where companies operate, form networks with various stakeholders and mutually shape future economic activities (NELSON & WINTER 1982; MARTIN & SUNLEY 2006; HIDALGO et al. 2007). Path-dependency is thus an incessant process in all areas of living and the more pronounced a path is and the longer it is followed, the harder it normally becomes to change it in the long term (GRABHER 1993).

In chapters 4 and 5, we highlighted governmental mission-oriented innovation policies and how changes occurred in spatial terms due to changes of priorities. In this section, we will now focus on the development of certain regions that are engaged in the biotechnology-bioeconomy landscape. In some specific cases, the following question is researched in this chapter:

> **How is the policy transition reflected at the regional level and what path-dependent processes occurred and can be detected in selected cases?**

In order to investigate this issue, we applied two methods for the identification of relevant and interesting examples. First, as established in chapters 4 and 5, biotechnology contributes to or rather enables the implementation of the bioeconomy to a great extent. Regions that specialise in this sector are therefore protagonists for shaping the future bioeconomy in Germany. In 1995, the German government announced the BioRegio competition with the intention to establish regional networks and clusters in the biotechnology sector (DOHSE 2000; EICKELPASCH & FRITSCH 2005). In this contest, four winning regions were chosen to become focal points for biotechnology industries in Germany. DOHSE (2000, p. 1121) highlighted the 'strengthening the strong' principle in this approach when assessing the choice of the winners. In 1999, three further regions, which lost in BioRegio, were declared the winners of another place-based biotechnology contest called BioProfile. Although ENGEL et al. (2013, p. 1751) labelled these winners as 'smaller […] rising stars', they already featured a decent biotechnology infrastructure. This selection of potent biotechnology regions now delivers a starting point for the analysis of bio-themed path development in Germany. Against this backdrop, the first part aims to discover patterns between first-mover biotechnology regions, follower regions, and late-comers. The following questions are covered here:

- Did specialisation occur in acknowledged biotechnology regions due to their early commitment and if so, to what extent?
- What types of path development can be identified in this context?

The second approach for the identification of bioeconomy regions is viewing the bioeconomy as a potential target for regional profiling, i.e., due to the multifaceted nature of the bioeconomy and the holistic notion that sectors along the entire value chain are to be integrated, specialisation tendencies are expected to appear in some regions. While the cluster analyses in chapter 5 elaborated solely the amount of bioeconomy projects per region, we now focus on bioeconomy projects in relation to regional characteristics. In doing so, the aim is to determine the drivers of bio-themed development and to find differences or commonalities in their economic structure. Hence, the second part of the survey will deal with the exploration of the following questions:

- Which regional economies show higher degrees of bioeconomy specialisation and
- in what way has this path development taken place?

The analyses in this chapter contribute to the existing literature in several respects. First, the literature of evolutionary economic geography delivers mostly either theoretical frameworks or highly relevant and in-depth insights into individual case studies, predominantly in qualitative research designs (i.a. TÖDTLING & TRIPPL 2005; MARTIN & SUNLEY 2006; HASSINK 2010a; MARTIN 2010; ISAKSEN & TRIPPL 2016; BOSCHMA et al. 2017; HASSINK et al. 2019; TRIPPL et al. 2020). Only the subject of path branching has been elaborated in a quantitative manner in numerous studies (e.g. FRENKEN et al. 2007; BOSCHMA & FRENKEN 2011; NEFFKE et al. 2011). To enrich this research strand, we apply a quantitative approach to highlight path development across all regions in Germany. This method allows a systematic comparison of all regions in Germany, while obviously not achieving the depth of content found in individual case studies. Moreover, the preceding examinations of the BioRegio and BioProfile competitions, the main objective was to measure certain performance-based numbers during and after the funding period. For instance, in order to assess the official mission to create a vigorous biotechnology sector in Germany, DOHSE & STAEHLER (2008) compared the number of biotechnology firms in the contest regions. ENGEL et al. (2013) also contrasted the funding and innovation activities of the winners of the BioRegio and BioProfile contests and GRAF & BROEKEL (2020) analysed network structures in co-patent-applications during and after the BioRegio initiative. In this study, in contrast, we add a qualitative dimension to quantitative data. By using and categorising the German subsidy database in the context of the bioeconomy, we are able to compare the path development of the winners and non-winners of contests and thereby evaluate the policy measure from another perspective. These more detailed insights will provide a qualitative perspective that has so far not been touched on by any study concerning those contests. Additionally, the identification of further regions that specialised in bioeconomic activities delivers the opportunity to include less widely studied units and to get a better picture of the bio-themed funding at the regional level. Lastly, the bioeconomy is still at an early stage as an object of research and more effort will be required to thoroughly understand it. However, due to its extensive nature with many facets, it enables us to study path development in a nuanced manner and to thereby increase its comprehension in the social sciences. Especially the spatial dimension and distribution of bioeconomy R&D has not been thematised in the past and illustrates the necessity for there to be more qualitative insights in the literature.

Addressing those issues, the paper is structured as follows: In section 2, an in-depth background of sources for varying path developments is presented. Afterwards, five different types of path development are shown and illustrated with specific examples. Section 4 provides some crucial information about the most important innovation policy measures in the context of biotechnology and bioeconomy with a detailed description of the analysed biotechnology contests. Section 5 covers our understanding and operationalisation of the notion bioeconomy. After a quick overview of data and methods in section 6, the comparison between the biotechnology contest groups follow. More thorough analyses of a few chosen regions continue the previous comparison of aggregated data. Lastly, a discussion and conclusion wrap up the key findings.

6.2 Causes for divergent path development

The understanding that the prevailing economic conditions of nations and regions commonly reflect the derivation of past structures has become the mainstream theoretical strand in economic geography within the last decade (HASSINK et al. 2019). MARTIN & SUNLEY

(2006) and MARTIN (2010) delivered a comprehensive theoretical framework that fused concepts of evolutionary economics with approaches from economic geography. This widely known Evolutionary Economic Geography (EEG) approach discusses the notion of path- and place-dependencies and the character of lock-ins on a regional level. In general, according to MARTIN & SUNLEY (2006, p. 403), 'the past […] sets the possibilities, while the present controls what possibility is to be explored'. In essence, the incessant underlying process stresses the significance for policy-makers and regional actors to consider existing place-specific endowments when implementing strategies to shape the future path. Scholars of the EEG highlight the path-dependency of regions, which necessitates measures fitting to the preconditions of the respective area in order to create a viable and potent economy (TÖDTLING & TRIPPL 2005; MARTIN 2010; NEFFKE et al. 2011; ISAKSEN et al. 2018; MACKINNON et al. 2019).

It is evident that one-size-fits-all approaches in regional policy are unable to meet the particular needs of the target regions and should be prevented as far as possible in order to ensure an efficient allocation of resources (TÖDTLING & TRIPPL 2005). Notwithstanding this paradigm, it does not necessarily mean one should follow the notion of 'strengthen the strong' exclusively. Rather, the aim should be to compile an adapted policy that consciously counteracts the risk of (technological) lock-ins (ASHEIM et al. 2011a). These lock-in-effects, which MARTIN & SUNLEY (2006, p. 405) describe as being 'over-committed' to a certain technology or industry, lead to an inertia which can only be overcome by disruptive events, such as external shocks, as well as great efforts and costs (MARTIN 2010). For this reason, there is increasing emphasis on a policy that does not encourage further specialisation, but pursues new structural development potential (ISAKSEN et al. 2018). Greater economic diversity reduces the risk of technological stagnation and of being left behind by more agile, innovative regions (HASSINK 2005).

Using the Ruhr region as an example, GRABHER (1993) demonstrated how the previously positive features of specialisation (in this case related to the steel industry) could plunge a region into crisis due to a lack of alternative bases, if the focus remained constant. The involved actors in industry and politics experienced lock-ins at diverse levels and following the sectoral downturn, the consequence was substantial the regional damage as interfirm linkages had been a core element of the region (GRABHER 1993). Other regions have had to face a similar reality. SCHAMP (2005) illustrated how the industrial cluster of Pirmasens, which was specialised in footwear production, declined after a severe crisis and how the region had to cope with the situation. The two coping measures mainly applied by the concerned actors were either to leave the region or to switch to another industry (SCHAMP 2005). Further cases that underpin the peril of too strong specialisation are manifold – e.g. Detroit and its car industry (KLEPPER 2007), the end of mass tourism in Benidorm in the aftermath of the financial crisis (IVARS I BAIDAL et al. 2013), or resource-based specialisation and declines in Latin America (cf. Dutch disease) (SACHS & WARNER 1999). But, in general, the subject of path-dependency is much more complex as BELUSSI & SEDITA (2009) demonstrate in their meta study on the coping mechanisms of industrial districts in Italy. Both private and state actors reacted differently, sometimes to the same or similar events, and thus underwent diverging developments. Furthermore, the point in time at which an external shock hits an industry or region plays a decisive role in the level of adaptability to different circumstances (BELUSSI & SEDITA 2009).

The causes of this varied territorial adaptability are, inter alia, the characteristics and performance of the specific national and regional innovation system (NIS or RIS) (ISAKSEN et al. 2018; TRIPPL et al. 2018). MARTIN & SUNLEY (2006) therefore remind readers of the fact that place-dependent processes are vital for the performance of regions, but also that particular decisions and developments go beyond their boundaries. The interplay between firms, organisations, policy-makers etc., which are embedded in regulatory frameworks, networks and markets, is complex and is a reminder that the degree of influence is tremendously dependent on the context and objective (MARTIN & SUNLEY 2006). Nevertheless, regional characteristics are still of great significance and the capacities of RIS are fundamental for the development of individual paths. In general, the notion of an innovation system follows the assumption that the entirety of a system consists of a variety of elements (actors, institutions, technological endowment, socio-cultural conditions) and that these individual components affect each other interdependently with respect to the creation of innovations (LUNDVALL 1992; FREEMAN 1995). The regionality of innovation systems is caused by the fact that, on the one hand, nations consist of structurally heterogeneous subsystems and, on the other hand, knowledge is often spatially bound, making interactive learning less likely with increasing distance (AUDRETSCH & FELDMANN 2004; ASHEIM & GERTLER 2005).

TÖDTLING & TRIPPL (2005) typologise RIS based on their level of organisational attributes. 'Organisationally thin' refers to systems in the periphery that have a low innovation capacity due to few clustering processes, small shares of R&D, limited knowledge generation and diffusion flows as well as a lower rate of highly educated labour. In contrast, 'organisationally thick' systems have a large work force and a denser network for knowledge transfers. Yet these systems can be further differentiated into diverse and specialised (ISAKSEN & TRIPPL 2016). Specialised regions exhibit rather closed, but strong intra-regional networks with little inflows of exogenous knowledge. These systems are often built on successively grown partnerships between large firms with a high level of trust and informal institutions (RODRÍGUEZ-POSE 2013). This kind of specialisation mostly occurs in regions that evolved over a long time period and hence operate in more mature and traditional industries that lack internal disruptive innovation impulses (TÖDTLING & TRIPPL 2005). Diversified RIS, however, have a more open structure that allows for firms from manifold industries and services to act in a more agile way. Mostly located in metropolitan areas, they offer a heterogeneous economic landscape that provides features which are considered to stimulate innovation. For example, they possess a large labour force with diverse knowledge skills to ensure knowledge generation along with necessary absorptive capacity to process relevant information from internal and external sources (ISAKSEN & TRIPPL 2016). At the same time, they lack pronounced linkages between the various resident industries and therefore cannot rely on long established institutions (TÖDTLING & TRIPPL 2005). The understanding of existing capacities and also the classification of the regional economic structure into the systematics of different regional innovation systems are both aspects that contribute to a better interpretation and conception of political strategies.

A firm is accordingly not the exclusive and central protagonist of a system. Rather, a multitude of private and public players contributes to the performance of an RIS (COOKE et al. 1998). In this perspective, ISAKSEN & JAKOBSEN (2017) stress that human agency is an integral driver for the productivity of a system. EMIRBAYER & MISCHE (1998, p. 970) define agency as 'constructed engagement by actors of different environments […] which […] produces and transforms those structures in interactive response to the problems posed by changing historical situations'. SOTARAUTA & SUVINEN (2018) break down agency, describing it as actions and measures conducted by actors in order to bring about a particular effect. ISAKSEN & JAKOBSEN (2017) differentiate between actor-based and system-based approaches that have the ability to foster or harm the innovativeness of a system. Actor-based agency is mainly associated with actors operating in private business such as entrepreneurs and firms, which contribute to the regional efficiency. Since they do not function in a vacuum, but are embedded in their specific environment, the significance of system-level agency should not be underestimated (BINZ et al. 2016). TRIPPL et al. (2020) point out that regional agency can be performed by both local and extra-regional actors. While e.g. economic development promoters implement strategies tailored to the region, politicians at higher levels might alter the system's institutional elements through laws and support schemes. MAZZUCATO (2014) illustrates the impact that governmental intervention may have on the development of individual companies and industries by using the example of 'Apple' and their pioneering introduction of the modern smartphone. The actual impact of cluster policies, however, is less clear. KIESE & HUNDT (2014), in a comparison of seven case studies, analyse the different scopes of approaches and conclude that cluster policies are more fruitful if based on available capacities. Other studies concentrate on specific measures such as the establishment of (temporal) networks or knowledge spillovers (e.g. LEHMANN & MENTER 2018; GRAF & BROEKEL 2020).

Public or quasi-public research institutes and particularly universities have the reputation of making a broad contribution to regional development (WOLFE 2005; VARGA 2009; YOUTIE & SHAPIRA 2008). By performing basic research and providing knowledge, they are able to attract companies seeking knowledge spillover as well as a diverse labour pool with highly educated workers (DRUCKER & GOLDSTEIN 2007). Especially in the interplay of a 'research institute that develops new knowledge together with regional firms, clusters or industries with the aim of enhancing their competitiveness', HASSINK et al. (2019, p. 1638) see an 'example of system-level agency that transcends institutional spheres'. Furthermore, alongside the qualification of students, universities are part of the 'triple helix' model of innovation, whereby it is their responsibility to also innovate themselves (especially in the USA) or to facilitate technology transfer by collaborating with industry (ETZKOWITZ & LEYDESDORFF 2000; BRAMWELL & WOLFE 2008). YOUTIE & SHAPIRA (2008) depict the evolving duties of a university and suggest that further deliberate integration into the region's economy could have the potential to create new capabilities and to stimulate path development. In its function as a 'knowledge hub', the university is deeply embedded in its environment and serves as a strategic partner for local companies in order to jointly exploit region-specific potentials. LESTER (2006) shows that the role of the university in an innovation system also depends on the type of path development that takes place or is proactively sought in the system.

In the previous section we mainly considered theoretical deliberations about the cause of evolutionary path-dependencies. In the following, the different types of path development will be discussed, and the outlined principles will be partially exemplified.

6.3 The types of path development

Based on LESTER'S (2006) typification, MARTIN & SUNLEY (2006) derived several path development scenarios, whereas other scholars have focussed on a certain type, mainly path creation (i.a. GARUD & KARNØE 2001; BOSCHMA et al. 2017; MACKINNON et al. 2019) and path branching (e.g. FRENKEN et al. 2007; BOSCHMA & FRENKEN 2011; NEFFKE et al. 2011). ISAKSEN et al. (2018) built on these classification systems and differentiate between five methods of path development, namely:

- path extension,
- path modernisation/upgrading,
- path branching,
- path importation, and
- path creation.

Plain path extension is closely related to the phenomenon of a regional lock-in. By continuing the incumbent path, incremental innovations in dominant industries are the primary source of future development or specialisation and thus increase the risk of a dependency on this particular trajectory (HASSINK 2010a). As established before, the Ruhr area and its steel industry in the 1960s and 1970s is one prominent example of functional, cognitive and political lock-ins that lead to a severe crisis of the entire RIS (GRABHER 1993). Over-specialisation, the lack of dynamism and capacity in the industry concerned will lead to the decline of associated firms, networks and regions. Particularly 'organisationally thick and specialised' RIS are faced with the challenge of overcoming mere path extension.

In order to avoid lock-ins of the system's prevalent technology, the possibility to avert imminent decline is, for example, the modernisation of a path. That means, by introducing disruptive changes within an existing path, even an ailing sector can be revitalised and thereby generate new growth (ISAKSEN et al. 2018). The integration of external technologies to enrich and complement the extant trajectory is one approach to upgrade the system. The watch industry in the Swiss Jura, for instance, experienced a heavy sectoral and regional recession in the 1970s and 1980s, aggravated by the emerging global competition. The integration of electronics into the established expertise of precision mechanical microtechnology, among other things, made a significant contribution to rejuvenate the struggling industry and to counter the territorial crisis (MAILLAT et al. 1997). Furthermore, ASHEIM et al. (2019) suggest that an advancement within the value chain or the utilisation of symbolic knowledge in extant industries represent two mechanisms to upgrade incumbent trajectories. Symbolic knowledge thereby refers to the creativity-based knowledge type and is characterised by its tacit nature (ASHEIM 2007). Hence, the integration of new values by changing the design, functionality or emotional attributes of products or brands provides the chance to modernise a rather conventional product or industry. The upgrade of a regional industrial path is feasible for any type of RIS. However, 'organisationally thin' regions mainly have to combine exogenous sources with existing industries, whereas 'organisationally thick and diverse' RIS can also draw on partners within the system in other industries (ISAKSEN et al. 2018; REIDOLF & GRAFFENBERGER 2019).

The type of path development which has been most elaborated is path branching. This process is based on the idea that nations and regions diversify technologically in such a way that they build on available products, knowledge and capabilities (HIDALGO et al. 2007; NEFFKE & HENNING 2013; RIGBY 2015). The degree of relatedness is therefore an essential driver for the future progress of innovation systems (BOSCHMA et al. 2017). Typically, there are two main types of this process. First, incumbent firms or industries diversify by introducing new product areas. That usually happens in sectors that are technologically not too different from the previously principal business (HIDALGO et al. 2007). In the past, Samsung's electronics division, for example, has rapidly diversified by manufacturing products that were not previously part of its portfolio. It has always been of the utmost strategic importance that they were able to make use of their knowledge of the prevailing products and technologies for new purposes (KIM 1997). Without the internal knowledge base, this rapid expansion would have been practically impossible, which underlines the importance of 'related variety'. The second method for path branching is the formation of new firms that are based on the skills and competencies in existing industries or universities. Entrepreneurs and spin-offs therewith act as knowledge filters by utilising the unexploited knowledge of an innovation system (AUDRETSCH & ALDRIDGE 2009). Spatially bound information, provided by regional companies, research institutes or universities, thus remain in the system and shape the subsequent path (JAFFE 1989; AUDRETSCH & FELDMANN 2004). In an in-depth study on the development of Detroit's car industry, KLEPPER (2007) shows that many spin-offs stay in the same region to benefit from established networks, the parent firm and further knowledge spillover. KLEPPER & SLEEPER (2005) find similar results when investigating the laser industry, while ROBERTS & MALONET (1996) emphasise the role of the system's entrepreneurial environment, which is crucial for dynamic and successful spin-off activities. In conclusion, numerous studies show that either or both mechanisms occurred not just in particular firms, but also on the regional level, irrespective of the RIS-type (e.g.

NEFFKE et al. 2011; HEIMERIKS & BOSCHMA 2014; BOSCHMA et al. 2015; ESSLETZBICHLER 2015).

Path importation represents the practice of introducing a trajectory that is already established in other RIS into the system. This can take place in several ways. ISAKSEN et al. (2018) point out that the drivers for technology transplantation can be subsidiaries of foreign companies that transfer their skills to the respective region. Strategic partnerships of domestic companies with external firms might also contribute to the integration of foreign trajectories. Foreign direct investments (FDI) are one specific case, with the intention being to get access to missing competencies. Since the investing companies tend to benefit more frequently from technology transfer, this is an established instrument of transplanting pathways (BORENSZTEIN et al. 1998). With the implementation of the 'Going Global' policy in 1999, the Chinese government started an extensive asset-seeking FDI strategy of Chinese firms. Complemented by the 'Made in China 2025' scheme, China is pursuing the goal of becoming the world leader in several industries. In this context strategic partnerships/ownerships are a common approach to improve internal innovation capacities and knowledge stocks, since many acquisitions are in developed countries (DENG 2009; RICHTER-TOKAR 2019). Another option is the migration of labour, which brings valuable skillsets to the system. SAXENIAN (2007) illustrates how migration flows might influence regional and national development. In her framework about 'brain circulation', she identifies the interconnections between the source and input region and highlights what long-term effects might eventually occur due to the movement of individuals. Accordingly, the rise of Taiwan's Hsinchu region to one of the leading manufacturers of semiconductor technology was partially a result of a close exchange of highly qualified workers between Taiwan and Silicon Valley, where the technology originated (MATHEWS 1997; SAXENIAN 2007). Path transplantation is often a meaningful source of support for peripheral regions, as they have rather limited internal R&D. At the same time, they face the problem that their absorptive capacity, i.e. the ability to extract economically usable knowledge from available information, is particularly low (TÖDTLING & TRIPPL 2005). Hence, knowledge diffusion from external sources and the application of non-domestic innovation might be one suitable approach to implement new paths in structurally weaker regions (MCCANN & ORTEGA-ARGILÉS 2013).

The creation of an entirely new path encompasses the emergence and establishment of a technology or industry that is radically new to both the innovation system, in which it is created, and the world. Many studies stress the fact that 'historical accidents' are in most cases not sufficient for the explanation of a path creation phenomenon. Instead they point at different catalysts that increase the probability of generating new trajectories (MARTIN & SIMMIE 2008; ISAKSEN et al. 2018; ASHEIM et al. 2019). As described earlier, a 'thick' RIS provides an environment, which is favourable to innovation. Elements such as innovative companies and an entrepreneurial-friendly atmosphere, working intra- and extra-regional networks, a versatile and skilled labour force, universities and research institutes, an enabling policy and regulating institutions are supportive ingredients for this type of path development. It therefore does not come as a surprise that an innovation system such as the Silicon Valley, which features most of these components, is the birthplace of several differing paths, especially in modern ICT (SAXENIAN 1996). The same goes for other examples like the regions Baden-Württemberg, Germany (COOKE & MORGAN 1994), Toronto, Canada (GERTLER et al. 2000; WOLFE & GERTLER 2004), and Bangalore, India (in the context of a developing country) (LORENZEN & MUDAMBI 2013), which exhibit different assets important for the creation of new pathways. In their conceptual work, BOSCHMA et al. (2017) refer to the discovery of penicillin, made by Alexander Fleming in London in 1928, as an example of a macro-innovation (big leap). Although the discovery was very fortunate and serendipitous (Fleming had been on holiday and forgotten a culture plate from which he then made the discovery), it is not surprising that the breakthrough occurred in an environment where sufficient laboratory capacity, research activities or scientists were available. The subsequent development into a medical drug and the first production was also mainly realised in the potent regions Oxford and London (THE ALEXANDER FLEMING LABORATORY MUSEUM 1999).

Nevertheless, new path development is also pursued in 'organisationally thin' regions or systems. The likelihood is, of course, much smaller, but GARUD & KARNØE (2003) signal that collective, deliberate actions and the interplay of individuals might lead to new opportunities for technological change in the innovation system. By slowly developing within a niche, the Danish wind power industry was able to form a new path even in a rather rural area and 'thin' RIS (SIMMIE 2012). CARVALHO & VALE (2018) underpin that the concept of 'bricolage' might be suitable for peripheral regions and innovation systems with lower capacities. Still, path creation predominantly takes place in 'organisationally thick and diversified' RIS (ISAKSEN et al. 2018). Nevertheless, the emergence and development of a whole new industry path is rarely an event that happens exclusively in one single region (ELLISON & GLAESER 1997). BERGEK et al. (2008) and BERGEK et al. (2015) explain, for example, how innovations are developed collectively within a technological innovation system (TIS), irrespective of geographical location. Additionally, BINZ & TRUFFER (2017) conceptualise the notion of a global innovation system (GIS) which is based on the increasing mobility and interconnectedness of people and knowledge and thus demonstrate that innovation also has global structures.

In conclusion, how regions develop depends on a variety of conditions. These include the characteristics of the regional innovation system in which it is geographically embedded and operates. Some types of path development are more common for different kinds of IS than others, and policy approaches should therefore be adapted to the prevailing circumstances to ensure an efficient allocation of resources. Moreover, the aspect of agency may be a highly relevant component of regional development. A guiding strategy, which is pursued in a target-oriented manner in the interaction of private and public actors, is a decisive building block for the region or system. This agenda can be developed by own capacities or by the integration of external partners and knowledge and illustrate the manifold mechanisms that determine path development.

Based on these theoretical and empirical findings, some assumptions for the present exploratory study can be derived. For example, we would expect a structural difference between 'thick and thin' RIS regarding their linkages to external partners. Since it is less likely for rural, peripheral systems to be the location for bigger publicly funded research facilities or universities, a greater involvement of private actors can be assumed. 'Thin' RIS are also expected to collaborate more intensively with actors from the outside. 'Thick specialised' systems, in contrast, might rely on their own capabilities and exhibit a bigger internal partnership scheme. They also tend to concentrate on certain industries with a greater proportion of private actors and have a lower level of path branching. Before testing these expectations and looking for patterns in the data, some background information about the specific testing environment is given in the following chapters.

6.4 Path development in biotechnology and the bioeconomy in Germany – The BioRegio and BioProfile contests

The emergence of advanced biotechnology has been dominated by the US from the very beginning in the early 1970s (GIESECKE 2000; CORTRIGHT & MAYER 2002; LAZONICK & TULUM 2011). Although Germany was one of the first countries to launch a publicly funded programme with the intention of closing the gap to the cutting edge in biotechnological research in the 1970s, the German biotech sector was not able to catch up with foreign competitors (WARMUTH 1991; LUX 1993). In the early 1990s, the biotechnology landscape in Germany still looked sparse. First reports and studies showed that there were few patents applied for, by large pharmaceutical or chemical companies, whereas in the USA and the UK mainly small- and medium-sized enterprises (SMEs) pushed the technological advancement (STRECK 1990; LUX 1993). In response to the absence of economic growth impulses at the beginning of the 1990s, the German government identified the biotechnology sector as a feasible and potential future branch (MÜLLER 2002). At the same time, the German innovation policy has changed to a novel approach to foster domestic industries. The cluster policies introduced, in which actors from one region (e.g. private actors, research institutes, universities, investors) have to cooperate with each other, were intended to create territorial innovation networks (EICKELPASCH & FRITSCH 2005). In this context, the BioRegio initiative was announced in 1995 with the ambitious goal of developing the German biotechnology sector into one of the most competitive in the world (DOHSE 2000).

In this initiative, 'regions', not further specified, had the opportunity to present a concept to mutually establish an entrepreneurial-friendly and knowledge-transfer oriented environment with relevant local actors. Eventually, 17 strategies were presented by alliances of different sizes (DOHSE 2000). Decision criteria were mostly based on the already extant knowledge infrastructure and the outlook for tying internal and external resources to the region, thereby initiating an amplifying system. Aside from the presence of operating and researching stakeholders the choice was based on, for instance, available and participating auxiliary services (patent offices, consultancies), specific strategies for prospective products, methods or services, or the involvement of regional financial institutes, economic developers and hospitals, and their willingness to contribute to the objective (STAEHLER et al. 2006). Those requirements already illustrate that the scheme was not a case of building the 'cathedral in the desert', but rather the aim was to 'pick winners'. The choice of the four winning regions confirmed this thought. Munich, the Rhineland network (Cologne, Aachen, Düsseldorf and Wuppertal) and the Rhine-Neckar consortium of Heidelberg, Mannheim and Ludwigshafen were selected by the board and consequently received EUR 25 million. Additionally, the city Jena was a grantee due to a special vote because of its promising profile and the economic policy objective within the framework of 'Aufbau Ost' to reduce disparities between East and West Germany. In a comparative study looking at the BioRegio winning regions and the other applicants, ENGEL et al. (2013) found an obvious bias favouring regions which were already strong in the field of biotechnology. In the subsequent place-based biotechnology competition BioProfile (which started in 1999), they concluded that the three winners – Berlin-Potsdam, the triangle consisting of Brunswick, Göttingen and Hanover, and the network of Stuttgart, Tübingen, Esslingen, Reutlingen and the Neckar-Alb district – were smaller, but dynamic 'rising stars'. The policy approach and criteria for applicants were quite similar to the BioRegio contest, but this time the competing consortia had to compile a certain profile which was their focus (STAEHLER et al. 2006). Again, the overarching goals were to create missing links between public research and private business in order to commercialise biotechnological knowledge and to stimulate competition.

As early as at the beginning of the millennium, it became apparent that Germany had been able to catch-up with the UK in terms of firms practicing within biotechnology (MÜLLER 2002). This development continued with the result that more such firms were registered in Germany than elsewhere in Europe. However, some scholars doubt the durability of the founded companies and predict a rather short-term trend (CASPER 2009; CHAMPENOIS 2012). Despite those pessimistic outlooks, more recent data reveal no significant slump in the number of biotechnology firms. As a matter of fact, there has been a consistent trend with moderate growth in the number of firms, from 539 in 2006 to 787 in 2017 (BIOCOM AG 2018). A similar trend regarding employees and revenues is documented. Whether those place-based schemes triggered development that would not otherwise have occurred is still unclear. In the official BMBF-funded evaluation of both contests STAEHLER et al. (2006) share the optimistic view that specifically the BioRegio contest has been a decisive component for the fulminant rise of the German biotechnology sector. GRAF & BROEKEL (2020), however, conclude in an analysis covering all 17 applicant regions (BioRegio) that lasting effects of cluster networks as well as innovation activities cannot be proven after the termination of the funding measures. In the same vein, the calculations of a study by ENGEL & HENERIC (2005) show no significant difference between the winning regions and the remaining 13 contest applicants in terms of their attraction or formation of new biotechnology firms. In a further evaluation of a somewhat longer time period, ENGEL et al. (2013) also find no sustainable effect of the undertaken policy measures and argue that especially the catching-up effects of smaller regions and the formation of novel biotech regions might cause this outcome. In fact, an inherent aspect was intended, i.e. that positive effects occur even in regional networks that are not chosen (EICKELPASCH & FRITSCH 2005). Through networking, strategy conception as well as proposal submission, potentials might be revealed which should also remain even without subsidies. However, the de facto effect is also not fully conclusive.

In essence, there has not been a clear assessment of the degree to which the innovation policy measures helped the biotechnology industry in Germany. At the same time, the impact of biotechnology on economic development (HOPKINS et al. 2007) and an innovation policy approach that favours a specific technology or industry, and thereby hampers others (cf. pretence of knowledge), are both contested. Nevertheless, many scholars highlight the necessity of the government's involvement to face urgent shortcomings that can only be tackled by guidance on a system-level (AGHION et al. 2009; MAZZUCATO 2014). Far-reaching issues or 'wicked problems' such as climate change or deeply embedded societal problems lead to a 'normative turn' in innovation policies and thus represent the rationale for the current generation of policy approaches (KATTEL & MAZZUCATO 2018). With regard to the promotion of biotechnology, there was often an evolution 'from a biotechnology-centric vision to an economic activity that spreads across several key sectors and policy families: agriculture and forestry, fisheries, food, trade, waste management and industry. As a result, the bioeconomy policy environment is much more complex than before' (OECD 2018, p. 11). According to this, the leitmotif changed from biotechnology to bioeconomy and HÜSING et al. (2017, p. 29) acknowledge a similar progress in Germany, in which 'overcoming great societal challenges' became one central objective of innovation policy. In Germany, a starting point for altering the incumbent approach was the introduction of the National Research Strategy Bioeconomy 2030 in 2010 (BMBF 2010). To illustrate this evolution in more detail, we have traced the relevant policy measures in the context of publicly funded bio-related R&D, which is presented in Table 4-1, p. 39.

Following the definition of the Communiqué of the GLOBAL BIOECONOMY SUMMIT (2018, p. 2) in Berlin, the 'Bioeconomy is the production, utilization and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information, products, processes and services across all economic sectors aiming toward a sustainable economy'. Biotechnology is in this bioeconomy concept intended to be the impetus for crucial knowledge-driven development (BMBF 2010). The OECD (2009, p. 15) expresses the clear potential value of biotechnology, seeing the chance for a future in which it 'contributes to a significant share of economic output'. Modern methods and processes are therefore to be applied to the multifaceted fields of the bioeconomy and thus have a sustainable and sector-rejuvenating effect (BMEL 2014).

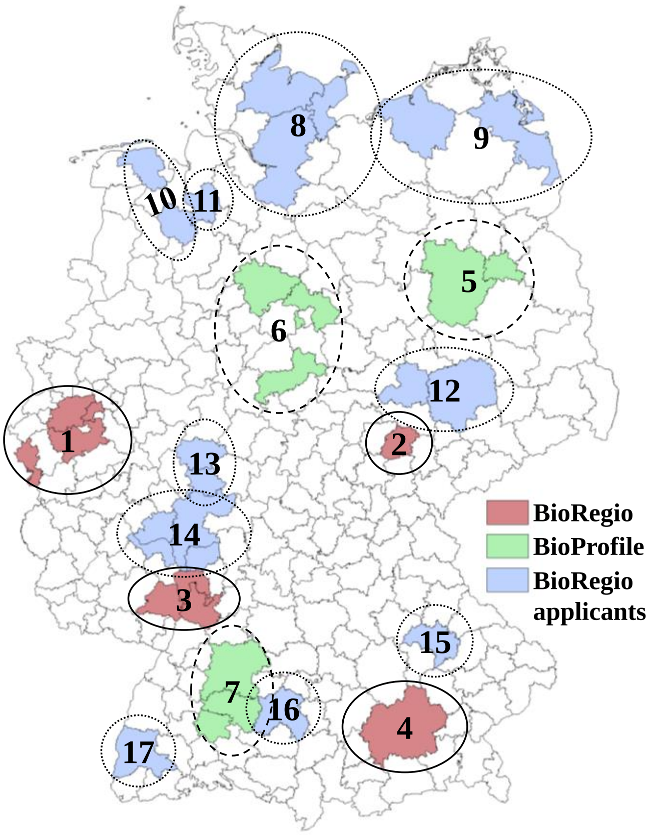
To sum up those thoughts, in Germany we find a policy push which started in the 1970s, but accelerated in the 1990s with the two contest-oriented measures to set up a competitive biotechnology industry. As a result, the biotechnology-centric perspective widened and lead to the bioeconomy concept. In this light, we research two main aspects. First, since biotechnology is a core element driving bioeconomic processes, the issue of the actual development of certain regions comes up. Although previous empirical evidence indicates that there are no measurable effects on the winning regions, the question as to how those regions actually developed is still unanswered. The choice of already potent biotechnology regions and the subsequent selection of vital consortia is a striking basis to get a better picture of regional path development in the transition from biotechnology to bioeconomy.

In other words, this development in the funding strategy provides the opportunity to get a grasp of the evolutionary characteristics of path-dependencies in the context of an emerging technology, while at the same time revealing the chances for regions and innovation systems to benefit from the implementation of the bioeconomy strategy. In this exploratory examination, we therefore not only include the mere number of undifferentiated developments in particular regions or systems, but additionally distinguish qualitatively between several components of the biotechnology and bioeconomy, respectively.

6.5 Data and method

As in the preceding analyses, the funding catalogue, the preparation of which is explained in detail in chapter 3, provides the data foundation for the present investigation. Based on this assembled data, we are able to calculate the project count and project funding of each bioeconomy dimension at any given time on any regional level. For this study, we work on the level of labour market regions, administered by the BBSR (2017). Labour market regions have the advantage that pronounced linkages between districts (‘*Kreise*’) are taken into account and thus provide a better view of the economic reality (e.g. commuting flows, urban-rural-relations) than administrative borders based on history. Moreover, even though a ‘region’ in regional innovation systems is somewhat undefined, we assume that labour market regions with their multi-level interrelations are more suitable for the notion of an RIS than the smaller districts.

These data allow us to observe regional differences in biotechnology and the bioeconomy and to identify potential trends and changes in the period from 1995 to 2015. As outlined earlier, the study uses two different methods for the identification of relevant cases. First, the place-based policy approaches BioRegio and BioProfile both offer a good starting point to trace the development of acknowledged biotechnology hubs in Germany. The implementation of this systematic funding raises the question as to whether and to what extent the winning regions developed differently than other regions which did not receive this type of promotion and publicity. In an exploratory procedure we will compare various regions in order to see whether this is attributable to underlying structural differences. Next to the BioRegio and BioProfile winners, we clustered the BioRegio applicants (winner regions excluded) as another group assuming these regions had emerging biotechnology sectors, too (see Fig. 6-1). All remaining labour market regions are also grouped to complete the picture. As it is our goal to gather overarching trends, we create different time frames, since we find large yearly fluctuation in the funding numbers. The decisive element is the year in which the project started.



BioRegio winners	
1	Rhineland (Cologne, Aachen, Düsseldorf and Wuppertal)
2	Jena
3	Rhine-Neckar (Heidelberg, Mannheim and Ludwigshafen)
4	Munich
BioProfile winners	
5	Berlin-Potsdam
6	Lower Saxony triangle (Brunswick, Göttingen and Hanover)
7	STERN (Stuttgart, Tübingen, Esslingen, Reutlingen and the Neckar-Alb district)
BioRegio applicants	
8	Kiel, Lübeck & Hamburg
9	Greifswald & Rostock
10	Wilhelmshaven & Oldenburg
11	Bremen
12	Halle & Leipzig
13	Marburg & Gießen
14	Wiesbaden, Mainz, Frankfurt & Darmstadt
15	Regensburg
16	Ulm
17	Freiburg

Fig. 6-1: Three clusters by biotechnology competition [source: own draft according to DOHSE (2000)]

The identification of bioeconomy regions that (a) have not participated in the BioRegio contest and (b) developed a specialisation in the bioeconomy is the second approach to determine suitable cases. This may enable further analysis of the path development of rural areas that were excluded by the selection criteria of the contests, such as the presence of a vibrant biotechnology sector. Urban areas that have hitherto flown under the radar and developed expertise in an individual area or holistically in the bioeconomy are also to be covered in this step. To achieve this, three cluster analyses for each time period (1995 - 2001, 2002 - 2008 and 2009 - 2015) are conducted. All clustering processes are calculated with the k-means algorithm and the parameters are the following five variables:

(i) the total number of projects in the *input dimension* divided by the population,
(ii) the total number of projects in the *processing (biotechnology) dimension* divided by the population,
(iii) the total number of projects in the *output dimension* divided by the population,
(iv) the total number of projects in the *socio-economic framework* divided by the population, and
(v) the share of the bioeconomy projects.

We included all four main pillars of the bioeconomy in order to cover the different nuances and specialisations of the bioeconomy. In contrast to study [ii], the respective count is divided by the population. It is obvious that the amount of funded projects is closely linked to the number of inhabitants. Since the purpose of this section is to identify specialised regions, the decisive parameters needed to be normalised by the population. The proportion of bioeconomy projects in the region has been integrated for the same reasons as in study [ii]. For one thing, this variable directly shows the involvement of a region in the bioeconomy and at the same time, contributes to methodological persistence. Moreover, for consistency reasons and a better comparability, the design of the analyses is aimed to be similar to the preceding cluster analyses in chapter 5.

Again, the unit of analysis is labour market regions. Standard tests and figures (Elbow/Scree plot; silhouette plot) mainly suggest the differentiation between four clusters in the last two periods. In the first period, they point to three clusters. Nevertheless, for a consistent differentiation, four clusters have been calculated. Since we are comparing different time periods, this proposal is the most sensible choice after having also trialled separation into either more or less than four clusters. Since the purpose of the second identification procedure is to detect specialised regions, we only included regions where the number of bioeconomy projects was above the median (13) within the entire observation period to ensure a certain association with the subject.

We include some regional data to catch patterns within and between the clusters. These data stem from the Regional database Germany ('Regionaldatenbank Deutschland') provided by STATISTISCHE ÄMTER DES BUNDES UND DER LÄNDER (2019). From the derived '*Förderkatalog*' data (funding database), we also calculated the amount of joint projects with a collaboration partner within the same labour market region. The same was done for extra-regional linkages and again for partnership between public and private actors (PPP). With those numbers we want to test if there are apparent differences between regions and whether or to which extent they utilise and benefit from their extant endowments or seek knowledge from distant places. Lastly, the percentage proportion of private business running the R&D projects and the share of projects operating in research-industry linkages are supplementary key figures worth contrasting.

As already mentioned when describing past biotechnology contests, some previous studies predicted the rise of biotechnology companies would be a phenomenon with a short duration. Therefore, we also include the population of biotechnology firms. BIOCOM AG provides statistics about specific industrial sectors and serves as a classified directory of biotechnology. These data give information about the year in which a firm was active, its specific location, and the year of foundation. Unfortunately, only data from 2005 to 2015 were available for the analysis. However, they nevertheless provide valuable insights into the commercial biotechnology in the regions we portray (BIOCOM AG 2017).

6.6 Results

6.6.1 BioRegio and BioProfile regions

The purpose of preceding studies dealing with the BioRegio and BioProfile contests was mainly to quantify the actual impact on the region's start-up and/or innovation activity and further, whether or not there were any sustained effects in the respective regions. How a regional system actually develops and what patterns emerge cross-regionally had not been covered so far. Especially in this regard, we contribute to the existing literature by combining quantitative numbers with qualitative insights. By showing the longitudinal development of the contest regions in the biotechnology-bioeconomy landscape, this study is able to shed light on thematic advancement, economic structure, relevant actors, and both intra- and inter-regional connections. Against this backdrop, in Table 6-1 we first compare the general development of the regions grouped by their participation and success in the competitions.

Table 6-1: Comparison of bioeconomy structure and evolution by different contest groups

		Winner BioRegio			Winner BioProfile			Applicants BioRegio			Remaining regions	
	1995-2001	2002-2008	2009-2015	1995-2001	2002-2008	2009-2015	1995-2001	2002-2008	2009-2015	1995-2001	2002-2008	2009-2015
Input	**∑ 7 %**	**14 %**	**19 %**	**10 %**	**20 %**	**32 %**	**21 %**	**26 %**	**33 %**	**16 %**	**27 %**	**35 %**
Agriculture & Forestry	2 %	11 %	16 %	1 %	15 %	26 %	2 %	16 %	22 %	3 %	22 %	29 %
Climate & Environm.	5 %	3 %	3 %	8 %	5 %	6 %	19 %	10 %	11 %	14 %	5 %	7 %
Processing	**∑72 %**	**75 %**	**67 %**	**76 %**	**70 %**	**50 %**	**65 %**	**63 %**	**47 %**	**65 %**	**62 %**	**44 %**
Green biotechnology	9 %	10 %	5 %	7 %	9 %	5 %	10 %	11 %	4 %	12 %	11 %	7 %
Red biotechnology	50 %	50 %	48 %	53 %	49 %	34 %	40 %	34 %	29 %	27 %	26 %	19 %
White biotechnology	13 %	15 %	14 %	15 %	12 %	11 %	15 %	17 %	13 %	26 %	24 %	18 %
Output	**∑ 5 %**	**6 %**	**6 %**	**8 %**	**5 %**	**9 %**	**8 %**	**7 %**	**10 %**	**13 %**	**8 %**	**11 %**
Products & Materials	3 %	2 %	1 %	5 %	1 %	1 %	4 %	2 %	2 %	8 %	2 %	2 %
Energy & Fuels	0 %	2 %	4 %	1 %	2 %	5 %	1 %	3 %	7 %	1 %	3 %	9 %
Food & Feed	2 %	2 %	1 %	2 %	2 %	3 %	3 %	3 %	1 %	4 %	2 %	2 %
Socio-econ. framework	**15 %**	**4 %**	**7 %**	**7 %**	**4 %**	**9 %**	**6 %**	**4 %**	**9 %**	**6 %**	**3 %**	**8 %**
∑ projects	**699**	**921**	**1,451**	**712**	**1,283**	**1,882**	**693**	**1,109**	**1,899**	**884**	**1,846**	**3,121**
(% of all projects)	**(23 %)**	**(18 %)**	**(17 %)**	**(24 %)**	**(25 %)**	**(23 %)**	**(23 %)**	**(21 %)**	**(23 %)**	**(30 %)**	**(36 %)**	**(37 %)**

[source: own calculations]

In this breakdown, the data show a growing number of projects over time in every subgroup. When comparing the first period with the most recent one, the count of projects nearly trebled (going from 2,988 in 1995 - 2001 to 8,353 in 2009 - 2015). Interestingly, a shift in the distribution appears. While there was an almost neatly divided ratio between the four groups in the first period, the winners of the BioRegio contest experienced a loss of importance in relative terms (from 23 % to 18 % and 17 %). This is clearly caused by the termination of the special BioRegio funding[17]. Next to a strong focus on growing start-up activities, BioRegio subsidies aimed at the formation of knowledge networks (DOHSE 2000; EICKELPASCH & FRITSCH 2005). Over time, the biggest drop in this group is evident in the pillar **socio-economic framework**, which represents, among others, the cooperation-building support. The share of the BioProfile's winner consortia as well as of the group of the ten BioRegio applicants remained quite stable with no fundamental change in any direction. It implies a net gain in relevance of the remaining regions which did not participate in any of the portrayed place-based contests. This group received considerably less attention during the time frame of BioRegio's main implementation than afterwards. It, thus, highlights a distinct privileging of a few regions at the expense of the majority and feeds the debate about the role of innovation policy and its potential responsibility to allocate resources more evenly (see chapter 5).

[17] Although the funding measure was active until the year 2005, there were few projects that started in the last three years. As shown in chapter 3, Table 3-2, p. 22, the average project duration is about 3 years.

The comparative examination of the thematic dimension provides insights into further development of the respective groups. Starting with the BioRegio winners, we detect a behaviour that differs remarkably from the others. In every group, we find a noticeable decline of the *processing pillar* to 50 % or lower in the period from 2009 to 2015. This occurrence is not surprising, since the latest period includes the introduction of the official bioeconomy strategy in 2010 as well as the subsequent endeavours to foster the holistic scheme. BioRegio winners, in contrast, only slightly shifted their thematic focus and still conduct two thirds of bio-related R&D in this field. Within the *processing dimension*, the **red biotechnology** dominates in those regions, in which, thus, every second R&D project is related to the medical segment. The **white (or industrial) biotechnology** has a stable share of 13 % to 15 %, whereas R&D in **green biotechnology** halved in the recent period. The greatest gain in this group was in the segment **agriculture & forestry**, which rose from almost nought to 16 %.

Nevertheless, looking at the other groups, this increase is still rather modest. This very component flourished most dynamically and eventually even surpassed every other segment in the group of 'remaining regions'. This is mainly caused by the fact that the Federal Ministry of Food & Agriculture is a crucial department in the bioeconomy strategy and it became increasingly involved over time (see chapter 4).

The aggregated numbers further reveal some insights about the contest's emphasis and the general understanding of biotechnology. Both BioRegio and BioProfile winners received major parts of their subsidies for R&D in biotechnology (72 % and 76 % respectively). This is not that different in both other groups with a share of 65 % each. However, the higher numbers in **red biotechnology** are striking. Against this background, it can be assumed that the notion of biotechnology was primarily associated with the development of medical solutions, i.e., regional systems and networks with greater experiences in medical biotechnology were favoured in the selection of both biotechnology competitions. Somewhat surprisingly, despite the relatively similar starting points, the three winner regions of the BioProfile contest still developed differently than the BioRegio winners. Not only were they able to maintain the share of roughly one quarter of all bioeconomy projects in every period, but they also acquired large funds in the **agriculture & forestry** field. At the same time, the focus on **red biotechnology** was reduced.

The profile of the class 'applicants BioRegio' differed slightly. With a less pronounced stress on **red biotechnology** than the contest winners, the regions tend to have become more diverse. For instance, at the start of the observation period, the *input* segment was three times as large as the BioRegio winners' share and twice as large as the BioProfile winners' *input dimension*. Particularly R&D funding in the context of **climate & environment** was a strong suit in this group. Although it declined noticeably in the subsequent periods, it is still is a bigger component than in the other groups.

With the termination of the competitions, the 'remaining regions' gained more attention in the funding landscape and caught up in terms of executed undertakings. With 3,121 projects, they now realise more than twice as many publicly funded bioeconomy R&D projects as the BioRegio winners. Regarding the qualitative structure, the distribution within the process dimension is most striking. The role of **white biotechnology** is notably bigger than in any other group. Irrespective of the time interval, medical biotechnology is not the paramount subclass as is usual; industrial biotechnology is equally important (although both are declining over time). For the rest, the numbers indicate more or less the overarching trends.

In all groups, the *output pillar* is constantly low in comparison with the other dimensions. The percentages range from a minimum of five to a maximum of eleven in each group at any given time. The data suggest a somewhat bigger share in the group 'remaining regions' and point at the rather diverse funding in those regions. In general, the subcategory **products & materials** lost its initial momentum and plays an almost negligible role. **Food & feed** show similar results, but methodological issues might have an impact in this case. In the database we find certain thematic overlaps between the **food & feed** and **agriculture & forestry** segments. This circumstance might have led to an overestimation of the latter in the process of the categorisation. We cannot preclude the assumption that R&D in **food & feed** also increased de facto. However, within the *output pillar*, **energy & fuels** is the only field in which a distinct measurable and steadily positive trend can be ascertained. Particularly the groups 'applicants BioRegio' and 'remaining regions' execute projects dealing with this sector. The overall trend might be explained by the governmental endeavour to transform the energy system in Germany, known as the *Energiewende* ('energy transformation'). While this development started slowly in a niche, it successively developed into a quantifiable and tangible component of the German industry (HAKE et al. 2015). As a reaction to Fukushima and the intensified shift away from fossil raw materials, this debate became more prominent again and subsequently led to an increase in R&D in novel fields of power generation, for example by using biomass (RENN & MARSHALL 2016).

It is also remarkable that there has been a congruent general trend in the **socio-economic framework** over all groups. In the interval from 2002 to 2008, in between the BioRegio contest and the start of the bioeconomy strategy, this pillar dropped to a level of three to four percent per group. The growing shares of seven to nine percent per group, however, are a reflection of the high value of this supporting element in the recent bioeconomy era. The numbers also indicate a more even distribution between these aggregated groups.

Nevertheless, the differing trends in terms of content are only one facet of the general picture. Table 6-2 displays more detailed information about the aggregated groups and condenses the structural differences. Although the varying specialisation between the groups in either the biotechnology core or the bioeconomy shell has been noted before, this table reveals the gradation clearly. Thus, the BioRegio winners are considered first-movers, the BioProfile winners as follower regions and the other two groups embody the late-comers. This is visibly reflected in the share of projects in the biotechnology core. In essence, the earlier a commitment to the biotechnology took place, the more profound the later involvement. Looking at the actors executing the bioeconomy in the respective groups, we find that in BioRegio regions private actors more frequently participate in bioeconomy projects than in BioProfile regions or the applicants’ group. The share in the group ‘remaining regions’ is even higher, leading to the assumption that many prominent research locations are already covered in the first mentioned groups and thus point at the relevance of the private sector outside of agglomerations. This explains the lowest GINI coefficient, which serves as a measure for the distribution of the involved actors. Although having the second most bioeconomy projects acquired during the observation period, the BioProfile winners have the least dispersed allocation of project operators. So, the bioeconomy drivers in this group are dominant publicly funded institutes with only minor involvement of private business. The statistics regarding the collaboration activities indicate two things. First, biotechnology centres (BioRegio, BioProfile) tend to rely more heavily on intra-regional knowledge and do not seek cooperations with external partners as often as the other two groups. Secondly, it might hint at the institutional dimension of a RIS. The winners of the BioRegio contests consistently stuck to their biotechnology-centred vision on the one hand and the collaborations were more inward-looking on the other. This indicates ‘thick and specialised’ RIS. A similar trend can be detected within the BioProfile group, yet it is less pronounced and moreover, highlights the diversification into other segments as a change in the future course.

Table 6-2: Key statistics of bioeconomy funding in aggregated groups

	Winner BioRegio	Winner BioProfile	Applicants BioRegio	Remaining regions
Projects				
Overall	18,749	22,519	22,287	63,555
Bioeconomy	3,071	3,877	3,701	5,851
Share of bioeconomy	.16	.17	.17	.09
Share of biotechnology core	.71	.62	.55	.53
Share of bioeconomy shell	.29	.38	.45	.47
Actors (Bioeconomy)				
Public sector	.66	.77	.74	.57
Private sector	.34	.23	.26	.43
Number of different actors	578	555	701	1,694
GINI coefficient	.73	.78	.73	.64
Collaborations in bioeconomy				
Intra-regional	.58	.58	.53	.49
Inter-regional	.87	.88	.90	.93
Average funding (in 1k EUR)				
All projects	515	507	535	519
Bioeconomy	524	449	414	369
Average project duration (in days)				
All projects	1,646	1,606	1,606	1,618
Bioeconomy	1,793	1,758	1,781	1,742

[source: own calculations]

In Fig. 6-2, we compare the number of actual biotechnology firms in the respective groups from 2005 to 2015. 2005 represents the starting value, but the absolute number for all four groups is surprisingly similar and ranges from 115 to 127. Interestingly, from 2005 to 2007 a stronger increase in the firm population in the applicant group is notable than in BioRegio winner regions. Yet, when considered over the entire timespan, it can be observed that the BioRegio winners record a steady and above-average increase in biotech companies and are thus the only one of the four groups to stand out. Whether this circumstance is a direct aftermath of the contest funding or whether this can be explained by factors that lead to the selection of exactly these regions in the first place, requires deeper qualitative insights and remains unclear. In any case, it supports the previous findings, which revealed the persistent emphasis on biotechnology on the part of the BioRegio winners.

This juxtaposition sheds light on some structural differences between the listed groups. There are still unanswered questions, for example why BioRegio and BioProfile winners developed differently in terms of their specialisation, what region thrived without place-based funding, or which regions have distinguished themselves in the bioeconomy over time. Against this backdrop, we disaggregate the groups and illustrate some specific regional profiles in order to get a deeper and better understanding of the respective regional systems.

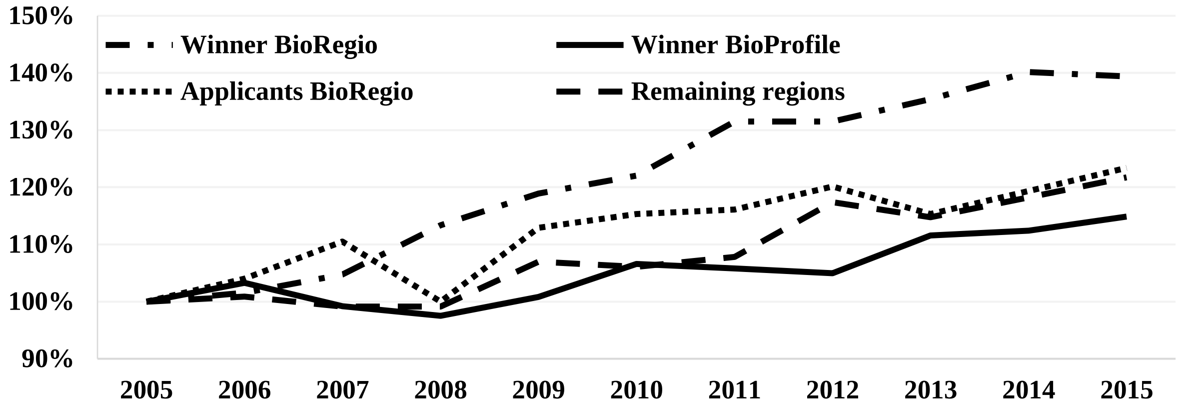


Fig. 6-2: Biotechnology firms by contest groups, 2005 - 2015

CHAMPENOIS (2012) already noted in a comparison of the BioRegio winner Rhine-Neckar Triangle and the BioProfile winner Berlin-Potsdam (Brandenburg) that the region Berlin-Potsdam possessed only one major pharmaceutical firm (then: Schering AG, now: Bayer Pharma AG), whereas there were multiple large enterprises situated in the Rhine-Neckar-Triangle (e.g. BASF, Merck, Roche). As posed in Table 6-2, we find further evidence attesting structural differences between the contest regions, where the involvement of the private sector is one factor, yet it is not the only one. We analysed all seven winning regions of the BioRegio and BioProfile competitions for a deeper understanding of the path development of acknowledged biotechnology regions and also to enrich the literature dedicated to evaluating policy measures. In order to do this, regional profiles that contain indicators with information about the main actors, the overall thematic development, firm population and inter- and extra-regional collaborations will be presented. However, for the sake of a better readability we exemplify the major differences in the text and illustrate the findings explicitly in two cases. Additionally, the remaining profiles are appended to this chapter to give a full picture (see App. 6-A, p. 130 & App. 6-B, p. 136). A more detailed comparison is made in the cases of the Rhineland network (Cologne, Aachen, Düsseldorf and Wuppertal) and the Lower Saxony network (Brunswick, Göttingen and Hanover,). The Rhineland network represents the BioRegio group since it shows how the future path is not only determined by a singular actor and also because it is an example of a vigorous biotechnology sector as was intended with the funding design. The Lower Saxony network, however, serves as the most pronounced example for the BioProfile regions, which are driven more by important public and quasi-public research institutes and universities. Moreover, it thus best illustrates how a region is able to redirect its focus to other paths.

A marked difference between the two competition winners is the breakdown of funding into private and public actors (see Table 6-3 & Table 6-4). In the Rhineland consortium the involvement of private business, at 37 %, is higher than in the Lower Saxony network with 18 %. This is in line with all other BioRegio winner profiles: 42 % in Rhine-Neckar, 30 % in Munich and 29 % in Jena. Berlin-Potsdam, in contrast, reaches a value of 26 % and in the STERN network every fourth project is granted to a private firm. If one excludes the regions Munich and Berlin-Potsdam, since they act as German bioeconomy hubs that both exhibit similar developments (see chapter 5 and App. 6-A, p. 130 & App. 6-B, p. 136), this might explain the **red biotechnology** specialisation of the BioRegio winners to some extent. In BioProfile regions more diverse universities and large public or semi-public research institutes attract most funding for basic and applied research. In contrast, the majority of private companies in the BioRegio winning regions tend to lead to intensified path-dependencies, i.e., since it is necessary for firms to develop a business which is profitable in the long term, they need to grow a strong expertise in one core area, e.g. **red biotechnology**. As established by many scholars, it is more likely for a company (or regional system) to diversify into a related business and not to shift the focus to unrelated activities. A similar picture emerges in terms of the biotechnology firm population of the BioRegio and BioProfile winners. All BioRegio winners registered a substantial gain in local businesses from 2005 to 2015, e.g. Rhineland from 27 in 2005 to 41 in 2015 and Jena from 6 in 2006 to 12 firms in 2012 (2015: 10). Even by direct comparison, Munich’s firm population rose slightly more than Berlin’s, namely increasing from 66 in 2005 to 90 in 2015, whereas it increased from 69 to 82 in Berlin in the same period, which was still a perceptible development. Even the STERN network in Baden-Württemberg, which is widely known for its extensive SME landscape, oscillated mainly between 23 and 25 companies with no quantifiable rise. Lower Saxony’s private biotechnology sector took a downturn and reached its initial firm count in the latter period. In essence, regions that won BioRegio either already possessed a greater share of private business at the beginning of the observation period and/or developed it more significantly over time than the BioProfile winning regions. This might lead to the assumption that private actors act as drivers for a path-dependency and specialisation of the system’s bioeconomy. However, since only rather ‘organisationally thick’ areas were integrated into this analysis, this argumentation might not be applicable to ‘thin’ RIS.

Going back to the Rhineland network, one finds a relatively small share of bioeconomy projects (Table 6-3). Just eleven percent of all projects have been linked to the bioeconomy. Expressed in terms of population, this gives a value of 72 bioeconomy projects per 100,000 inhabitants. Lower Saxony displays a visible focus on the bioeconomy; since 2004 approximately every fourth public R&D project has operated in one of its segments. 177 bioeconomy projects per 100,000 inhabitants were conducted from 1995 to 2015. Of all the winning regions, irrespective of the contest, only Jena reaches a higher value (198). Apart from the universities, public research institutes, such as the Max Planck Society, Fraunhofer Society or Helmholtz Centres, acquired numerous projects in all the contest winner regions. By looking at the top five executing organisations[18] in Rhineland, there are some corporate activities from QIAGEN GmbH and UCB Pharma GmbH as well as the private research establishment nova-Institute. Corresponding to the private/public R&D-debate before, in Lower Saxony exclusively public research institutes are listed. Despite this one-sided impression, a few firms, such as IBA GmbH (12), Sartorius Stedim Biotech GmbH (12) and ASA Spezialenzyme GmbH (11), are also among the top executing organisations. Again, private companies in Rhineland, QIAGEN GmbH (25) and UCB Pharma GmbH (15), are primarily involved in medical solutions. Some commercial businesses in Lower Saxony, e.g. ASA Spezialenzyme, also deal with biotechnology applications in agriculture or other industries.

In terms of the average project duration, there is no clear difference between the contests. Biotechnology projects are on average somewhat longer and more expensive (see chapter 3), but further patterns are not apparent. A general observation is the systematic growth in the number of cooperative projects across all regions. In particular since the mid 00's, bioeconomy projects have noticeably more often been in partnerships. Inter-regional collaborations seeking knowledge not available in their own regional system, represent the main type of joint projects.[19] Yet, the bigger and more diverse agglomerations, Berlin and Munich, show an exceptionally high but decreasing value of intra-regional cooperations. 65 % and 61 % of all joint bioeconomy projects respectively featured at least two partners from their own region. Due to their sheer size and diversity, they benefit to a greater extent from their endowments than smaller regions.[20] For that reason, both regions are, without exception, ranked first or second in the location of the project partners. For all regions in the south of Germany, collaborating partners tend to be sought in southern areas. But it cannot

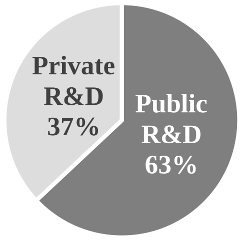
[18] 'Recipients' are superordinate authorities such as a university that receives the grant. The 'executing organisations' are the specific subgroup, like institutes or chairs, within the superordinate authority.
[19] In the case of network regions, we calculated inter- and intra-regionality for each labour market region. For instance, a collaboration between Hanover and Brunswick counts as **inter-regional** cooperation (in their own interest).
[20] Interestingly, Jena reaches similarly high values (not only in the bioeconomy) and at the same time has a slightly smaller number of partnerships with other labour market regions.

conclusively be stated whether joint projects in the bioeconomy are in spatial proximity more often.

Table 6-3: Regional profile Rhineland (Cologne, Aachen, Düsseldorf & Wuppertal)

Key figures of the funding landscape

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
All Projects	588	608	710	747	1,290	1,387	1,470	6,800
Projects Bioeconomy	62	60	65	76	193	162	156	774
Share of BE-Projects	.11	.10	.09	.10	.15	.12	.11	.11
BE-Proj./100k inhab.	5.7	5.6	6.0	7.0	17.9	15.0	14.4	71.6



Top 5 Recipients and executing organisations

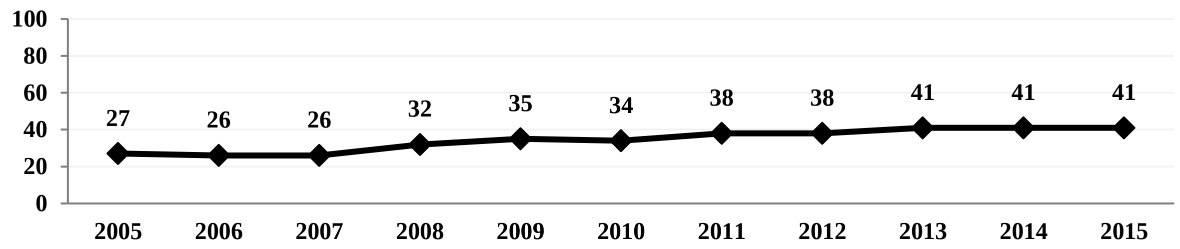
#	Recipient	# Proj.	% Pr.	Executing organisation	# Proj.	% Pr.
1	RWTH Aachen University	120	15.5	Fraunhofer Institute for Molecular Biology and Applied Ecology (IME)	36	4.7
2	University of Cologne	90	11.6	Max Planck Institute for Plant Breeding Research	28	3.6
3	Heinrich Heine University Düsseldorf	79	10.2	QIAGEN GmbH	25	3.2
4	Max Planck Society	54	7.0	UCB Pharma GmbH	15	1.9
5	Fraunhofer Society	46	5.9	nova-Institute for Ecology and Innovation	11	1.4

Evolution of the bioeconomy funding by fields

Bioeconomy dimension		1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Input	∑	**.10**	**.07**	**.09**	**.04**	**.13**	**.21**	**.20**	**.14**
Agriculture & Forestry		.00	.00	.02	.01	.10	.18	.17	.10
Climate & Environment		.10	.07	.08	.03	.03	.03	.03	.04
Processing	∑	**.76**	**.67**	**.80**	**.75**	**.77**	**.67**	**.69**	**.72**
Green biotechnology		.16	.25	.15	.14	.12	.13	.03	.12
Red biotechnology		.45	.23	.38	.38	.47	.35	.44	.40
White biotechnology		.15	.18	.26	.22	.18	.19	.22	.20
Output	∑	**.00**	**.12**	**.05**	**.08**	**.07**	**.05**	**.04**	**.06**
Products & Materials		.00	.08	.03	.04	.01	.00	.01	.02
Energy & Fuels		.00	.02	.02	.04	.06	.04	.02	.03
Food & Feed		.00	.02	.00	.00	.00	.01	.02	.01
Socio-economic framew.	∑	**.15**	**.15**	**.06**	**.13**	**.04**	**.07**	**.07**	**.08**
Total (Project count)		**62**	**60**	**65**	**76**	**193**	**162**	**156**	**774**

Average subsidy amounts and project duration

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Av. fund. (1k EUR) - All Proj.	451	528	398	456	424	421	430	437
Av. fund. (1k EUR) - Bioec.	548	902	653	660	476	420	296	500
Av. duration (days) - All Proj.	1,618	1,643	1,600	1,675	1,658	1,650	1,546	1,623
Av. duration (days) - Bioecon.	1,733	1,947	1,756	1,713	1,822	1,808	1,741	1,789



Biotechnology firms per year, 2005 - 2015

Comparison of cooperation structures over time

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Joint Projects	**.45**	**.55**	**.68**	**.67**	**.68**	**.66**	**.67**	**.64**
Intra-regional	.66	.64	.62	.63	.57	.62	.61	.61
Inter-regional	.93	.93	.95	.90	.91	.92	.93	.92
Joint Bioeconomy Projects	**.55**	**.65**	**.68**	**.78**	**.83**	**.75**	**.74**	**.74**
Intra-regional	.53	.36	.66	.49	.41	.52	.50	.48
Inter-regional	.82	.77	.91	.90	.91	.89	.92	.89
Intra-regional PPP	.44	.28	.52	.34	.25	.35	.31	.33

Top 5 cooperating regions – Overall (top table; left figure) and in the bioeconomy (bottom; right)

All Projects

#	Partner in	Pr.	%
1	Munich	894	7.3
2	Berlin	786	6.4
3	Stuttgart	736	6.0
4	Karlsruhe	382	3.1
5	Dresden	346	2.8

Bioeconomy

#	Partner in	Pr.	%
1	Berlin	113	7.6
2	Munich	104	7.0
3	Heidelberg	60	4.0
4	Bonn	53	3.6
5	Stuttgart	52	3.5

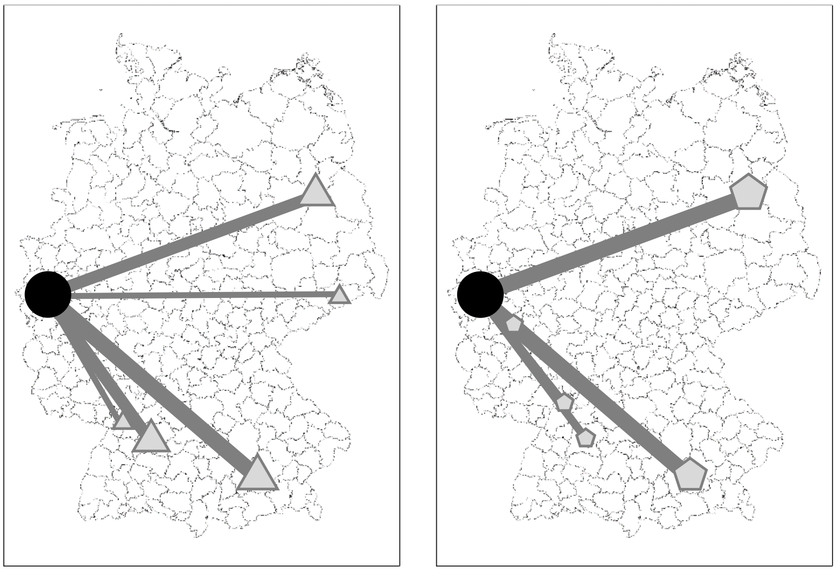
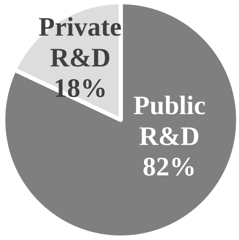


Table 6-4: Regional profile Lower Saxony (Brunswick, Göttingen & Hanover)

Key figures of the funding landscape

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
All Projects	428	432	489	600	955	1,047	1,113	5,064
Projects Bioeconomy	82	81	81	156	239	262	260	1,161
Share of BE-Projects	.19	.19	.17	.26	.25	.25	.23	.23
BE-Proj./100k inhab.	12.5	12.4	12.4	23.8	36.5	40	39.7	177.1



Top 5 Recipients and executing organisations

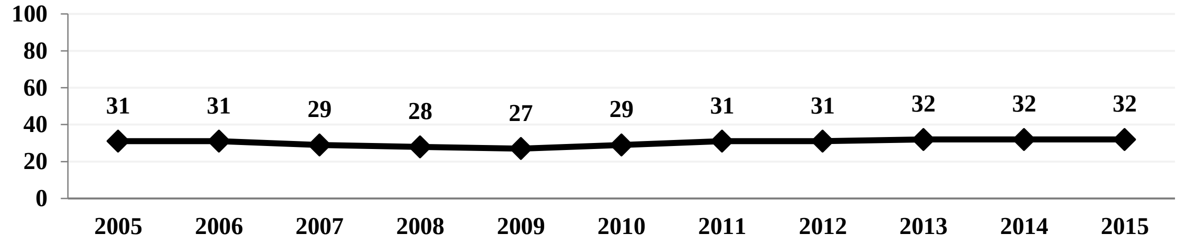
#	Recipient	Proj.	% Pr.	Executing organisation	Proj.	% Pr.
1	Georg August University of Göttingen	251	21.6	Fraunhofer Institute for Wood Research Wilhelm-Klauditz-Institut	39	3.4
2	Technichal University of Braunschweig	117	10.1	Helmholtz Centre for Infection Research	26	2.2
3	Helmholtz Centre for Infection Research	93	8.0	J.H.v. Thünen Institute - Fed. Research Inst. for Rural Areas, Forestry and Fisheries - Inst. of Agricult. & Biosystems Technology	16	1.4
4	Leibniz University of Hanover	75	6.5	University of Applied Sciences & Art - Department of Bioprocess Engineering	15	1.3
5	Hanover Medical School	65	5.6	Julius Kühn Institute - Federal Research Centre for Cultivated Plants - Institute for Crop and Soil Science	15	1.3

Evolution of the bioeconomy funding by fields

Bioeconomy dimension		1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Input	∑	**.07**	**.11**	**.11**	**.24**	**.39**	**.44**	**.47**	**.34**
Agriculture & Forestry		.00	.01	.09	.21	.33	.37	.42	.28
Climate & Environment		.07	.10	.02	.04	.06	.07	.06	.06
Processing	∑	**.73**	**.69**	**.68**	**.65**	**.52**	**.43**	**.38**	**.52**
Green biotechnology		.09	.05	.06	.12	.10	.08	.03	.07
Red biotechnology		.51	.44	.51	.42	.33	.27	.22	.34
White biotechnology		.13	.20	.11	.11	.09	.08	.13	.11
Output	∑	**.04**	**.17**	**.11**	**.06**	**.05**	**.04**	**.03**	**.06**
Products & Materials		.04	.15	.05	.00	.00	.01	.00	.02
Energy & Fuels		.00	.00	.02	.02	.03	.01	.00	.01
Food & Feed		.00	.02	.04	.04	.01	.02	.02	.02
Socio-economic framew.	∑	**.16**	**.02**	**.10**	**.05**	**.04**	**.09**	**.12**	**.08**
Total (Project count)		**82**	**81**	**81**	**156**	**239**	**262**	**260**	**1,161**

Average subsidy amounts and project duration

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Av. fund. (1k EUR) - All Proj.	398	618	564	410	403	359	348	408
Av. fund. (1k EUR) - Bioecon.	393	445	525	546	390	433	422	442
Av. duration (days) - All Proj.	1,647	1,797	1,684	1,759	1,990	1,939	1,755	1,816
Av. duration (days) - Bioecon.	1,619	1,693	1,538	1,722	1,780	1,724	1,568	1,663



Biotechnology firms per year, 2005 - 2015

Comparison of cooperation structures over time

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Joint Projects	**.39**	**.49**	**.60**	**.62**	**.66**	**.62**	**.65**	**.60**
Intra-regional	.71	.57	.60	.62	.52	.58	.58	.58
Inter-regional	.90	.94	.89	.92	.92	.89	.92	.91
Joint Bioeconomy Projects	**.33**	**.56**	**.57**	**.61**	**.76**	**.76**	**.77**	**.68**
Intra-regional	.48	.47	.65	.54	.40	.52	.49	.49
Inter-regional	.85	.84	.80	.87	.91	.86	.91	.88
Intra-regional PPP	.41	.24	.50	.29	.23	.26	.30	.29

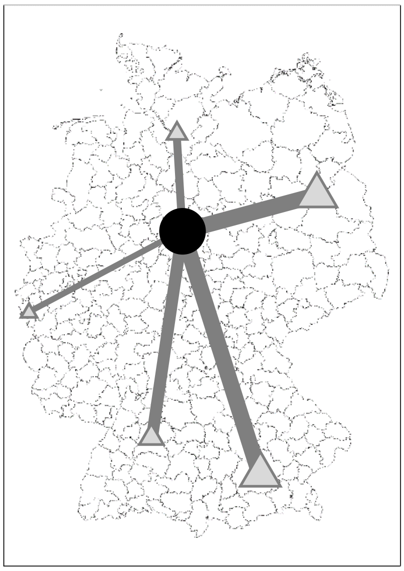
Top 5 cooperating regions – Overall (top table; left figure) and in the bioeconomy (bottom; right)

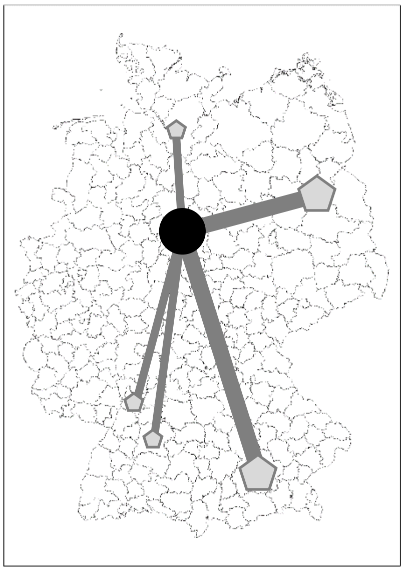
All Projects

#	Partner in	Pr.	%
1	Berlin	761	8.1
2	Munich	758	8.1
3	Stuttgart	495	5.3
4	Hamburg	343	3.7
5	Aachen	313	3.3

Bioeconomy

#	Partner in	Pr.	%
1	Berlin	127	7.3
2	Munich	119	6.8
3	Heidelberg	64	3.7
4	Stuttgart	64	3.7
5	Hamburg	59	3.4





6.6.2 The identification of specialised bioeconomy regions

The regions shown and contrasted above have been examined in more detail in several scientific publications. However, it became evident that during the observation period a shift towards less localised promotion took place (see Table 6-1, p. 105 & chapter 5). Therefore, the following section deals with the identification and closer inspection of further biotechnology and bioeconomy sites.

First, three cluster analyses were conducted in order to classify the regions into different groups. This step served the purpose of identifying relevant labour market regions, while at the same time considering the chronological development of the individual regions. Subsequently, selected regional profiles will be shown in order to get a grasp of different bioeconomy paths in Germany.

As a reminder, regions with fewer than 13 projects in the entire period were not included in the analyses. This ensures that all regions have a certain minimum relevance for the subject matter. In Table 6-5, some regional statistics of the aggregated groups are presented. The first cluster displays regions which either only occasionally acquire bioeconomy projects or where the bioeconomy plays a very minor role in contrast to other lively sectors. This group is characterised by a wide diversity of regions, in which R&D wealthy regions such as Nuremberg, Frankfurt/Main and even the BioRegio winners Düsseldorf and Cologne (Rhineland only has a bioeconomy share of eleven percent of all projects – cf. its profile above) are categorised together with rather sparse regions like Mecklenburgische Seenplatte, Borken and Homburg/Saar (full list in App. 6-C, p. 140). Their combined bioeconomy share has values of around ten percent, the lowest among all groups – with no clear increase over time. Each of the bioeconomy dimensions are below average. This underlines the loose connection with the bioeconomy. Since this cluster features the greatest number of regions, it reveals the low degree of penetration of the bioeconomy in Germany. Interestingly, the GDP per employee is at the top end compared to the other groups and might indicate that particularly less wealthy regions have taken up the bioeconomy scheme thus far.

The second group features the most projects on average in the recent period. Even before that period, the project count was considerably higher than in the groups 1 and 4. Approximately every fifth project is bioeconomy-themed. Biotechnology seems to play a marginally greater role in those regions than the bioeconomy shell. The high population density reflects, along with the high GDP and the share of people employed in knowledge-intensive sectors, the nature of most regions in this cluster. From these parameters, we can derive that it includes urban and diverse regions with a connection to some strands of the bioeconomy. With some exceptions, like Südvorpommern and Mittelsachsen, the majority of this class are larger labour market regions and agglomerations. Munich (17 %) and Berlin (group 1 in the first period; 16 %), for example, are listed in this category and have values even below the group's average of 18 % to 20 % bioeconomy share. A small excerpt with economically vibrant regions such as Aachen, Heidelberg, Karlsruhe, Leipzig or Magdeburg (all in group 2 for at least the two latest periods) reveal that important bioeconomy research

Table 6-5: Region-specific key data of the estimated clusters

Year	N	Proj.	BE-Proj.	% Bio-econ.	% Bio-Tech.	% BE-Shell	Input per Pop.	Biotech. per Pop.	Output per Pop.	SEF per Pop.	GDP per Empl.	Pop.-density	% Empl. Know.	% Agri. & Forest.	% Intrar. Proj.	% Interr. Proj.	% Proj. Private	% PPP
1 - Regions with occasional bioeconomy projects																		
1995 - 2001	85	167	15	.08	.06	.03	.2	1.3	.2	.1	66,873	469	9.1	.077	.52	.87	.33	.33
2002 - 2008	79	117	15	.14	.09	.06	.9	2.2	.2	.1	66,778	406	8.6	.078	.51	.93	.45	.46
2009 - 2015	77	287	30	.11	.05	.06	2.2	2.7	.6	.5	66,695	460	8.8	.077	.45	.94	.41	.53
2 - Larger, more diverse regions with some touch points to the bioeconomy																		
1995 - 2001	28	281	49	.20	.10	.10	2.3	5.8	.9	.8	62,978	251	9.5	.081	.59	.84	.25	.28
2002 - 2008	33	466	78	.20	.12	.08	2.6	7.1	1.1	.5	66,190	511	10.5	.077	.59	.90	.30	.42
2009 - 2015	30	855	140	.18	.10	.09	5.4	11.8	2.2	1.9	67,691	452	11.0	.078	.56	.89	.26	.47
3 - Larger (urban) regions with bioeconomy focus																		
1995 - 2001	1	492	106	.22	.15	.07	2.6	37.3	1.6	13.5	60,264	210	10.0	.087	.60	.71	.31	.41
2002 - 2008	7	515	125	.30	.15	.15	9.8	19.8	1.7	1.3	60,002	213	10.0	.084	.59	.87	.21	.42
2009 - 2015	6	646	183	.31	.10	.21	24.8	23	4.2	5.3	59,913	182	9.7	.084	.52	.90	.16	.43
4 - Rural regions with bioeconomy focus																		
1995 - 2001	17	28	10	.40	.32	.09	.3	3.9	.5	.2	64,015	287	6.8	.081	.35	.78	.57	.36
2002 - 2008	12	57	30	.64	.42	.22	2.4	9.3	.3	.4	59,696	135	6.1	.085	.59	.80	.46	.53
2009 - 2015	18	57	21	.35	.13	.22	6.4	4.6	1.3	.5	59,464	106	5.6	.085	.46	.94	.51	.69

N: Cluster size; **Proj.:** average number of projects; **BE-Proj.:** average number of bioeconomy projects; **% Bioecon.:** average share of bioeconomy projects; **% Bio-Tech.:** average share of biotechnology projects; **% BE-Shell:** average share of bioeconomy shell projects; **Input/Biotech/Output/SEF per Pop.**: average projects from the respective dimension per 100,000 inhabitants (Determinants for cluster analyses); **GDP per Empl.:** average GDP per employed person; **Pop.-density:** average population per km²; **% Empl. Know.:** average share of people employed in knowledge-intensive industries; **% Agri. & Forestry:** average share of agricultural and forest area per total area; **% Intrar. Proj.:** average share of joint bioeconomy projects with the project partner within the same region; **% Interr. Proj.:** average share of joint bioeconomy projects with the project partner located in another region; **% Proj. Private:** average share of bioeconomy projects executed by private companies; **% PPP**: Projects with at least one partner in both public and private sector

[source: own calculations]

is executed not only in highly specialised regions. Instead, this clarifies that, from a spatial perspective, the contribution of public research surpasses the initial biotechnology competitions and shows that is successively being carried out in more than a handful of locations. Compared to group 1, the low average percentage of private actors stands out. Only 25 % to 30 % of all bioeconomy projects have been conducted by private businesses. This is the case because many of the regions assigned to this cluster are the home of big public research facilities, such as universities and (quasi-)public research institutes, which attract large amounts of subsidies and thus the relative share for private segment funding is rather small.

As an interim conclusion, we find that up to this point very few regions in Germany have really adopted the bioeconomy scheme as a strategy for the future. Cluster 1 and 2 are representative of the majority of the examined labour market regions (the lower half with hardly measurable numbers have not even been included) and are considered to be loosely linked to the subject. Cluster 3 and 4, in contrast, we consider as units with a strong or developing tie to the bioeconomy. Since some examples of BioRegio or BioProfile winners have been pictured in more detail earlier or in the appendix, two further regionale profiles, one for each cluster, will be selected and presented with their regional profiles in order to display different path for bioeconomy development on a regional level.

The third cluster registers by far the most projects and projects per capita in each of the bioeconomy dimensions at any point. The characteristics suggest that the assigned regions combine thematic specialisation in asbolute and relative terms. The bioeconomy and the bioeconomy shell both gain in importance over time, especially the bioeconomy shell, which does so significantly. The regions in the two latest intervals are consistent. During the time from 1995 to 2001 Jena forms a single cluster and is thereby the only regional system counting as a 'larger region with bioeconomy focus'. Even though Jena reaches a similar share of bioeconomy projects (around 20 %) as the regions in group 2, it reveals high figures in terms of bioeconomy projects per capita. The remaining representatives of this cluster are Brunswick, Göttingen/Osterode, Potsdam-Brandenburg, Rostock and Eschwege. Dresden appeared here in the second period, but was then assigned to group 2 in the third period. At first impression, Eschwege is the only one that does not really correspond to the image of an urban and diverse region. Interestingly, one particular department[21] of the University of Kassel is situated in this region, and it attracts projects frequently, thereby contributing to

[21] Faculty of Organic Agricultural Sciences

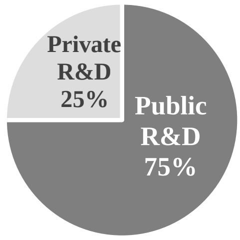
the high numbers affecting the decisive parameters of the cluster analyses. In general, this cluster does not exhibit the textbook characteristics of leading urban high-tech centres whatsoever. Their average population density is higher than that of the rural regions of cluster 4, but less than half of cluster 1 and 2. The average share of agricultural and forestry area is as high as in cluster 4. However, initially biotechnology and later the bioeconomy shell play a larger role in those regions. Almost every third project was dedicated to one of those fields. By looking at the size of projects from private firms, it becomes clear that this development is being steered by larger public research institutes in particular. As one example case from this cluster, the region of Rostock will now be highlighted in more detail (see Table 6-6). Rostock is a fitting example to show what role geography can play for the path development in the context of the bioeconomy. Moreover, as part of a network which applied for funding in the BioRegio contest, comparisons to the BioRegio and BioProfile winner regions can be drawn more easily.

Rostock has an overall share of bioeconomy projects of 26 % with an increasing tendency in the last time intervals. This is the case particularly since 2007, as Rostock has since been able to attract funding in the bioeconomy, more than doubling the count compared to the earlier period. For this group, Rostock has a relatively high number of private firms involved in funded bioeconomy R&D. In terms of the content, they operate fairly diversely with an initial focus on **green biotechnology** shifting towards **agriculture & forestry** over time. The topic **climate & environment** is also of more importance here than in other regions. Due to its location by the sea, coastal protection, for example, is covered by the Leibniz Institute for Baltic Sea Research. Except for 2015, the development of a biotechnology landscape is quite promising, with the the firm population increasing from nine to 15. The average funding amount is, however, modest even in stages with a great focus on biotechnology. Collaborations are comparable to most other regions of this size. The main partners are, again, Berlin and Munich, but also some closer sites such as Südvorpommern and Kiel. Overall, the profile unveils an underlying progress in which the regional system is increasingly focussing on the bioeconomy. Due to its location and the contribution of larger research institutes, Rostock has specialised over time and seems to also be benefiting from the policy shift from biotechnology to bioeconomy.

Table 6-6: Regional profile Rostock

Key figures of the funding landscape

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
All Projects	95	97	177	214	289	276	237	1,385
Projects Bioeconomy	16	19	17	42	97	87	76	354
Share of BE-Projects	.17	.20	.10	.20	.34	.32	.32	.26
BE-Proj./100k inhab.	3.76	4.46	3.99	9.87	22.79	20.44	17.85	83.16



Top 5 Recipients and executing organisations

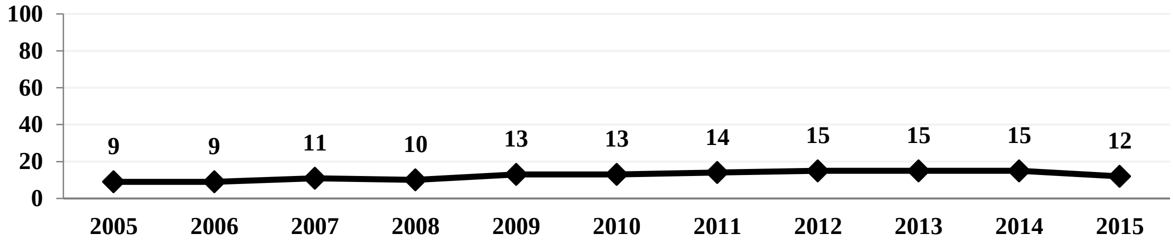
#	Recipient	Proj.	% Pr.	Executing organisation	Proj.	% Pr.
1	University of Rostock	137	38.7	Leibniz Institute for Baltic Sea Research	26	7.3
2	Leibniz Institute for Baltic Sea Research	30	8.5	Federal Research Centre for Cultivated Plants - Institute for Breeding Research on Agricultural Crops	18	5.1
3	Leibniz Institute for Farm Animal Biology	25	7.1	University of Rostock – Faculty of Agricultural and Environmental Sciences	13	3.7
4	Federal Research Centre for Cultivated Plants	23	6.5	Leibniz Institute for Catalysis at the University of Rostock	12	3.4
5	Rostock University Medical Center	16	4.5	NORIKA-Nordring-Kartoffelzucht- und Vermehrungs-GmbH	10	2.8

Evolution of the bioeconomy funding by fields

Bioeconomy dimension		1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Input	∑	**.63**	**.32**	**.24**	**.17**	**.41**	**.44**	**.57**	**.42**
Agriculture & Forestry		.00	.00	.18	.02	.28	.29	.36	.23
Climate & Environment		.63	.32	.06	.14	.13	.15	.21	.18
Processing	∑	**.31**	**.58**	**.76**	**.74**	**.55**	**.38**	**.28**	**.47**
Green biotechnology		.13	.37	.18	.38	.24	.07	.05	.17
Red biotechnology		.13	.16	.29	.26	.21	.20	.16	.20
White biotechnology		.06	.05	.29	.10	.10	.11	.07	.10
Output	∑	**.06**	**.05**	**.00**	**.07**	**.02**	**.08**	**.03**	**.05**
Products & Materials		.06	.05	.00	.02	.00	.00	.00	.01
Energy & Fuels		.00	.00	.00	.05	.02	.05	.03	.03
Food & Feed		.00	.00	.00	.00	.00	.03	.00	.01
Socio-economic framew.	∑	.00	.05	.00	.02	.02	.10	.13	.07
Total (Project count)		**16**	**19**	**17**	**42**	**97**	**87**	**76**	**354**

Average subsidy amounts and project duration

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Av. fund. (1k EUR) - All Proj.	369	444	567	325	364	396	398	402
Av. fund. (1k EUR) - Bioecon.	372	184	649	287	298	314	302	315
Av. duration (days) - All Proj.	1,647	1,797	1,684	1,759	1,990	1,939	1,755	1,816
Av. duration (days) - Bioecon.	1,619	1,693	1,538	1,722	1,780	1,724	1,568	1,663



Biotechnology firms per year, 2005 - 2015

Comparison of cooperation structures over time

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Joint Projects	**.17**	**.46**	**.63**	**.70**	**.74**	**.70**	**.70**	**.64**
Intra-regional	.50	.76	.80	.80	.69	.70	.60	.71
Inter-regional	.94	.80	.77	.84	.81	.82	.91	.83
Joint Bioeconomy Projects	**-**	**.74**	**.47**	**.79**	**.76**	**.76**	**.78**	**.72**
Intra-regional	-	.43	.88	.76	.62	.62	.49	.60
Inter-regional	-	.93	.50	.79	.77	.89	.97	.85
Intra-regional PPP	-	.21	.38	.48	.45	.44	.34	.41

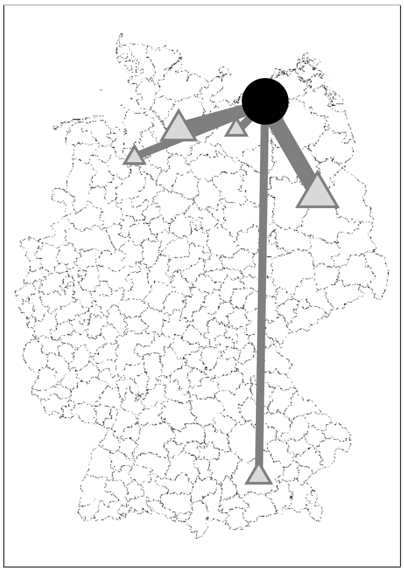
Top 5 cooperating regions – Overall (top table; left figure) and in the bioeconomy (bottom; right)

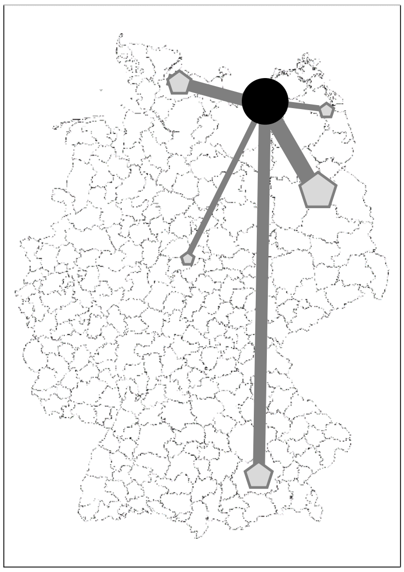
All Projects

#	Partner in	Pr.	%
1	Berlin	178	8.6
2	Hamburg	156	7.5
3	Munich	100	4.8
4	Bremen	80	3.9
5	Schwerin	74	3.6

Bioeconomy

#	Partner in	Pr.	%
1	Berlin	47	8.3
2	Munich	35	6.1
3	Kiel	31	5.4
4	Südvorpom.	20	3.5
5	Göttingen/ Osterode	17	3.0





Category 4 predominantly includes 'structurally thin' regions dedicated to the bioeconomy. Of all the clusters they attracted by far the smallest quantity of projects on average. However, of those few projects a considerable number is operating within the scope of the bioeconomy. Due to the small cluster size, the share fluctuates considerably from 35 % to 64 % of all projects. There has been a shift in favour of the bioeconomy shell in the last period. In contrast, biotechnology was of much greater relevance in early stages. This development is also reflected in the group's composition, i.e., in the first period, larger cities like Leverkusen and Ludwigshafen were assigned to this cluster. On average, wealthier and more densely populated labour market regions were engaged with biotechnology, as already established in chapter 5. It is only later on that regions focussing on other aspects of the bioeconomy were included to this group. This means that the 'bioeconomy group' revealed an identifiable shift from biotechnology towards bioeconomy, where regions with emphasis on biotechnology (driven by companies such as Bayer and BASF) were 'replaced' by rural regions with an increasing focus on the bioeconomy shell. The engagement of private actors is the highest among all groups due to the lack of public research facilities in rural areas. The proportion of cooperation between public and private partners is also notably higher than in other groups. In some cases, one particular actor dominates the development in the given region. In Einbeck the company KWS (seed producer and plant breeding) attracts 81 % of all bioeconomy projects in the region. In Eberswalde, again, it is the Eberswalde University for Sustainable Development that is responsible for a major part of the region's bioeconomy activities. In Salzlandkreis, the Leibniz Institute of Plant Genetics and Crop Plant Research executes 65 % of the public bioeconomy subsidies. In the latter case, however, a quite lively involvement of further private actors is visible. The region Uelzen in the Lüneburg Heath specialised in one particular thematic area. Small resident firms tend to mainly be engaged in R&D in areas of plant breeding and cultivation, focussing on potatoes and grain. This shows that path development in the bioeconomy can be affected and shaped by a variety of structures and processes. It can be carried out privately or publicly, by a single actor, or collectively. In most cases, however, a content focus develops, which in turn can be further explored. From the cases mentioned above, this is demonstrated briefly using the example of the Salzlandkreis profile. The region Salzlandkreis is a case that neatly represents the role of historical accidents and their long-term effects on the one hand and, how knock-on induced from the policy can shape a path, especially in a peripheral region on the other (see Table 6-7). Also, as apparent in Table 6-5, most regions in cluster 3 do not acquire bioeconomy projects in large quantities. A detailed regional profile with aggregated data would thus not be meaningful.

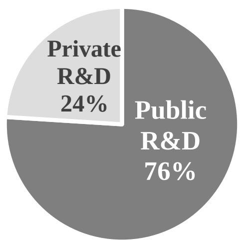
Within the entire observation period, 71 % of 272 publicly subsidised projects were linked to the bioeconomy. After the implementation of the dedicated bioeconomy strategy, it even reached the values of 79 % and 77 %. The Leibniz Institute of Plant Genetics & Crop Plant Research accounts for 65 % of the bioeconomy projects, while 24 % were carried out by private firms. This is an exception in cluster 4, where the percentage of private entities is on average higher. Overall, most R&D is within **green biotechnology**. It is, therefore, not surprising that in the recent intervals the overarching trend towards **agriculture & forestry** is more pronounced than usual. The relatedness between these two bioeconomy strands is apparent due to much research in **green biotechnology** often being applied in **agriculture & forestry**. This comes with an anticipated consequence. Namely, a tremendous drop in the average financial support in the period from 2013 to 2015. Surprisingly, we find a negative trend for local biotechnology firms. In 2005, four firms were established in the region. All but one have not been listed since 2013.[22] SunGene GmbH has been fully acquired by BASF. The Leibniz Institute of Plant Genetics & Crop Plant Research (IPK) was a hotbed for some founded companies, even though this did not remain the case through to 2015 (IPK 2020). While joint projects with external partners are similar to many regions, the share of collaborations within the Salzlandkreis is rather low and demonstrates the demand for regionally available knowledge. However, it is noteworthy that the relatively short geographical distance to Berlin has not figured prominently in the past. Here, the proximity to Magdeburg and Harz is more intensely exploited.

The Salzlandkreis profile reflects the range of path-dependency triggered by governmental intervention. The driving force that led to the current situation, in which the Salzlandkreis displays a solid framework in the bioeconomy scheme, was the IPK in Gatersleben. Its predecessor institute at this site was already formed in 1945 and re-established in 1992 after the German reunification. Our data suggest that in the beginning of the observation period neither bioeconomy R&D nor much other public R&D was carried out in this region. Over the observed time period, those numbers successively started to grow with a distinct emphasis on the bioeconomy. As the IPK is still the central actor in this area, the 24 % share of private actors conducting funded projects also reveals that some commercial businesses benefit from the existence of the research institute and thus contribute to the region’s economic development.

Table 6-7: Regional profile Salzlandkreis

Key figures of the funding landscape

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
All Projects	6	21	50	41	51	56	47	272
Projects Bioeconomy	5	13	29	27	39	44	36	193
Share of BE-Projects	.83	.62	.58	.66	.76	.79	.77	.71
BE-Proj./100k inhab.	2.2	5.8	12.8	11.9	17.2	19.5	15.9	85.3



[22] There are indicators for the existence of another founded company in 2009, which is not listed in the Biocom database.

Top 5 Recipients and executing organisations

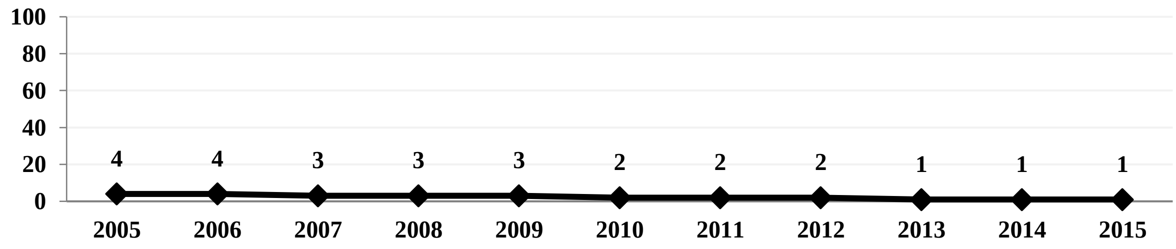
#	Recipient	Proj.	% Pr.	Executing organisation	Proj.	% Pr.
1	Leibniz Institute of Plant Genetics & Crop Plant Res.	126	65.3	Leibniz Institute of Plant Genetics & Crop Plant Research	91	47.2
2	Anhalt University of Applied Sciences	14	7.3	Anhalt University of Applied Sciences – Department of Agriculture, Ecotrophology & Landscape Develop.	10	5.2
3	TraitGenetics GmbH	10	5.2	TraitGenetics GmbH	10	5.2
4	Dr. Junghanns GmbH	6	3.1	Dr. Junghanns GmbH	6	3.1
5	SunGene GmbH & Co. KGaA	5	2.6	SunGene GmbH & Co. KGaA	5	2.6

Evolution of the bioeconomy funding by fields

Bioeconomy dimension		1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Input	∑	**.40**	**.00**	**.10**	**.07**	**.13**	**.23**	**.61**	**.23**
Agriculture & Forestry		.40	.00	.07	.07	.13	.23	.56	.21
Climate & Environment		.00	.00	.03	.00	.00	.00	.06	.02
Processing	∑	**.60**	**.77**	**.86**	**.89**	**.85**	**.75**	**.33**	**.73**
Green biotechnology		.20	.62	.69	.70	.64	.68	.22	.58
Red biotechnology		.40	.08	.07	.04	.21	.00	.06	.08
White biotechnology		.00	.08	.10	.15	.00	.07	.06	.07
Output	∑	**.00**	**.08**	**.03**	**.00**	**.03**	**.00**	**.00**	**.02**
Products & Materials		.00	.08	.00	.00	.00	.00	.00	.01
Energy & Fuels		.00	.00	.00	.00	.03	.00	.00	.01
Food & Feed		.00	.00	.03	.00	.00	.00	.00	.01
Socio-economic framew.	∑	.00	.15	.00	.04	.00	.02	.06	.03
Total (Project count)		**5**	**13**	**29**	**27**	**39**	**44**	**36**	**193**

Average subsidy amounts and project duration

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Av. fund. (1k EUR) - All Proj.	294	512	421	249	488	519	263	405
Av. fund. (1k EUR) - Bioecon.	288	605	550	304	563	632	289	485
Av. duration (days) - All Proj.	1,647	1,797	1,684	1,759	1,990	1,939	1,755	1,816
Av. duration (days) - Bioecon.	1,619	1,693	1,538	1,722	1,780	1,724	1,568	1,663



Biotechnology firms per year, 2005 - 2015

Comparison of cooperation structures over time

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Joint Projects	**.83**	**.38**	**.62**	**.66**	**.71**	**.84**	**.85**	**.71**
Intra-regional	.80	.38	.55	.44	.50	.49	.42	.48
Inter-regional	.40	1.00	.84	.85	1.00	.87	.92	.89
Joint Bioeconomy Projects	**.80**	**.46**	**.62**	**.63**	**.82**	**.95**	**.89**	**.78**
Intra-regional	.75	.17	.56	.29	.47	.50	.34	.44
Inter-regional	.25	1.00	.83	.76	1.00	.86	.91	.87
Intra-regional PPP	.25	.17	.39	.24	.41	.48	.31	.37

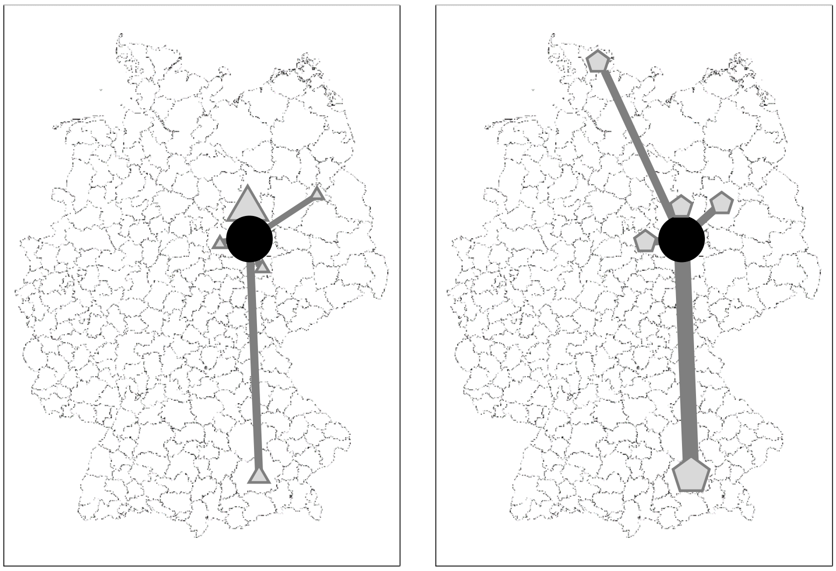
Top 5 cooperating regions – Overall (top table; left figure) and in the bioeconomy (bottom; right)

All Projects

#	Partner in	Pr.	%
1	Magdeburg	75	13.0
2	Munich	31	5.4
3	Harz	23	4.0
4	Berlin	22	3.8
5	Halle	19	3.3

Bioeconomy

#	Partner in	Pr.	%
1	Munich	27	6.9
2	Magdeburg	18	4.6
3	Harz	16	4.1
4	Kiel	16	4.1
5	Potsdam-Brandenb.	16	4.1



6.7 Discussion & Conclusion

The thematic focus of the presented study is the development of a diverse spectrum of regional systems in the context of the change from public support of specifically biotechnology towards support of the bioeconomy as a whole. The various types of path development are considered in an exploratory manner on the basis of both established and upcoming regions with significance in terms of bioeconomy. Against the background of an evolutionary perspective, the first section of this paper examined in more detail how regions can possibly develop. Path dependencies are usually very complex, and if it becomes necessary to do so, they can only be overcome with difficulty and great effort. Lock-ins, which tend to have negative connotations in economic geography, exhibit in an illustrative way how regions may become dependent on dominant actors and industries. Whether and how an entity can detach itself from negative path dependencies rest on, among other things, space-specific characteristics in the innovation system. Adaptation strategies and policies therefore need to be designed according to the regional context in order to utilise resources as efficiently as possible. In this light, the study shows that regional systems may develop significantly differently despite similar initial situations. Extant endowments, public governance and agency are exemplary fundamental ingredients that may determine the future course.

In this analysis, we utilise the German funding database 'Förderkatalog' which gives information about the scope of public involvement in regional R&D activities. At the same time, they serve as a proxy for a qualitative description of a region's engagement in the bioeconomy. The cases of biotechnology and bioeconomy demonstrate a compelling field for research due to its broad emergence in the 1990s and the change of thematic emphasis in the last decade. The place-based policy measures BioRegio and BioProfile delivered an appropriate starting point for longitudinal analyses comparing winning and losing participants. The comparison reveals measurable differences between the respective groups. BioRegio winners persistently focus on **(red) biotechnology** with a higher share of private actors operating in their regions. Moreover, a growing number of firms contribute to a less pronounced diversification into other fields such as **agriculture & forestry**. Biotechnology as an industry is still an advancing technology that has not yet reached the status of saturation and decline. Hence, a specialisation, partially driven by private business, as a key element for thematic development, is not necessarily connected to a negative regionalised lock-in. On the contrary, agile and profit-seeking companies are crucial for a vibrant RIS. When considering the literature on RIS, we find some characteristics that indicate the typical characteristics for the classification of 'thick and specialised' RIS. The early-mover regions in this example tend to specialise and at the same time, rely more strongly on internal capacities than the compared groups. The Rhineland consortium, a highlighted example from this group, retained its biotechnology interests and thus stuck to its extant course. In fact, a few BioRegio winners such as Rhineland and the Rhine-Neckar triangle possess larger chemical and pharmaceutical companies. This can be interpreted in two ways. First, rather traditional sectors such as chemicals might have experienced an upgrade due to the application of biotechnological solutions. Secondly, these traditional branches also enabled further specialisation since they could rely on related knowledge. The different types of path development would thus not necessarily occur seperately, but might reinforce each other.

BioProfile winners tend to serve as more diverse and flourishing hubs with a large share of R&D in universities and federal research institutes. Whether this is caused by the different approaches in the contests (start-up finance in BioRegio) or whether the selection was already based on the prevailing context, is not clear and thus a qualitative analysis is needed.

Regions that did not compete in the contests raised their overall share and, interestingly, did and do not focus mainly on **medical biotechnology**, but are equally engaged in **industrial biotechnology**. The Lower Saxony network took up the emerging bioeconomy scheme to a greater extent and diversified especially into **agriculture & forestry** R&D.

In a second approach for the identification of bioeconomy regions, we found regions that specialised under different circumstances in specific bioeconomy fields. The BioRegio applicant Rostock diversified from the *processing segment* into the *input pillar* with **agriculture & forestry** and **climate & environmental** protection. The engagement in the latter segment can be explained by their location. Due to their location by the Baltic Sea, coastal protection is one main issue for R&D. Rostock’s development path is largely shaped by public and quasi-public research institutes and the data suggest a positive connection with the bioeconomy. ‘Organisationally thin’ regions with sparse R&D activities in particular could profit most from this course. The Salzlandkreis provided an example of how regions can adopt and make use of these political trends. Fuelled by governmental funding, it was able to attract (‘transplant’) specialised labour that subsequently diffused knowledge to regional actors. In general, it seems possible that further capacities will be enabled by an initial stimulus, which in turn might contribute to the creation of new paths or the modernisation of existing industries. Until now, however, the number of bioeconomy regions has remained relatively moderate and, given the small number of projects, it is too early to assume the occurrence of perceptible and lasting pathways.

With these results, we contribute to three existing literature strands. First, the evolutionary perspective is indeed one of the most researched paradigms in economic geography and often delivers profound case studies focussing on certain path development mechanisms. Furthermore, many scholars highlight the role of path branching (related variety) from very different perspectives. As just mentioned, only using funding data we cannot refer to established or even emerging paths. Nonetheless, by comparing certain labour market regions, we approached this research area in a quantitative manner for country-wide analyses. By creating regional profiles, we are able to combine quantitative numbers with some qualitative insights to deliver more detailed pictures of the evolution and the actors involved in the identified bioeconomy regions. Secondly, most preceding work evaluating the place-based policy measures BioRegio and BioProfile used performance measures to assess the success during and after the treatments. The present study, however, uses different measures and includes somewhat more nuanced statistics to trace the thematic evolution of the concerned regions. Thirdly, social science literature regarding the bioeconomy is still at the very beginning due to its recent conceptualisation. When there is still discord about a standard bioeconomy definition, deeper insights, especially those linked to geographical issues, are quite rare. At this time, one is effectively groping in the dark trying to make the concept more comprehensible and tangible. Hence, every study, this examination included, sheds light on a new aspect and helps enable a better understanding. The breakdown into four pillars delivered a qualitative facet to quantitative indicators. Especially by looking at the labour market region level, clear differences are detectable and reveal how the policy is implemented in spatial terms.

While the provision of these novel insights is based on meaningful data and elaborated analyses, some things need to be kept in mind. Namely, the reality is not quantifiable solely by means of funding data. With these, we are able to detect some patterns, but, as described, the system's developments are much more complex than plain input-output calculations. Political actions and policy measures are just some elements that function together with other parameters and affect each other directly and indirectly. Therefore, we should not overestimate the findings. Nevertheless, by also including qualitative considerations such as the overarching development in the bioeconomy and other data independent of the funding database, the results seem quite robust and provide a genuine reflection of a part of the actual actions. That is certainly true for bigger regions. The latter part of the analyses is, however, dedicated to territories which tend to be less densely populated. Those examples indicate development in a certain direction, but in some cases we are speaking of rural areas in which perhaps four to eight projects have been conducted in a three year period. This calls, of course, for a qualitative research approach and thus these areas cannot be sufficiently covered in a study like this one.

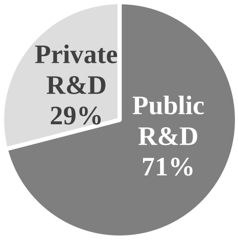
Appendix

App. 6-A: BioRegio winners

Regional profile Jena

Key figures of the funding landscape

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
All Projects	192	175	275	221	305	349	345	1862
Projects Bioeconomy	43	32	49	44	62	83	68	381
Share of BE-Projects	.22	.18	.18	.20	.20	.24	.20	.20
BE-Proj./100k inhab.	22.29	16.59	25.4	22.81	32.14	43.03	35.25	197.51



Top 5 Recipients and executing organisations

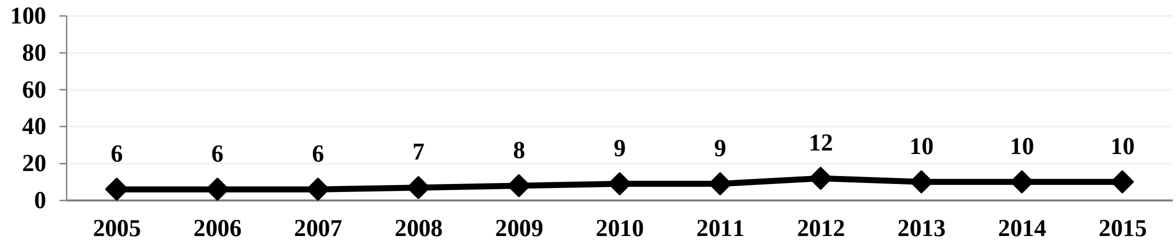
#	Recipient	Proj.	% Pr.	Executing organisation	Proj.	% Pr.
1	University of Jena	83	21.8	Leibniz Institute for Natural Product Research and Infection Biology	45	11.8
2	Leibniz Inst. Natural Product Res. and Infection Biology	49	12.9	Leibniz Institute on Aging - Fritz Lipmann Institute (FLI)	22	5.8
3	University Hospital Jena	34	8.9	Thuringian State Office for Agricult. & Rural Areas - Centre for Renewable Resources	21	5.5
4	Leibniz Institute on Aging - Fritz Lipmann Institute	30	7.9	Leibniz Institute of Photonic Technology	18	4.7
5	Thuringian State Office for Agriculture & Rural Areas	26	6.8	Microfluidic ChipShop GmbH	9	2.4

Evolution of the bioeconomy funding by fields

Bioeconomy dimension		1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Input	∑	**.02**	**.06**	**.04**	**.09**	**.16**	**.22**	**.18**	**.13**
Agriculture & Forestry		.00	.00	.00	.02	.11	.17	.12	.08
Climate & Environment		.02	.06	.04	.07	.05	.05	.06	.05
Processing	∑	**.77**	**.44**	**.84**	**.82**	**.73**	**.70**	**.68**	**.72**
Green biotechnology		.02	.06	.08	.02	.00	.02	.00	.03
Red biotechnology		.67	.25	.47	.57	.63	.43	.62	.53
White biotechnology		.07	.13	.29	.23	.10	.24	.06	.16
Output	∑	**.00**	**.06**	**.04**	**.07**	**.03**	**.05**	**.03**	**.04**
Products & Materials		.00	.06	.02	.05	.02	.02	.01	.02
Energy & Fuels		.00	.00	.00	.00	.02	.02	.01	.01
Food & Feed		.00	.00	.02	.02	.00	.00	.00	.01
Socio-economic framew.	∑	**.21**	**.44**	**.08**	**.02**	**.08**	**.04**	**.12**	**.12**
Total (Project count)		**43**	**32**	**49**	**44**	**62**	**83**	**68**	**381**

Average subsidy amounts and project duration

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Av. fund. (1k EUR) - All Proj.	678	427	462	448	616	518	469	520
Av. fund. (1k EUR) - Bioecon.	455	340	330	460	500	607	530	476
Av. duration (days) - All Proj.	1,647	1,797	1,684	1,759	1,990	1,939	1,755	1,816
Av. duration (days) - Bioecon.	1,619	1,693	1,538	1,722	1,780	1,724	1,568	1,663



Biotechnology firms per year, 2005 - 2015

Comparison of cooperation structures over time

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Joint Projects	**.64**	**.73**	**.78**	**.71**	**.69**	**.73**	**.68**	**.71**
Intra-regional	.74	.61	.81	.67	.63	.69	.70	.70
Inter-regional	.88	.88	.76	.85	.95	.93	.86	.88
Joint Bioeconomy Projects	**.70**	**.62**	**.73**	**.77**	**.77**	**.86**	**.76**	**.76**
Intra-regional	.73	.25	.75	.62	.48	.59	.71	.61
Inter-regional	.53	.75	.83	.91	.81	.93	.83	.82
Intra-regional PPP	.47	.25	.58	.44	.29	.51	.58	.46

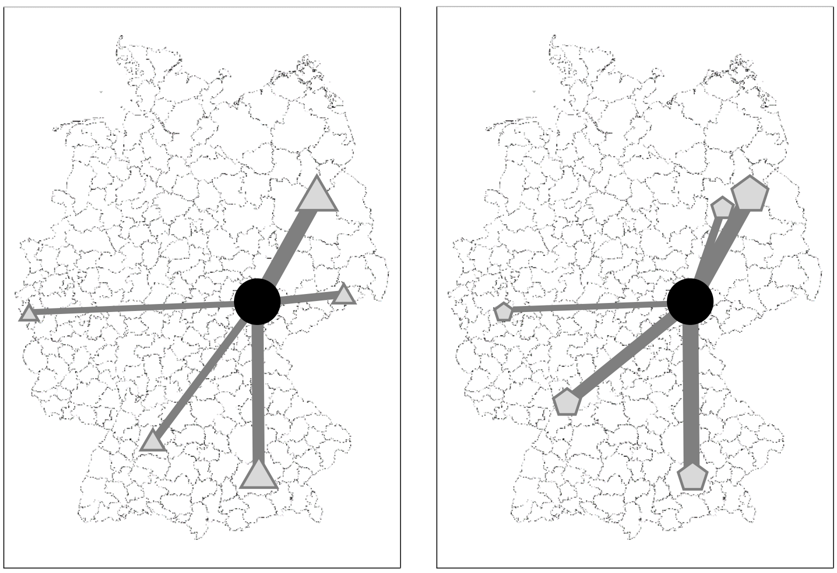
Top 5 cooperating regions – Overall (top table; left figure) and in the bioeconomy (bottom; right)

All Projects

#	Partner in	Pr.	%
1	Berlin	285	7.8
2	Munich	245	6.7
3	Stuttgart	168	4.6
4	Dresden	158	4.4
5	Aachen	112	3.1

Bioeconomy

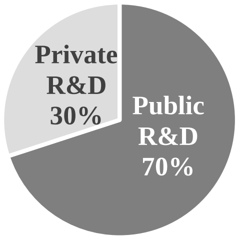
#	Partner in	Pr.	%
1	Berlin	42	7.2
2	Munich	41	7.0
3	Heidelberg	31	5.3
4	Potsdam-Brb.	24	4.1
5	Bonn	18	3.1



Regional profile Munich

Key figures of the funding landscape

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
All Projects	686	731	788	796	1,271	1,456	1,383	7,111
Projects Bioeconomy	81	115	131	160	264	229	217	1,197
Share of BE-Projects	.12	.16	.17	.20	.21	.16	.16	.17
BE-Proj./100k inhab.	3.3	4.7	5.3	6.5	10.7	9.3	8.8	48.6



Top 5 Recipients and executing organisations

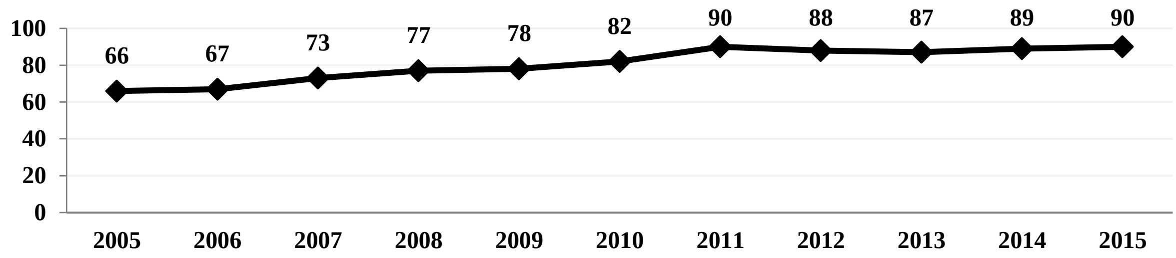
#	Recipient	Proj.	% Pr.	Executing organisation	Proj.	% Pr.
1	Technichal University of Munich (TUM)	292	24.4	Fraunhofer Institute for Process Engineering and Packaging	29	2.4
2	Ludwig Maximilian University of Munich	185	15.5	Max Planck Institut of Biochemistry	26	2.2
3	Helmholtz Zentrum Munich - German Research Center for Environmental Health	72	6.0	Bavarian State Research Center for Agriculture - Institute for Plant Production and Plant Breeding	21	1.8
4	Bavarian State Research Center for Agriculture	66	5.5	TUM - School of Life Sciences Weihenstephan - Plant Breeding	18	1.5
5	Max Planck Society	52	4.3	Helmholtz Zentrum Munich - German Research Center for Environmental Health - Institute of Bioinform. & Systems Biology	16	1.3

Evolution of the bioeconomy funding by fields

Bioeconomy dimension		1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Input	∑	**.06**	**.17**	**.04**	**.16**	**.20**	**.19**	**.30**	**.18**
Agriculture & Forestry		.01	.09	.02	.13	.16	.16	.24	.14
Climate & Environment		.05	.09	.02	.03	.04	.03	.07	.05
Processing	∑	**.84**	**.59**	**.79**	**.78**	**.70**	**.65**	**.51**	**.68**
Green biotechnology		.10	.08	.05	.11	.13	.10	.02	.09
Red biotechnology		.56	.43	.63	.55	.49	.42	.36	.48
White biotechnology		.19	.09	.11	.12	.08	.12	.12	.11
Output	∑	**.00**	**.06**	**.15**	**.04**	**.07**	**.08**	**.08**	**.07**
Products & Materials		.00	.03	.05	.00	.00	.01	.00	.01
Energy & Fuels		.00	.00	.01	.03	.05	.04	.05	.03
Food & Feed		.00	.03	.08	.01	.02	.03	.03	.03
Socio-economic framew.	∑	**.10**	**.17**	**.02**	**.02**	**.02**	**.08**	**.11**	**.07**
Total (Project count)		**81**	**115**	**131**	**160**	**264**	**229**	**217**	**1197**

Average subsidy amounts and project duration

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Av. fund. (1k EUR) - All Proj.	431	665	478	479	493	490	428	490
Av. fund. (1k EUR) - Bioecon.	632	684	705	627	624	580	490	605
Av. duration (days) - All Proj.	1,647	1,797	1,684	1,759	1,990	1,939	1,755	1,816
Av. duration (days) - Bioecon.	1,619	1,693	1,538	1,722	1,780	1,724	1,568	1,663



Biotechnology firms per year, 2005 - 2015

Comparison of cooperation structures over time

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Joint Projects	**.41**	**.51**	**.60**	**.69**	**.67**	**.70**	**.70**	**.63**
Intra-regional	.73	.69	.74	.72	.67	.69	.67	.69
Inter-regional	.91	.93	.93	.92	.90	.88	.92	.91
Joint Bioeconomy Projects	**.36**	**.45**	**.73**	**.74**	**.76**	**.76**	**.80**	**.71**
Intra-regional	.69	.48	.87	.63	.59	.53	.57	.61
Inter-regional	.59	.81	.86	.82	.86	.89	.90	.86
Intra-regional PPP	.45	.25	.72	.36	.35	.37	.34	.39

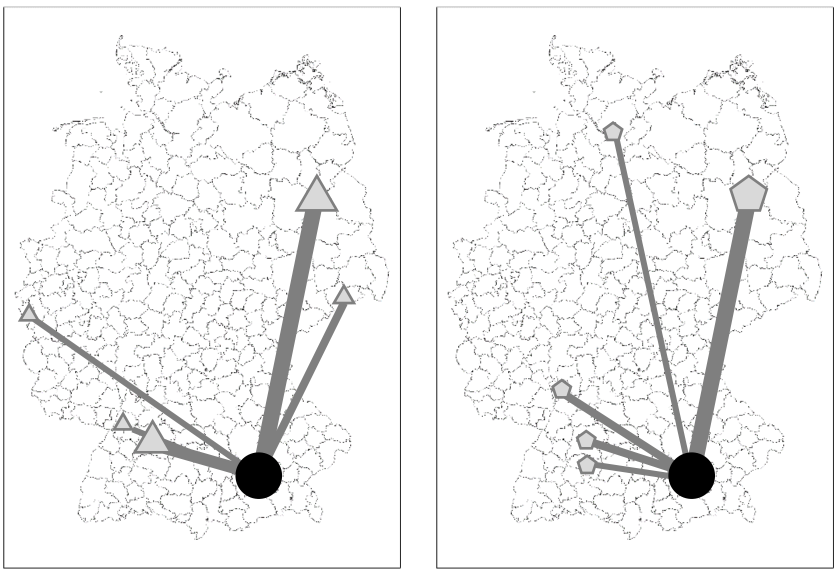
Top 5 cooperating regions – Overall (top table; left figure) and in the bioeconomy (bottom; right)

All Projects

#	Partner in	Pr.	%
1	Berlin	1,028	8.0
2	Stuttgart	923	7.2
3	Dresden	483	3.8
4	Karlsruhe	391	3.0
5	Aachen	387	3.0

Bioeconomy

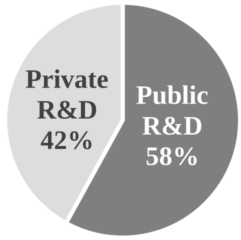
#	Partner in	Pr.	%
1	Berlin	133	7.8
2	Heidelberg	68	4.0
3	Stuttgart	65	3.8
4	Hamburg	57	3.3
5	Reutl./Tüb.	50	2.9



Regional profile Rhine-Neckar Triangle (Heidelberg, Ludwigshafen & Mannheim)

Key figures of the funding landscape

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Projects	228	287	280	317	567	654	643	2,976
Projects Bioeconomy	64	76	58	86	170	153	112	719
Share of BE-Projects	.28	.26	.21	.27	.30	.23	.17	.24
BE-Proj./100k inhab.	10.4	12.4	9.5	14.0	27.7	25.0	18.3	117.3



Top 5 Recipients and executing organisations

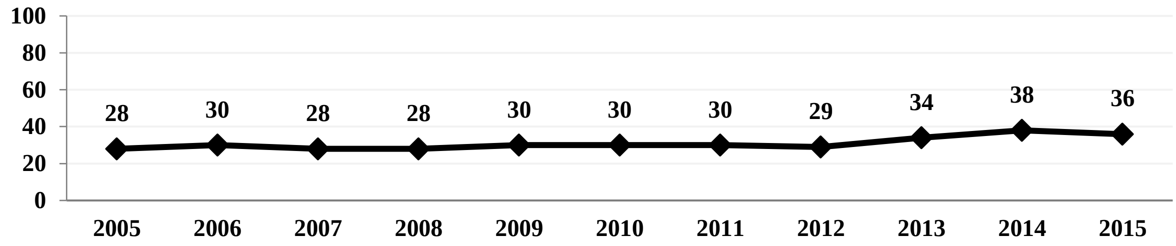
#	Recipient	# Proj.	% Pr.	Executing organisation	# Proj.	% Pr.
1	Heidelberg University	151	21.0	BASF SE	39	5.4
2	German Cancer Research Center	123	17.1	German Cancer Research Center - Division of Molecular Genome Analysis	21	2.9
3	BASF SE	39	5.4	European Molecular Biology Laboratory	18	2.5
4	European Molecular Biology Laboratory	35	4.9	Südzucker AG	16	2.2
5	Mannheim University of Applied Sciences	25	3.5	German Cancer Research Center - Division of Functional Genome Analysis	14	2.0

Evolution of the bioeconomy funding by fields

Bioeconomy dimension		1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Input	∑	**.05**	**.04**	**.07**	**.08**	**.10**	**.19**	**.16**	**.11**
Agriculture & Forestry		.00	.00	.05	.07	.10	.18	.14	.10
Climate & Environment		.05	.04	.02	.01	.00	.01	.02	.02
Processing	∑	**.70**	**.66**	**.74**	**.81**	**.82**	**.68**	**.72**	**.74**
Green biotechnology		.02	.04	.09	.03	.04	.03	.03	.04
Red biotechnology		.53	.54	.48	.66	.69	.50	.57	.58
White biotechnology		.16	.08	.17	.12	.09	.14	.13	.12
Output	∑	**.03**	**.05**	**.09**	**.09**	**.05**	**.05**	**.02**	**.05**
Products & Materials		.00	.03	.05	.02	.01	.01	.00	.01
Energy & Fuels		.00	.00	.00	.05	.03	.03	.02	.02
Food & Feed		.03	.03	.03	.02	.01	.01	.00	.02
Socio-economic framew.	∑	**.22**	**.25**	**.10**	**.01**	**.02**	**.09**	**.10**	**.09**
Total (Project count)		**64**	**76**	**58**	**86**	**170**	**153**	**112**	**719**

Average subsidy amounts and project duration

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Av. fund. (1k EUR) - All Proj.	569	715	436	771	754	512	449	611
Av. fund. (1k EUR) - Bioecon.	451	497	496	565	586	425	485	499
Av. duration (days) - All Proj.	1,570	1,953	1,682	1,948	1,891	1,795	1,718	1,812
Av. duration (days) - Bioecon.	1,691	1,760	1,678	1,776	1,844	1,590	1,493	1,670



Biotechnology firms per year, 2005 - 2015

Comparison of cooperation structures over time

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Joint Projects	**.43**	**.50**	**.55**	**.66**	**.75**	**.63**	**.62**	**.62**
Intra-regional	.60	.64	.59	.65	.60	.56	.59	.60
Inter-regional	.86	.89	.92	.95	.94	.93	.90	.92
Joint Bioeconomy Projects	**.53**	**.53**	**.53**	**.67**	**.74**	**.80**	**.82**	**.70**
Intra-regional	.59	.50	.58	.60	.67	.59	.61	.61
Inter-regional	.74	.78	.90	.86	.93	.85	.92	.88
Intra-regional PPP	.44	.22	.39	.22	.41	.43	.26	.35

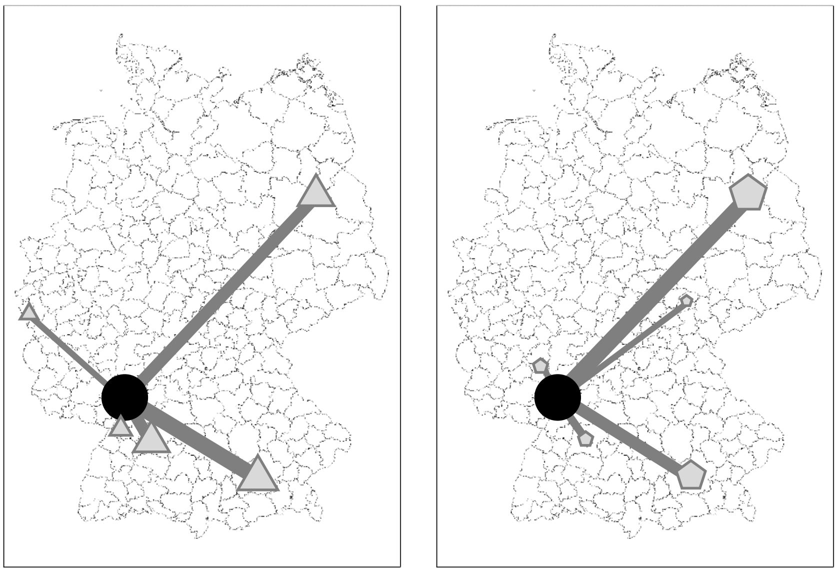
Top 5 cooperating regions – Overall (top table; left figure) and in the bioeconomy (bottom; right)

All Projects

#	Partner in	Pr.	%
1	Munich	529	7.8
2	Berlin	473	7.0
3	Stuttgart	446	6.6
4	Karlsruhe	364	5.4
5	Aachen	227	3.4

Bioeconomy

#	Partner in	Pr.	%
1	Berlin	105	10.3
2	Munich	86	8.4
3	Stuttgart	37	3.6
4	Mainz	36	3.5
5	Jena	34	3.3

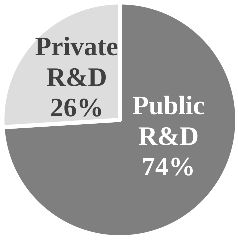


App. 6-B: BioProfile winners

Regional profile Berlin-Potsdam

Key figures of the funding landscape

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
All Projects	879	859	1,125	1,232	2,030	2,171	2,316	10,612
Projects Bioeconomy	129	129	184	254	354	331	369	1,750
Share of BE-Projects	.15	.15	.16	.21	.17	.15	.16	.16
BE-Proj./100k inhab.	6.5	6.5	9.2	12.7	17.7	16.6	18.5	87.7



Top 5 Recipients and executing organisations

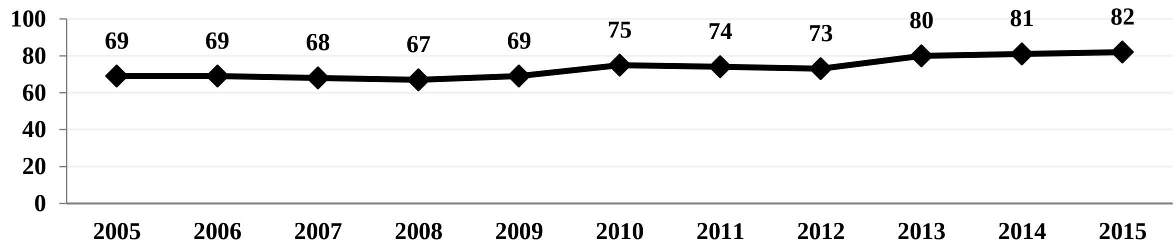
#	Recipient	Proj.	% Pr.	Executing organisation	Proj.	% Pr.
1	Max Planck Society	153	8.7	Max Planck Institute of Molecular Plant Physiology	53	3.0
2	Humboldt University of Berlin	131	7.5	Fraunhofer Institute for Applied Polymer Research	51	2.9
3	Charité - Berlin University Medicine	129	7.4	Max Planck Institute for Molecular Genetics	49	2.8
4	Technichal University of Berlin	120	6.9	Max Delbrück Center for Molecular Medicine in the Helmholtz Association	42	2.4
5	Free University of Berlin	103	5.9	Leibniz Institute for Agricultural Engineering and Bioeconomy	31	1.8

Evolution of the bioeconomy funding by fields

Bioeconomy dimension		1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Input	∑	**.09**	**.03**	**.06**	**.13**	**.19**	**.31**	**.32**	**.20**
Agriculture & Forestry		.02	.02	.02	.08	.14	.23	.22	.14
Climate & Environment		.08	.02	.04	.05	.05	.08	.09	.06
Processing	∑	**.83**	**.85**	**.83**	**.77**	**.66**	**.46**	**.54**	**.65**
Green biotechnology		.06	.11	.07	.06	.11	.08	.02	.07
Red biotechnology		.64	.60	.63	.57	.47	.29	.38	.47
White biotechnology		.12	.13	.14	.14	.08	.09	.14	.12
Output	∑	**.02**	**.07**	**.03**	**.06**	**.10**	**.11**	**.07**	**.07**
Products & Materials		.00	.05	.02	.01	.01	.00	.00	.01
Energy & Fuels		.00	.01	.00	.04	.07	.06	.02	.04
Food & Feed		.02	.02	.01	.01	.02	.05	.04	.03
Socio-economic framew.	∑	**.06**	**.05**	**.08**	**.04**	**.06**	**.11**	**.08**	**.07**
Total (Project count)		**129**	**129**	**184**	**254**	**354**	**331**	**369**	**1,750**

Average subsidy amounts and project duration

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Av. fund. (1k EUR) - All Proj.	559	860	468	420	512	445	382	483
Av. fund. (1k EUR) - Bioecon.	836	820	552	481	646	507	487	584
Av. duration (days) - All Proj.	1,647	1,797	1,684	1,759	1,990	1,939	1,755	1,816
Av. duration (days) - Bioecon.	1,619	1,693	1,538	1,722	1,780	1,724	1,568	1,663



Biotechnology firms per year, 2005 - 2015

Comparison of cooperation structures over time

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Joint Projects	**.32**	**.47**	**.55**	**.55**	**.59**	**.60**	**.66**	**.57**
Intra-regional	.76	.75	.73	.71	.71	.69	.69	.71
Inter-regional	.89	.89	.84	.90	.89	.83	.82	.85
Joint Bioeconomy Projects	**.50**	**.58**	**.77**	**.74**	**.75**	**.70**	**.78**	**.71**
Intra-regional	.73	.73	.75	.72	.60	.60	.58	.65
Inter-regional	.81	.91	.96	.87	.92	.85	.83	.88
Intra-regional PPP	.58	.59	.61	.46	.44	.43	.40	.47

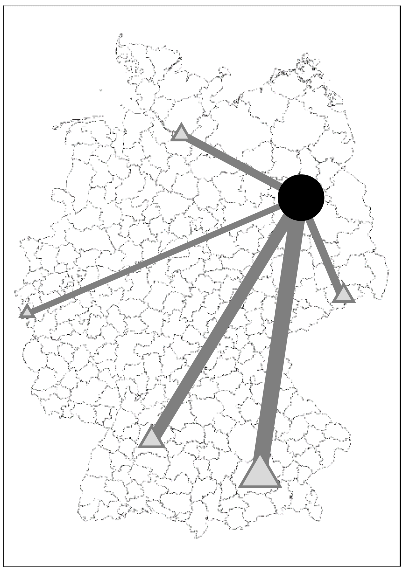
Top 5 cooperating regions – Overall (top table; left figure) and in the bioeconomy (bottom; right)

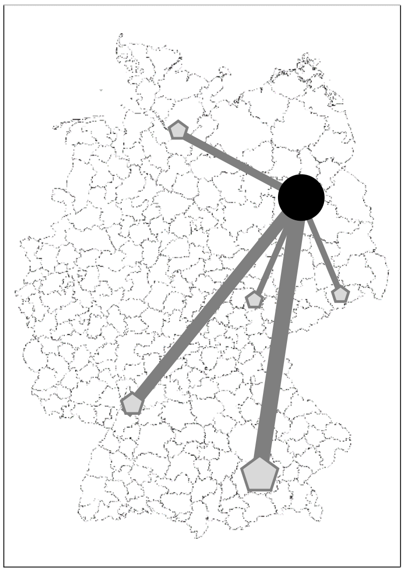
All Projects

#	Partner in	Pr.	%
1	Munich	1,162	8.9
2	Stuttgart	706	5.4
3	Hamburg	492	3.8
4	Dresden	476	3.6
5	Aachen	369	2.8

Bioeconomy

#	Partner in	Pr.	%
1	Munich	156	7.9
2	Heidelberg	88	4.5
3	Hamburg	70	3.5
4	Dresden	62	3.1
5	Jena	61	3.1

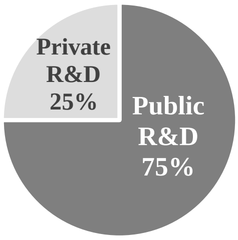




Regional profile STERN (Stuttgart, Tübingen, Esslingen, Reutlingen & Neckar-Alb)

Key figures of the funding landscape

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
All Projects	618	660	718	773	1,152	1,460	1,462	6,843
Projects Bioeconomy	61	71	95	164	199	193	183	966
Share of BE-Projects	.10	.11	.13	.21	.17	.13	.13	.14
BE-Proj./100k inhab.	6.0	6.9	9.3	16.0	19.4	18.8	17.9	94.3



Top 5 Recipients and executing organisations

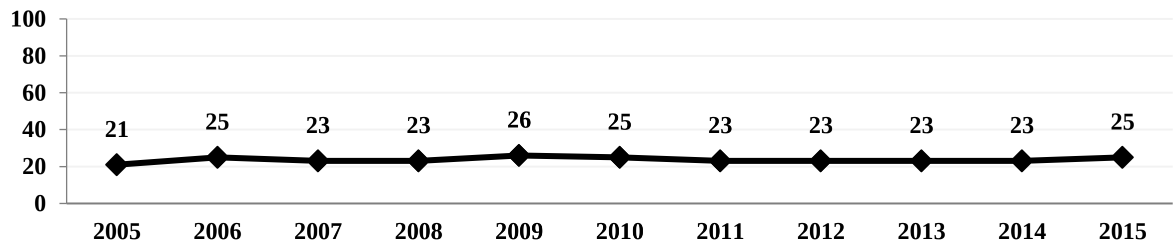
#	Recipient	Proj.	% Pr.	Executing organisation	Proj.	% Pr.
1	Eberhard Karls University of Tübingen	184	19.1	Natural and Medical Sciences Institute at the University of Tübingen	71	7.4
2	University of Hohenheim	169	17.5	Fraunhofer Institute for Interfacial Engineering and Biotechnology	49	5.1
3	University of Stuttgart	134	13.9	University of Hohenheim - State Plant Breeding Institute	23	2.4
4	Natural and Medical Sciences Inst. at the Uni. of Tübingen	73	7.6	EMC microcollections GmbH	17	1.8
5	Fraunhofer Society	71	7.4	University of Stuttgart - Institute for Technichal Biochemistry	16	1.7

Evolution of the bioeconomy funding by fields

Bioeconomy dimension		1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Input	∑	**.26**	**.20**	**.09**	**.10**	**.18**	**.23**	**.27**	**.19**
Agriculture & Forestry		.03	.01	.03	.06	.16	.19	.23	.13
Climate & Environment		.23	.18	.06	.04	.03	.05	.04	.06
Processing	∑	**.59**	**.66**	**.72**	**.80**	**.71**	**.58**	**.53**	**.65**
Green biotechnology		.07	.10	.05	.06	.09	.06	.03	.06
Red biotechnology		.36	.39	.48	.60	.49	.39	.34	.45
White biotechnology		.16	.17	.18	.13	.13	.12	.15	.14
Output	∑	**.05**	**.13**	**.15**	**.09**	**.10**	**.11**	**.08**	**.10**
Products & Materials		.03	.08	.08	.03	.01	.00	.01	.03
Energy & Fuels		.00	.01	.01	.02	.09	.08	.04	.05
Food & Feed		.02	.03	.05	.04	.00	.03	.03	.03
Socio-economic framew.	∑	.10	.01	.04	.02	.01	.08	.11	.05
Total (Project count)		**61**	**71**	**95**	**164**	**199**	**193**	**183**	**966**

Average subsidy amounts and project duration

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Av. fund. (1k EUR) - All Proj.	753	551	362	359	536	382	354	438
Av. fund. (1k EUR) - Bioecon.	512	457	410	413	521	427	358	435
Av. duration (days) - All Proj.	1,647	1,797	1,684	1,759	1,990	1,939	1,755	1,816
Av. duration (days) - Bioecon.	1,619	1,693	1,538	1,722	1,780	1,724	1,568	1,663



Biotechnology firms per year, 2005 - 2015

Comparison of cooperation structures over time

	1995-1997	1998-2000	2001-2003	2004-2006	2007-2009	2010-2012	2013-2015	1995-2015
Joint Projects	**.54**	**.67**	**.72**	**.68**	**.71**	**.69**	**.66**	**.67**
Intra-regional	.73	.77	.71	.67	.66	.69	.68	.69
Inter-regional	.95	.95	.89	.93	.91	.91	.91	.92
Joint Bioeconomy Projects	**.31**	**.55**	**.67**	**.72**	**.78**	**.80**	**.77**	**.72**
Intra-regional	.63	.46	.66	.58	.63	.56	.52	.58
Inter-regional	.79	.90	.88	.78	.88	.88	.90	.87
Intra-regional PPP	.37	.33	.55	.47	.47	.43	.33	.43

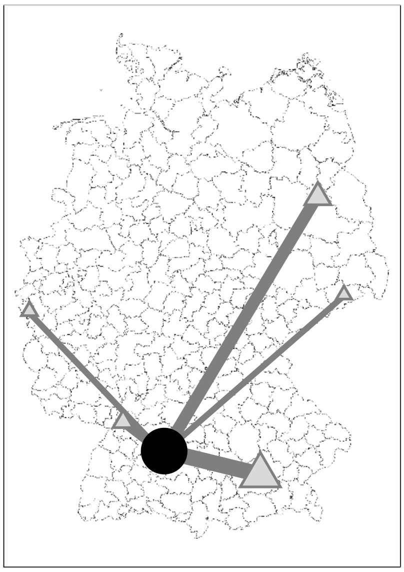
Top 5 cooperating regions – Overall (top table; left figure) and in the bioeconomy (bottom; right)

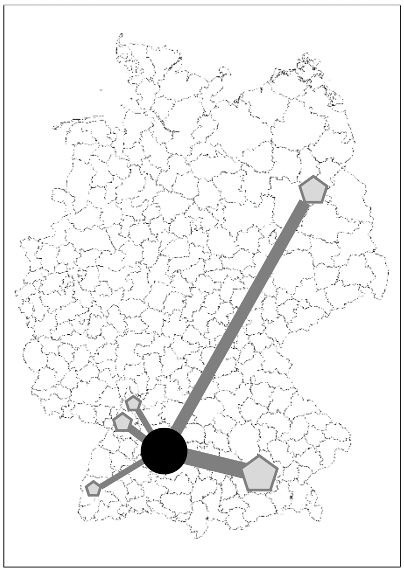
All Projects

#	Partner in	Pr.	%
1	Munich	1,232	9,6
2	Berlin	799	6,2
3	Karlsruhe	627	4,9
4	Aachen	483	3,8
5	Dresden	429	3,3

Bioeconomy

#	Partner in	Pr.	%
1	Munich	118	8,2
2	Berlin	76	5,3
3	Karlsruhe	53	3,7
4	Heidelberg	48	3,3
5	Freiburg	46	3,2





App. 6-C: Cluster transformation of labour market regions over time

1 – Regions with occasional bioeconomy projects

Aalen, Augsburg, Bautzen, Biberach, Bielefeld, Borken, Chemnitz, Cologne, Detmold, Dortmund, Duisburg, Düsseldorf, Erfurt, Erzgebirgskreis, Essen, Flensburg, Frankfurt/Main, Frankfurt/Oder, Friedrichshafen, Gelsenkirchen, Görlitz, Gütersloh, Hanau, Heilbronn, Homburg/Saar, Ingolstadt, Kaiserslautern, Kassel, Koblenz, Konstanz, Krefeld, Lübeck, Mannheim, Mecklenburgische Seenplatte, Meißen, Meschede, Nordvorpommern (Northern Hither Pomerania), Nuremberg, Oranienburg, Osnabrück, Paderborn, Pirmasens, Ravensburg, Rosenheim, Saarbrücken, Schwäbisch Hall, Schwerin, Soest, Steinfurt, Trier, Viersen, Villingen-Schwenningen, Weimar, Wetzlar, Wiesbaden, Wuppertal, Zwickau

2 – More diverse regions with some touch points to the bioeconomy

Düren, Freiburg, Gießen, Halle, Heidelberg, Kiel, Magdeburg, Mainz, Marburg, Mittelsachsen, Munich, Südvorpommern (Southern Hither Pomerania)

3 – Larger regions with bioeconomy focus

Jena

4 – Rural regions with bioeconomy focus

Celle, Eberswalde, Eichsfeld, Einbeck, Kelheim-Mainburg, Salzlandkreis, Uelzen

Labour market region	1995-2001	2002-2008	2009-2015
Amberg	1	1	2
Erlangen	1	1	2
Luckenwalde	1	1	2
Münster	1	1	2
Regensburg	1	1	2
Ulm	1	1	2
Heide	1	1	4
Prenzlau	1	1	4
Stade	1	1	4
Ahrweiler	1	2	1
Arnstadt	1	2	1
Bochum	1	2	1
Goslar	1	2	1
Hamburg	1	2	1
Stuttgart	1	2	1
Vogtlandkreis	1	2	1
Aachen	1	2	2
Berlin	1	2	2
Bonn	1	2	2
Darmstadt	1	2	2
Hanover	1	2	2
Karlsruhe	1	2	2
Leipzig	1	2	2
Harz	1	2	4
Helmstedt	1	4	1
Bad Kreuznach	1	4	4
Straubing	1	4	4

Labour market region	1995-2001	2002-2008	2009-2015
Mühlhausen	1	4	4
Bayreuth	2	1	1
Bremen	2	1	1
Oldenburg	2	1	1
Ratzeburg	2	1	1
Bremerhaven	2	1	2
Finsterwalde	2	1	4
Garmisch-Partenk.	2	1	4
Cottbus	2	2	1
Anhalt-Bitterfeld	2	2	4
Saalfeld	2	2	4
Dresden	2	3	2
Braunschweig	2	3	3
Göttingen/Osterode	2	3	3
Potsdam-Brb.	2	3	3
Rostock	2	3	3
Reutlingen/Tübingen	2	4	2
Baden-Baden	4	1	1
Balingen	4	1	1
Landau	4	1	1
Leverkusen	4	1	1
Weilheim	4	1	1
Vechta	4	1	2
Ludwigshafen	4	2	1
Nordhausen	4	2	1
Würzburg	4	2	2
Eschwege	4	3	3

7 COMPREHENSIVE CONCLUSION

7.1 Individual and comprehensive summary of research results

This work has scrutinised the policy shift in Germany with the change in leitmotif from biotechnology to bioeconomy and examined the associated implications at various levels. In all three studies, which first looked at the topic more in general and then progressed to greater levels of detail some of the results derived were expected, whereas some others were somewhat surprising discoveries.

Study [i], covered in chapter 4, portrayed the actual processes taking place during a change in the political leitmotif. Mission-oriented policies are to a certain extent negatively connotated with regard to their strict top-down character and are criticised as biased against natural competition due to the pretence of knowledge. Research in politics looking at the topic of policy-making processes, however, suggests that, in reality, a dictation of specific strategies seldom occurs (SABATIER & WEIBLE 2014). In the present case, the findings reveal two main arguments. First, in relation to the entity of public funding, there is no evidence that the bioeconomy was a strong focus of political attention after the implementation of the dedicated strategy in 2010. The bioeconomy, according to its present-day understanding and definition, has been funded continuously with some fluctuations and at no time in the observation period could a massive prioritisation be found. Secondly, however, the structures and priorities within the bioeconomy changed considerably and this allows one to draw inferences. The biotechnology nucleus has gradually lost some of its relevance, but still plays an important role. The additional dimensions of the bioeconomy shell, accordingly, now receive more attention and complement shortcomings in the former innovation policy rather than replace the entire biotechnology scheme. It is thus more likely that path-dependency also determines the policy landscape. In essence, new strategies build on previous endeavours and existing capabilities suggesting that, in this case, some criticism about mission-oriented policies can be mitigated. This instance might be an exception, but it seems logical that the subject of a mission does not spontaneously occur out of nowhere. In accordance with these results, public authorities, on the one hand, minimise risks by pursuing multiple different topical research fields and by not allocating limited resources unidirectionally. On the other hand, they do not plainly ‘choose races and place bets’, but rely on preceding efforts and extant knowledge. The initially chosen course is possibly a matter of anticipation with some elements of gambling, but with perpetual evaluations and readjustments governments are able to create the necessary degree of continuity for executive actors at the lower level.

The second study dealt with the structural shift within the bioeconomy funding revealed in study [i]. The exmaination emphasised the inclusiveness of innovation policy and the capability to distribute public R&D funds more evenly when investing in areas of the bioeconomy shell (e.g. agriculture, food, energy from biomass). In line with this, theoretical considerations about new generations of innovation policy and frames, that have been discussed in the former study, can also be confirmed in this case (KATTEL & MAZZUCATO 2018; SCHOT & STEINMUELLER 2018). By calculating GINI coefficients, mapping the spatial distribution of funded projects, conducting comparative regressions, and performing cluster analyses, constitutional differences between public investments in the biotechnology nucleus and the bioeconomy shell can be attested. Hence, bioeconomy shell projects tend to have a stronger connection to rural, less wealthy regions with a higher unemployment rate. While this is not the case for biotechnology projects at any point, the tendency to include less potent regions is evident due to the detected shift towards the bioeconomy shell. An increasing number of regions participate in research projects and are therefore beneficiaries of the documented policy shift. In other words, the adjustments in the political course have led to an alteration of funded projects in spatial terms so that the group of regions profiting from receiving public investments is a different one than before. Assuming that this particular trend will be sustained in the future, the diffusion of available (but remote) knowledge into peripheral areas and traditional sectors is more likely to happen than with former biotechnology-centric schemes. Moreover, research projects in rural areas are more often carried out by private firms than R&D in urban (bioeconomy) regions. Neither the significance of providing biotechnological methods nor the utmost importance of eventually integrating these into practical solutions for concerned industries should be underestimated. This symbiotic relationship within the bioeconomy concept reveals the need for a fruitful interplay between rural and urban regions on the one hand and between public and private actors on the other. In general, it can be confirmed that inclusive aspects in the political agenda have been acknowledged and put into practice. The bioeconomy in its entirety as a policy target, thus, has high potential both to contribute to a faster catching-up process of structurally weak regions and to shake up existing routines in traditional branches by complementing them with external knowledge sources from biotechnology or other general purpose technologies. Study [ii], therefore, proves that changes at the top can eventually be measured significantly at lower levels and illustrates the transmissibility in innovation policy.

While the first study investigated the general development of biotechnology and bioeconomy funding in Germany and study [ii] researched its spatial distribution, the last study in the dissertation covered individual regional development. Against the backdrop of path-dependent mechanisms, study [iii] therefore portrays and compares a series of regional pathways. The literature in economic geography research exposes the far-reaching ramifications of regional path-dependencies. They show that connections, orders, routines and institutions are commonly established over a longer period of time (DAVID 1985; ARTHUR 1989; MARTIN & SUNLEY 2006). This tying process leads to the situation that a dissociation from the chosen path rarely occurs and if so, only in a limited manner. It is argued that, given the uniqueness of regions, innovation policy should be tailored to the context in order to achieve the desired objective as efficiently as possible (TÖDTLING & TRIPPL 2005). Therefore, this section featured an exploratory approach to discover regional patterns within its bio-themed funding. In the first part of the empirical analyses, all regions that participated in the BioRegio and BioProfile initiatives (both winners and non-winners) were investigated. Some remarkable structural differences between BioRegio winners and the other groups have been found – e.g. a high involvement in **red biotechnology** at any given point, a greater share of private business, larger growth rates in biotechnology start-ups, but a declining trend regarding the relative quantity of funded R&D projects. That inevitably led to a less pronounced diversification into other fields of the bioeconomy as happened in most other highlighted regions. The three BioProfile winning regions, in contrast, with a high and stable share of publicly funded R&D projects, serve as providers of more diverse knowledge within the bioeconomy. The second part of the analyses identified regions with a distinct specialisation in the bioeconomy, but that had either not won or not even participated in any of the competitions. As established in study [ii], an increasing number of regions became involved with the bioeconomy and they exhibited different approaches towards engagement within the new scheme – e.g. an anchoring public institution, the geographical location or a network around one core subject. In conclusion, all regions had in common that a certain degree of a path-dependency determined the entire progress. However, due to policy involvement, agency or other aspects smaller or larger changes might occur which then become and remain decisive for future path development.

The review of the separate chapters already indicates how extensively this issue can be explored. But beyond that, a holistic reflection reveals additional insightful conclusions. The quintessence of this entire doctoral thesis is that, on the one hand, politics does not operate independently of a framing context, but is influenced by various variables and, on the other hand, its defined course can cause far-reaching effects that manifest themselves on various scales.

Concrete evidence for the aspect first mentioned can be observed in a number of different ways in respective studies. For instance, there are compelling indications that policy approaches follow the scientific theorems. As highlighted in chapter 4, innovation policy had a clear focus on sectoral growth, namely on biotechnology. It corresponded to the mainstream neoclassical economic model at this time. Subsequently, novel methods were applied based on considerations about regional innovation systems. There was an emphasis placed on collaborative learning and was put into practice in form of the BioRegio and BioProfile contests. In study [i], this focus is reflected in the high share of the pillar *socio-economic framework*, in which, amongst others, network generating projects have been funded more heavily. The comparison of the contest regions in study [iii] confirms that especially the BioRegio winning regions received those funds and have developed differently. In study [i], it is shown that the current generation of innovation policies addresses more comprehensive issues. This can be understood as a transformation in response to emerging problems and altered priorities regarding the economic system and what is expected of it. This dissertation delivered a better picture of this transition by demonstrating that it [i] was a fluid shift within specific programmes and R&D projects, [ii] has a growing inclusive element which promotes structurally weaker regions, and [iii] underlies a path-dependent process at the regional level, where existing structures play a vital role in the implementation of bioeconomic activities. In conclusion, the occurrence of a political leitmotif is not as random as it sometimes seems, but it resembles a co-evolution of a general framework and applied policies. They are rather a result of existing problems, prevalent theorems, and the extant capabilities and visions of the respective government. Politics both acts and reacts in a similar way and thereby guides the direction to a certain degree. It picks up previous trends, fine-tunes the path that has previously been followed and provides a crucial framework for actors at the bottom level. The keynotes of the leitmotif, again, trickle-down, change the foci of funding in spatial terms and enable (or disable) further development of some actors and regions. These modifications are then evaluated, consequences are drawn and the course is reinforced, adjusted or terminated against the background of the present context.

The second overarching finding is the profound implications of this co-evolutionary procedure. The interplay between the top, intermediary and bottom level demonstrate the complexity of innovation policy. In study [i], it is argued that mission-oriented policy often needs to involve taking risks and that it comprises a gambling component when the mission is chosen because it is by nature difficult to manage. Studies [ii] and [iii] are good examples to confirm the validity of this concern. The first of them demonstrated that the thematical shift is accompanied by consequences in the geographical scope. By prioritising the bioeconomy as a holistic concept, more attention is paid to areas in the periphery which often lack economic vitality. Against the backdrop of the current public and scientific discourse, this is an intentional consequence, but whether the approach meets the expectation of actually contributing to an uplifting of rural regions with weak economic performance requires continuous evaluation and targeted research. In study [iii] the findings indicate that innovation policy is able to trigger certain effects. BioRegio winner regions, for instance, were heavily funded in the late 1990s and specialised in **red biotechnology**. At the same time, the growth rate for dedicated biotechnology firms was eye-catchingly high compared to most other regions from BioProfile or elsewhere. That trend has persisted to this day and might reveal that the targeted mission to generate a vibrant biotechnology sector in Germany was able to be accomplished in these particular regions. The BioProfile winning regions, in contrast, in the sequence established themselves as providers of knowledge generated by major public and quasi-public research facilities. They were able to sustain their overall share and diversified into other bioeconomy fields than **red biotechnology**. In the same study, further regions have been identified that benefitted from the thematical shift due to favourable pre-conditions or determined agency. Others, however, lack these requirements and fail to profit or even suffer from being overlooked in terms of public R&D. Yet, study [ii] reveals that a growing number of regions has been included and suggests a lower entry barrier compared to a commitment in biotechnology.

7.2 Contribution to the academic literature and policy recommendations

The present thesis in its entirety and its individual studies contribute to scientific theories and practices in various ways. First, the boundaries and the structure of the bioeconomy are still contested within and between public authorities, industry representatives, and the scientific community. Attempts to measure the bioeconomy thus depend heavily on its definition and result in hardly comparable figures from study to study. In chapter 2, an extensive review of strategy papers and literature from different fields has been conducted in order to include the most relevant aspects within the bioeconomy. By breaking down the different definitions it was possible to divide the bio-based economy into categories along the value chain. This framework provides a modularity that allows the addition of new components or exclusion of redundant ones when required and, furthermore, enables a more systematic measurement of the bioeconomy. The data, comprehensively derived via text-mining, also allow the inclusion of the socio-economic segment of the bioeconomy in a quantitative measurement for the first time. Earlier research has concentrated on specific aspects of the bioeconomy, its gross domestic product, how many people are employed or estimates of material flows (BRINGEZU et al. 2020). The classification also enabled the calculation which parts received the most political attention and in consequence illustrates the bioeconomy's scope and depth. Information about the location led to new interesting insights about the spatial dimension of the bioeconomy and facilitated the possibility to differentiate between the individual components. Since research about the bioeconomy in a social science sense is in general quite rare, this work improves existing literature in the bioeconomy context in several ways.

Secondly, mission-oriented policy approaches have increasingly been the focus of attention over the last decades and MAZZUCATO (2014) pushed the issue considerably into the spotlight. While the effects of innovation policy have been investigated in the past, the underlying process of how a mission is chosen and implemented is rather under-researched (WEIBLE 2014). Since these issues are not commonly addressed in the studies concerned, it leads to the assumption that the government is actively steering and announcing missions without reference to in-depth sources. This top-down perspective is the source of most criticism of mission-led policies and not necessarily realistic as the presented dissertation findings suggest. Also, research in political science lacks empirical work to confirm its theories (SABATIER 1999). Most current scholars agree that thinking strictly in stages, starting from agenda setting, then implementation, then evaluation of the applied instruments, is not sensible (SABATIER & WEIBLE 2014). The case elaborated here demonstrates that, in reality, the policy-making process has an iterative character but does not follow a linear sequence, and therewith empirically confirms this understanding. This work makes a twofold contribution to the research by (a) diminishing the proactive steering argument that suggests a dictation-like distortion of the natural competition and (b) supplementing the political science literature which mainly deals with this issue on a theoretical basis.

Another ingredient of this dissertation which will enrich the bioeconomy discourse is the integration of the spatial dimension into the analysis. Few previous scholars have made a clear connection between geography and the bio-based economy. Study [ii] of the thesis illustrated the locations in which different parts of the bioeconomy are operating and empirically tests which type of regions profit from the thematical shift from biotechnology to bioeconomy. Taking into consideration the more inclusive innovation policy, the dissertation sought to answer whether the change within the bioeconomy was accompanied by a more even allocation of public resources in spatial terms. The intention of (supra)national policy strategies is to upgrade traditional industries with biotechnological knowledge and to foster rural regions (BMEL 2014; EC 2018a). The past, however, has proven that the focus of applied measures was often R&D in urban areas. In the context of the acknowledgement of holistic missions, the thesis highlighted in what way the target of a bioeconomy might be capable of contributing to this type of inclusive innovation policy. By fostering structurally weaker regions and sectors that are often located in these regions, e.g. **agriculture & forestry** and **energy & fuel** production with biological materials, the bioeconomy represents a valid starting point to pursue a policy practice that proactively counters regional disparities. Moreover, since concrete inclusive policy designs seem rare, yet increasing significance is being placed on the general consensus that development in regions off the beaten track should be fostered, these findings depict a clear-cut example for national and regional policy-makers.

Although evolutionary economic geography is currently the mainstream strand in its field, it mainly delivers empirical findings derived from singular case studies. Quantitative data, however, provide the opportunity to cover and to compare a greater number of cases in a systematic manner. MARTIN & SUNLEY (2006) conceptualised different types of path development that would help to understand the different flavours of path-dependent processes. Further classifications have been proposed (e.g. BOSCHMA 2015; ISAKSEN et al. 2018) and empirically tested, but concentrated on the most frequently occurring path branching mechanisms (e.g. FRENKEN et al. 2007; NEFFKE et al. 2011). TÖDTLING & TRIPPL (2005) already suggested, legitimately, the need to apply policy practices that, due to specific contexts, are suited to the region and the goal to be accomplished. The present thesis researched the possible models of path development and how regional systems cope with changes in innovation policy. It adds new perspectives to the existing literature by providing comparable quantitative and time-specific data for all labour market regions in Germany. Using these data it was possible to identify what path development type is most common and what drives the regional economy. At the same time, a comparison between the innovation policies of regions which won or participated in biotechnology-themed contests highlighted the impact of policy as a determining factor for path development and what consequences can be expected.

Moreover, the dissertation yields some policy recommendations as well. First, innovation policy targets and designs need to be well-founded, constantly evaluated and developed, and implemented with great care. Although policy has not been the exclusive cause for past developments, it has certainly contributed to the status quo. MAZZUCATO (2014) emphasised the leading role of providing visions and capital for humankind to reach milestones like the moon landing and for the creation of new technologies like biotechnology or the development of the smartphone. Nonetheless, the dark side of innovation policy is almost completely neglected in the discourse. It is only recently that the negative aspects of innovation itself have been the subject of more research by a few scholars (LEE 2011; BIGGI & GIULIANI 2020), but it is perfectly logical that policies that encourage the generation of innovation also prompt harmful effects. For example, the current generation of policies with holistic approaches, which no longer concentrate solely on the highest possible economic growth and financial returns, is more or less the response to previous generations. When considering what has been accomplished by means of governmental support, its impact should not be underestimated. Consequently, it is necessary to design and apply this powerful tool wisely.

Secondly, as already discussed previously, the bioeconomy as a whole represents a suitable mission or target for an inclusive policy. Politicians, who genuinely acknowledge existing shortcomings and deficiencies in the current system and share the view that these problems can only be tackled if done so comprehensively, might advocate bioeconomy activities in the future. However, what needs to be kept in mind is the design of policy measures. Both in theory and in practice, it is stressed that knowledge has already been generated on a significant scale. That same knowledge has to be diffused more systematically. Therefore, strategic partnerships between the biotechnological nucleus and the bioeconomy shell should be pushed more aggressively than has been the norm to date. Without consistently testing the results of research in practice, synergies will not be efficiently exploited and potentials for companies, (traditional) industries and entire regions will be wasted.

Lastly, bioeconomy strategies have commonly been the domain of national or supranational governments and organisations. Only few authorities at the lower level have adopted the scheme and pursued an adjusted plan of action. This challenges regional developers and local policy-makers to establish formats specifically adapted to regional endowments to ensure the optimal use of limited means. This is in line with modern 'smart' approaches that demand such bottom-up initiatives (MCCANN & ORTEGA-ARGILÉS 2013). The identification of exemplary regions that have already engaged with the bioeconomy notion provides some starting points to initiate or enhance path development. Platforms for networking, the acquisition of matching companies, funding for promising projects are just some of the tools to launch progress from the bottom tier.

7.3 Critical appraisal and outlook for future research avenues

Despite the considerable effort made to portray the change in leitmotif as comprehensively as possible, this work is still not without its limitations. For this reason, there are some drawbacks that need to be mentioned and discussed here, and starting points for future research will also be provided.

First, we accompanied the known shift from biotechnology towards bioeconomy. While on the one hand this allows detection and tracing of latent structures and processes in the policy-making process as well as to measure resulting effects, it reflects just one specific case. It is, for instance, conceivable that some policy strategies are based on nothing more than the vision of the state's responsibilities. Or, it is possible that the biotechnology-bioeconomy relationship is unique and therefore hardly comparable. However, the empirical evidence is transparently linked to established theoretical remarks or previous findings. That means, as is typical in research, no investigation is entirely transferable, but involves context-specific differences that must be taken into account when the results are considered. Nevertheless, research in this direction will certainly contribute to a better understanding of policy processes in general and help to interpret the present study in another light.

Secondly, the funding data that have been used for every original study in this dissertation have certain restraints in terms of their derivation and explanatory power. With regards to the former aspect, it must be noted that projects have been identified based on either their classification by the BMBF or their project title. Ergo, the categories of the BMBF have been a determining factor for the categorisation of the data. Random samples proved its quality, yet it remains a potential source for minor errors. More information about the projects would have also led to a more sound identification and categorisation. As a result, some suitable projects have presumably not been diagnosed as belonging to the bioeconomy. Irrelevant projects, however, have been removed from the database and do not bias the results. In general, by means of the partially manually executed classification, the reliability of the data is nevertheless assumed to be quite high. The information value of the data is thus reasonable and fitting for the research topic. It is nevertheless a somewhat one-sided view of matters. Federally funded R&D projects do not represent the entire spectrum of all the employed policy tools. In addition, market-shaping instruments were neither covered extensively in the thesis nor was funding from other instances such as the EU or the *Länder* included. Regretfully, the private sector perspective has not been dealt with either. Output determinants like patent data would have enriched the analyses and given better insights into the actual impact of policy measures. Although a meaningful dataset from the Patstat database has been derived via more advanced text-mining methods, the data lacked the necessary georeferences. In consequence, whether project funding eventually triggers diffusion and innovation in the respective region, remains unclear. The involvement of further data sources would have enabled, on the one hand, the presentation of implications of the funding policy that have not been mentioned and, consequently, an evaluation of the applied instruments. On the other hand, the scope of policy transitions could have been examined from other viewpoints.

With respect to the last mentioned limitation, it must be noted that the thesis looked at or touched upon many different areas and discussed them mainly through a political, geographical and economic lens. This has two consequences. First, in every field, more in-depth analyses would supplement the presented results. When dealing with the policy-making process, the emphasis was placed on coupling the content with the temporal dimension in order to comprehend the evolution of policy changes and their practical implementation. More in-depth investigations, e.g. how individual instances have been affected and which processes take place in the decision-making process, were not considered here and are presumably the subject of qualitative research. The second and third papers dealt with spatial consequences induced by the policy shift and, against the backdrop of increasing disparities between regions as well as the path-dependent character of regional economies, represent an important component. But this, naturally, does not cover the entirety of its implications. It can be assumed that a great variety of the holistic social system is affected by the change of courses. Effects which both become established in society and also shape it, e.g. the awareness of a bioeconomy or specific products, an altered behaviour of the population, or the willingness to pay more than for conventional products, are worthy of examination. The same goes for the impact on actors from the private sector, e.g. whether they cope with negative externalities and pursue approaches to counter them, which firms suffer or benefit due to the policy change, or what kind of policy measures they would appreciate. And the list could be continued with the addition of further fields. This clearly illustrates the far-reaching scope of the future research linked to the topic.

Lastly, although the dissertation dealt with the scope and depth of the bioeconomy, it does not cover some relevant parts of it. Some results in the chapters suggest that bioeconomy funding in absolute terms gained relevance and grew over time. Whether in reality, for example more biomass has been produced, processed or utilised, additional people have been employed in bioeconomy-themed sectors, or greater turnover has been generated, was not the topic here and has thus not been answered. In order to evaluate and monitor the development of the bioeconomy, several studies are seeking to answer and approach the objective systematically (SYMOBIO 2020; BIOMONITOR 2020). Until now, no uniform and coherent method has been established and therefore, this too requires further research. Moreover, sustainability is one core objective of the bioeconomy, but often neglected in research due to the challenge involved in its measurement. Additionally, some studies signal that capacity conflicts might occur and are sceptical about the bioeconomy's capabilities to contribute positively to environmental issues. Therefore, in order to answer this fundamental question this is a perspective that inevitably needs to be explored further, to prevent a situation where the replacement system exacerbates the problems with the existing one. And finally, in order to address all these issues, a fitting policy design is a key for a faster and better implementation of the policy driven concept. As a corollary, systematic evaluation of past approaches and also monitoring of ongoing initiatives are essential to ensure an efficient and successful implementation. Only by researching best practices and previous mistakes can designs conducive to successful achievement of sustainability be derived, thereby allowing policy-makers to steer and shape future path development in a truly sustainable fashion.

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APPENDIX

BMBF classification (LPS) and their relevance to the bioeconomy (‘Class’)

Labels automatically translated by deepl.com
In ‘Class’ is captured in which of the three classes (chapter ‘Data and method’) the respective LPS category was assessed.
The column VC shows what LPS category have been categorised into the bioeconomy concept:
A&F – Agriculture & Forestry
CEP – Climate & Envrionmental Protection
GBT – Green Biotechnology
RBT – Red Biotechnology
WBT – White Biotechnology
P&M – Products & Materials
E&F – Energy & Fuels
F&F – Food & Feed
SEF – Socio-Economic Framework
MIX & no entry – Class could not classified blanketly individual categorisation process
‘Pr.’ corresponds to the number of projects within the observation period from 1995 – 2015

Code	Funding area	Funding priority	Label	Class	VC	Pr.
AA0110	A - Health research and health economy	AA - Health research and health economy	Infection	[iii]		88
AA0120			Nervous system and psyche	[iii]		119
AA0130			Cardiovascular	[iii]		0
AA0140			Cancer	[iii]		2
AA0150			Metabolism	[iii]		8
AA0160			Other disease-related and cross-cutting measures	[iii]		14
AA0210			Medical genome and post-genome research	[ii]	RBT	227
AA0220			Basics of regenerative medicine	[iii]		79
AA0230			Systems Biology	[i]	RBT	1174
AA0231			Systems Medicine	[iii]		0
AA0232			Medical Informatics	[iii]		0
AA0240			computational neuroscience	[iii]		2
AA0250			Translational Research	[ii]	RBT	458
AA0260			Clinical evaluative research	[iii]		7
AA0270			Specific population groups	[iii]		47
AA0280			Research on framework conditions / ELSA	[ii]	SEF	80
AA0285			Alternative methods to animal testing	[ii]	RBT	152
AA0289			Methodology development	[ii]	RBT	2
AA0310			Prevention	[iii]		0
AA0320			Nutrition	[ii]	RBT	130
AA0330			Epidemiology	[iii]		1
AA0410			Care-related research	[iii]		0
AA0420			Health Economics	[iii]		0
AA0430			Specific measures	[iii]		0
AA0510			Medical Technology	[ii]	RBT	95
AA0520			Pharmaceuticals/active substance research	[ii]	RBT	115
AA0530			Structural measures	[iii]		3
AA0610			widespread diseases	[iii]		65
AA0620			Individualized medicine	[ii]	RBT	177
AA0630			Prevention and nutrition research	[iii]		0
AA0650			Health Management	[iii]		13
AA0710			Programme planning, international cooperation (including KX)	[ii]	SEF	8
AA0720			Other in the Health Research Framework Programme (including DO, VER, KX)	[iii]		1
AA110			NA	[iii]		0
AA140			NA	[iii]		0
AA5090			Project staff costs	[iii]		0
AA5099			Other in the context of health and medicine	[iii]		0
AA610			NA	[iii]		0
B00101	B - Bioeconomy	B - Bioeconomy	Plant research	[i]	GBT	359
B00102			World Food Supply	[i]	F&F	56
B00109			International cooperation	[i]	MIX	145

B00201	Biological safety research	[i]	MIX	172
B00202	Innovative plant breeding in the cultivation system	[i]	MIX	29
B00203	Competence networks in agricultural and food research	[i]	MIX	64
B00204	Sustainable land use	[i]	MIX	63
B00209	International cooperation	[i]	MIX	29
B00301	German Plant Phenotyping Network DPPN	[i]	GBT	3
B00302	Animal breeding and husbandry	[i]	GBT	69
B00309	International cooperation	[i]	MIX	40
B00401	Sustainable organic production	[i]	MIX	166
B00402	Bioindustry 2021	[i]	WBT	143
B00403	Purification technologies	[i]	MIX	47
B00404	Biotechnology 2020+	[i]	WBT	99
B00405	Innovation initiative on industrial biotechnology	[i]	WBT	60
B00406	Genome research on microorganisms	[i]	MIX	137
B00407	Biorefineries	[i]	MIX	26
B00409	International cooperation	[i]	MIX	125
B00501	BioEnergy2021	[i]	E&F	40
B00509	International cooperation	[i]	MIX	3
B00601	BioChancePLUS	[i]	MIX	260
B00602	KMU-innovativ: Biotechnology-BioChance	[i]	MIX	410
B00603	GO-Bio	[i]	MIX	105
B00604	BioProfiles	[i]	MIX	176
B00605	BioFuture	[i]	MIX	57
B00606	New products for the bioeconomy	[i]	MIX	71
B00609	International cooperation	[i]	MIX	198
B00701	Junior research groups within the framework of the concept \Bioeconomy as social change\""	[i]	SEF	0
B00702	Thematic projects and consortia	[i]	SEF	0
B00703	Monitoring within the framework of the concept "Bioeconomy as social change\".	[i]	SEF	0
B00992	Advisory bodies (SK)	[i]	SEF	1
B00993	Events	[i]	SEF	1
B01001	Environmental biotechnology	[i]	MIX	11
B01002	BioChance	[i]	MIX	47
B01004	BioRegio	[i]	MIX	131
B01005	Neurobiological research	[i]	RBT	59
B01006	Medical Genome Research: Systematic Methodological Platforms (SMP)	[i]	RBT	192
B01007	Medical genome research: Disease-oriented genome networks (KG)	[i]	RBT	1
B01008	Medical Genome Research: Exploratory Projects (EP)	[i]	RBT	36
B01013	Biomass production (completed in 1992)	[i]	A&F	0
B01014	Process for the conversion of biomass (completed in 1992)	[i]	GBT	0
B01015	Use of biomass -without renewable energy- (completed in 1992)	[i]	MIX	0
B01016	Gene Centres	[i]	MIX	0
B01017	Other priority projects in biotechnology	[i]	WBT	0
B01020	Projects on ethical, legal and social issues (bioethics); public discourse (see now 3004 / 685 31)	[i]	SEF	11
B01021	Research Fellowships	[i]	SEF	6
B01022	strain collections, databases for protein and gene sequences	[i]	MIX	1
B01023	Studies, accompanying investigations, preparation and evaluation of support measures (biotechnology)	[i]	SEF	7
B01024	Cooperation projects (biotechnology)	[i]	MIX	4
B01031	Other within the scope of biotechnology	[i]	SEF	6
B01034	Other in the framework of human genome research	[i]	SEF	18
B01035	Nanobiotechnology	[i]	MIX	1
B01037	RNA Technologies	[i]	RBT	4
B01038	tissue engineering	[i]	MIX	30
B01045	Alternative methods to animal testing	[i]	SEF	0
B01046	Lead project nutrition	[i]	GBT	33
B01047	Prevention	[i]	F&F	3
B09901	Promotion of the biotechnology industry - indirect specific promotion (Phase I)	[i]	MIX	0
B09902	Promotion of the biotechnology industry - indirect specific funding (Phase II)	[i]	MIX	31
C01010	Scenario-oriented security research	[iii]		0
C01020	Technology alliances	[iii]		0

C01030	C - Civil security research	C - Civil security research	Humanities and social science dimensions of security research	[iii]		0
C01050			International cooperation	[iii]		0
DA0100	D - Food, agriculture and consumer protection	DA - Food	Healthy nutrition, improvement of eating habits and nutritional information	[ii]	SEF	13
DA0101			Studies on nutritionally active substances and the nutritional effects of foods and food ingredients	[ii]	SEF	2
DA0102			Studies on the health effects of nutrition, individual foods and food components, including allergies and intolerances	[iii]		0
DA0103			Further development of monitoring methods and their implementation in nutritional issues	[iii]		1
DA0104			Research on the information and communication behaviour of consumers and development of strategies for effective nutrition communication	[ii]	SEF	0
DA0105			determinants of dietary behaviour, including studies on diseases related to malnutrition and physical inactivity and on the effectiveness of preventive measures to improve relationships and behaviour	[iii]		0
DA0106			Studies on nutritional and health claims in the marketing of food and on warnings	[iii]		0
DB0200		DB - Sustainable agriculture and rural areas	Sustainable agriculture, horticulture, forestry, fisheries and food industry; development of the potential of renewable raw materials	[i]	MIX	948
DB0201			Evaluation and conservation of genetic resources in agriculture, horticulture, viticulture, forestry, fisheries and the food industry, and testing of plant and animal genetic resources for their agronomic and breeding suitability	[i]	MIX	43
DB0202			Studies on the recording, conservation and sustainable use of biological diversity in agro-ecosystems, forests, inland waters and seas	[i]	CEP	21
DB0203			Breeding research, including the development and evaluation of breeding methods to improve the sustainability of agricultural production, in particular to improve the quality of plant products, the resistance to biotic and abiotic stress, and the quality of agricultural products	[i]	MIX	145
DB0204			Evaluation of genetically determined characteristics of plant varieties and further development of methods for genotypic differentiation of plant varieties and development of phenotypic criteria which can influence the progress of breeding in agricultural and horticultural crops.	[i]	GBT	15
DB0205			Breeding of high quality and climatically adapted vine and fruit varieties with high resistance to biotic and abiotic causes of damage	[i]	GBT	12
DB0206			further development of environmentally sound, socially equitable and economically viable production, storage, handling and processing methods for agricultural, horticultural, forestry and fishery products	[i]	A&F	154
DB0207			Risk and safety research on genetically modified organisms (GMOs) and their release, including the development of concepts and strategies for monitoring GMOs and research to ensure the coexistence of agricultural production systems	[i]	SEF	3
DB0208			Studies and assessments of the impact of invasive alien species	[ii]	CEP	0
DB0209			Risk-based phytosanitary research and assessment of harmful organisms on plants and plant products and development of scenarios as a basis for future management decisions and further development of concepts for monitoring methods and procedures.	[i]	A&F	33
DB0210			Studies and evaluations of the effects of the use of substances relevant to agriculture (e.g. plant protection products, veterinary medicines, fertilisers) on the environment	[i]	CEP	40
DB0212			Studies for the further development of orderly, sustainable and near-natural forest management, including forest reproductive material	[i]	A&F	6
DB0213			Studies on the dynamics and management of wildlife populations, including hunting	[i]	MIX	3
DB0214			Studies on the biology, diagnosis and prognosis of harmful organisms and abiotic damage to plants and plant products as well as to food, feed, renewable raw materials and wood	[i]		102
DB0215			studies on the prevention and control of animal diseases and the economic consequences of animal diseases	[i]		33
DB0216			Investigations to reduce the risks that can arise from the use of plant protection products and plant protection processes for humans, animals and the natural environment	[i]		84
DB0217			Identification, evaluation and impact assessment of the impact of different production systems in the agriculture, horticulture, forestry, timber, fisheries and food sectors in terms of sustainability, including life cycle assessment studies; and	[i]	MIX	5
DB0218			Development or further development of strategies for the improvement of production methods, also with regard to changed climatic conditions or the conservation of soil resources for good agricultural practice in conventional agriculture, in organic farming	[i]	A&F	190
DB0219			Studies for the protection of inland water ecosystems and for the sustainable use of aquatic resources of inland waters	[i]	CEP	3
DB0220			Studies and monitoring for the protection of marine ecosystems and the sustainable management of living marine resources	[i]	CEP	5
DB0221			Recording and assessment of the exposure of marine organisms to pollutants and their biological effects; radioactivity monitoring in biota	[i]	CEP	1
DB0223			Investigation of the interaction between production, processing, trade and consumers on the national, EU-wide and international markets, also with a view to improving the market position and the information available to German producers	[ii]	SEF	2
DB0224			National and international, macro- and micro-economic competition analyses of the agricultural, horticultural, forestry, timber, fisheries	[ii]	MIX	0

		and food industries, including renewable raw materials and products of organic farming			
DB0225		Studies on the effectiveness, targeting and accompanying effects of policy measures such as direct payments (including cross-compliance), compensatory allowances, agri-environmental measures, environmental legislation and market regulation measures, as well as product and agricultural policy	[iii]		1
DB0226		Investigations on the occurrence of wood and agricultural biomass, on the mobilisation of utilisation and production reserves and on increasing the use of wood and agricultural raw materials including new production processes and products	[i]	A&F	689
DB0227		Analysis and evaluation of the effects of increasing material and energetic use of renewable raw materials as well as of corresponding promotional measures on the food and feed market and the competition of material and energetic uses	[i]	MIX	0
DB0228		Studies on business management issues in agriculture, horticulture, forestry, fisheries and food industry	[ii]	MIX	6
DB0229		Studies on occupational health and safety and on professional qualifications in the agricultural sector	[iii]		0
DB0230		Studies on the situation and securing world food supplies	[i]	F&F	2
DB0300		Perspectives for rural areas	[iii]		0
DB0301		Economic, social and environmental policy impact assessment, including analysis of the overall system of rural development policy, such as agri-environmental programmes	[iii]		0
DB0303		Studies on demographic development and changes in living and working conditions in rural areas, on design and control options for securing services of general interest and infrastructure, and on socio-economic development	[iii]		0
DB0304		Studies on growth and employment and on the development of job and value creation potentials in rural areas	[iii]		0
DB0400		Climate protection and adaptation to climate change	[i]	CEP	15
DB0401		Analysis of the effects of climate change on agriculture, forestry, horticulture, fisheries, the food industry, cultural landscapes, rural areas and aquatic ecosystems, including inventory of undesirable immissions (Depositio	[i]	MIX	18
DB0402		studies for the characterisation, prevention and control of organisms harmful to plants and abiotic pests, natural contaminants, animal diseases and zoonoses, new or increased as a result of climate change and, where appropriate, their	[i]	MIX	48
DB0403		Analysis and development of methods, cultivation systems, products and services for the adaptation of agriculture to changing climate conditions, including their economic and ecological evaluation	[i]	A&F	10
DB0404		Inventory of undesirable climate-relevant and air-polluting emissions from the agricultural and food industry, including studies on the comprehensive recording of gaseous emissions from soil and vegetation and their evaluation	[i]	CEP	1
DB0405		Development or further development of methods to reduce undesirable climate-relevant emissions from agriculture	[i]	CEP	8
DB0407		Development or further development of the protection and expansion of biogenic carbon reservoirs	[i]	E&F	4
DB0408		Further development of renewable raw materials for a sustainable and stronger substitution of fossil energy sources and fossil/mineral raw materials as well as evaluation of technological, economic, ecological and social aspects	[i]	E&F	5
DB1000		Ecological aspects of sustainability	[i]	MIX	19
DC0500	DC - Health and economic consumer protection	Health protection of consumers by improving food and product safety; combating zoonoses	[ii]	MIX	27
DC0501		Investigation and development of monitoring systems and analytical methods for the identification, characterisation and quantitative assessment of risks from undesirable and desirable substances in feed and food, ornamental plants and cut flowers (	[ii]	MIX	5
DC0502		Investigations on hygiene and on general and process-specific hygiene parameters of food and feed including the development of methods for the detection of microbial hazards for risk-based assessment of food	[ii]	F&F	11
DC0503		studies on contaminants and residues in food and feed including risk assessment, assessment of population exposure and development of mitigation strategies	[ii]	F&F	2
DC0504		Development of concepts and strategies to detect, assess, control and minimise microbiological, chemical and particle size risks in feed and food (including R	[ii]	F&F	18
DC0505		Assessment of the resistance situation of microorganisms and development of avoidance strategies including minimisation of the use of veterinary drugs in livestock farming and use of new substances to promote performance	[ii]	A&F	18
DC0506		Improvement of production methods, product and process quality in livestock farming and feeding and in plant production from the point of view of food and feed safety and of other products	[ii]	MIX	43
DC0508		Development of models for risk analysis for animal diseases and zoonotic agents and risk assessment and communication for animal diseases and zoonoses	[ii]	MIX	0
DC0509		Development or enhancement of methods for diagnosis, prevention and control of animal diseases, zoonoses and other infectious diseases, including new or emerging infectious diseases in animals, including vector-borne infectious diseases	[ii]	A&F	14
DC0510		Development of modern diagnostics and vaccines for animal diseases and zoonoses as well as development of drugs for diseases in economically less important animal species such as fish, bees etc.	[ii]	A&F	1

DC0511			Studies on the physiology and pathophysiology of the immune system of animals	[ii]	A&F	1
DC0512			Development of strategies for good practice in feeding, feed production, animal husbandry and animal breeding to ensure or improve animal health	[ii]	A&F	14
DC0513			Examination of the effectiveness of monitoring and sanctioning regulations under pharmaceutical law in animal husbandry and research into the possible effects of various distribution channels for veterinary medicinal products on drug safety and consumer protection	[ii]	MIX	1
DC0514			Develop or upgrade databases to monitor the health status of animals and plants and the movement of animals and goods of animal and plant origin	[ii]	F&F	3
DC0516			Identification and evaluation of health risks arising from material properties of cosmetic products, tattooing agents, tobacco products, allergenic plants, plant products and consumer goods, as well as development of S	[ii]	MIX	0
DC0600			Ensuring and improving product and process quality in food, feed and other products	[ii]	F&F	22
DC0601			Development of chemical, physical, microbiological and sensory methods and processes for characterising product properties and assessing the quality of food, feed and other agricultural products	[ii]	F&F	40
DC0602			Studies on the influence of applied and possibly novel technological and biotechnological processes, market structural and legal framework conditions on the production chain and the quality of food and feed	[ii]	MIX	13
DC0603			Studies on the life cycle assessment of food and other agricultural products	[ii]	F&F	0
DC0604			studies on private and public trademarks, quality or quality labels and the protection of geographical indications and designations of origin for agricultural products, foodstuffs and other products and services	[ii]	F&F	0
DC0605			Breeding research to improve the quality of agricultural and horticultural products	[ii]	MIX	2
DC0606			Studies to improve animal welfare in connection with animal breeding, animal husbandry, live stock, animal transport and slaughter	[ii]	SEF	59
DC0608			Development or evaluation of scientific and organisational procedures for traceability and control of the origin of food and other products including those from organic production (e.g. by means of isotope analysis)	[iii]		0
DC0610			Development of concepts and strategies for the improvement of production methods, for the increase of product and process quality in animal and plant production	[ii]	A&F	56
DC0700			Economic consumer protection; improving consumer information	[iii]		0
DC0701			studies on the determinants of consumer behaviour, including the information and communication behaviour of consumers	[iii]		0
DC0702			Studies on the influence of advertising and similar practices	[iii]		0
DC0703			Studies and concepts on the possibilities of improving market transparency for consumers of goods and services, including the improvement of product and process transparency within the value chain	[iii]		7
DC0704			Development of concepts to protect consumers against deception and misleading	[iii]		0
DC0705			Analysis of the institutional, organisational, legal and technical framework for consumer information and possibilities for its further development	[iii]		2
DC0706			Studies and concepts for the further development of institutional, financial, organisational, legal and technical frameworks for the protection of consumers' economic interests or for the protection or representation of such interests	[iii]		1
DC9910			Other projects	[iii]		0
DC9990			Project staff costs	[iii]		0
EA1110	E - Energy research and energy technologies	EA - Rational energy conversion	prospecting of coal	[iii]		0
EA1120			Exploration of coal	[iii]		0
EA1131			Mining of coal - tunnelling and mining technology	[iii]		0
EA1132			coal mining - mine planning and logistics	[iii]		0
EA1140			Coal preparation	[iii]		0
EA1150			Underground conversion and coal research	[ii]	WBT	1
EA1180			Other activities in connection with the exploration, extraction and processing of coal	[iii]		0
EA1211			Oil and gas - Prospection	[ii]	WBT	0
EA1212			Oil and gas - exploration	[iii]		0
EA1213			Oil and gas - extraction, transport and storage	[iii]		0
EA1219			Oil and gas - Other	[iii]		0
EA1221			Bitumen and heavy oil - Methods of extraction	[iii]		0
EA1222			Bitumen and heavy fuel oil - treatment processes	[iii]		0
EA1229			Bitumen and heavy oil - Other	[ii]	WBT	0
EA1231			Tertiary oil production - Chemical development	[iii]		0
EA1232			Tertiary oil production - field trials	[iii]		0
EA1239			Tertiary oil production - Other	[iii]		0

EA1240	Deep drilling technology for fossil fuels	[iii]		0
EA1250	Oil shale	[iii]		0
EA1260	Microbiological processes in energy technology - petroleum	[i]	WBT	0
EA1311	Conventional power plant technology - Process development	[iii]		0
EA1312	Conventional power plant technology - component development	[iii]		0
EA1313	Conventional power plant technology - Environmental protection technology	[iii]		0
EA1314	Conventional power plant technology - system studies	[iii]		0
EA1321	Advanced power plant systems - Fluidized bed technology unpressurized	[iii]		0
EA1322	Advanced power plant systems - fluidized bed technology under pressure	[iii]		0
EA1323	Advanced power plant systems - power plants with pressurized coal gasification	[iii]		0
EA1324	Advanced power plant systems - Other systems	[iii]		0
EA1325	Advanced power plant systems - Component development	[iii]		0
EA1326	Advanced power plant systems - power plants with zero emissions	[iii]		0
EA1330	Combustion technology for industry and small-scale consumption	[iii]		0
EA1340	Other within the scope of firing and power plant engineering	[iii]		2
EA1410	Coal liquefaction - Construction of pilot plants	[iii]		0
EA1420	Coal liquefaction - operation of pilot plants	[iii]		0
EA1430	Coal liquefaction - component development and basics	[iii]		0
EA1440	Coal liquefaction - demonstration plants	[iii]		0
EA1480	Coal liquefaction - Other	[iii]		0
EA1510	Coal gasification - construction of pilot plants	[iii]		0
EA1520	Coal gasification - operation of pilot plants	[iii]		0
EA1530	Coal gasification - component development and basics	[iii]		0
EA1540	Coal gasification - environment and safety	[ii]	WBT	0
EA1580	Coal gasification - other	[iii]		0
EA1910	Coke production	[iii]		0
EA1920	Other coal conversion technologies	[iii]		0
EA1940	Combustion and power plant technology for fossil fuels -except coal-	[iii]		0
EA1990	Project staff costs	[iii]		0
EA1999	Other activities Fossil fuels	[iii]		0
EA2111	Parameter studies, methodological studies on supply concepts	[iii]		0
EA2112	Regional supply concepts	[iii]		0
EA2113	Local supply concepts	[iii]		0
EA2114	Studies on district heating supply	[iii]		0
EA2120	Studies and basic research on combined heat and power (CHP)	[iii]		0
EA2121	Cooling of thermal power plants and waste heat recovery	[iii]		0
EA2122	District and local heat generation - decoupling from large power plants	[iii]		0
EA2123	district and local heat generation - industrial waste heat for district heating purposes	[iii]		0
EA2126	District and local heat generation - Combined heat and power plants (CHP)	[iii]		0
EA2128	District and local heat generation - cooling from district heating	[iii]		0
EA2141	Large heat storage tank	[iii]		0
EA2142	Aquiferos Storage	[iii]		0
EA2143	High temperature storage	[iii]		0
EA2144	Low temperature storage tank	[iii]		0
EA2148	Mechanical and other memories	[iii]		0
EA2151	Heat transport and distribution - new installation methods	[iii]		0
EA2152	Heat transport and distribution - Self-biasing	[iii]		0
EA2153	Heat transport and distribution - Friction reducer	[iii]		0
EA2155	Heat transport and distribution - VSI-Rohrtechnik	[iii]		0
EA2156	Heat transport and distribution - Operation optimisation	[iii]		0
EA2157	heat transport and distribution - mobile district heating	[iii]		0
EA2158	Heat transport and distribution - District heating renovation-East	[iii]		0
EA2211	Hydrogen production - electrolysis - PEM	[iii]		0
EA2212	Hydrogen production - electrolysis - alkaline	[iii]		0
EA2213	Hydrogen production - High temperature electrolysis	[iii]		0
EA2214	Hydrogen production - Reformer	[iii]		0
EA2215	Hydrogen production - photochemistry and photoelectrochemistry	[ii]	E&F	0
EA2219	Hydrogen production - Other technologies and not allocated	[iii]		0
EA2220	Electrolysis, transport, storage	[iii]		0

EA2221	Hydrogen storage - pressure	[iii]		0
EA2222	Hydrogen storage - solid state	[iii]		0
EA2223	Hydrogen storage - cryocomp	[iii]		0
EA2229	Hydrogen storage - Other technologies and not allocated	[iii]		0
EA2231	Hydrogen conversion - Methanation	[ii]	E&F	3
EA2232	Hydrogen conversion - production of higher hydrocarbons	[iii]		0
EA2239	Hydrogen conversion - Other technologies and not allocated	[ii]	E&F	0
EA2251	Fuel cell - PEMFC	[iii]		0
EA2252	Fuel cell - HT-PEMFC	[iii]		0
EA2253	Fuel cell - MCFC	[iii]		1
EA2254	Fuel cell - SOFC	[iii]		0
EA2255	Fuel cell - DMFC	[iii]		0
EA2259	Fuel cells - Other technologies and not allocated	[iii]		0
EA2273	Electricity storage	[iii]		0
EA2279	Electricity Miscellaneous	[iii]		0
EA2295	Hydrogen transport - All technologies	[iii]		0
EA2299	Material storage and fuel cells - Miscellaneous and unallocated	[iii]		0
EA2311	Electrochemical storage - sodium-sulphur batteries	[iii]		0
EA2312	Electrochemical storage - Lithium-based batteries	[iii]		0
EA2313	Electrochemical storage - redox flow batteries	[iii]		0
EA2314	Electrochemical storage - Zinc-air batteries	[iii]		0
EA2315	Electrochemical storage - Sodium nickel chloride batteries	[iii]		0
EA2319	Electrochemical storage - Other technologies and not allocated	[iii]		0
EA2321	Electrical storage tanks - Capacitors	[iii]		0
EA2322	Electric storage tanks - SMES	[iii]		0
EA2329	Electrical storage - Other technologies and unallocated	[iii]		0
EA2331	Mechanical accumulators - Compressed air	[iii]		0
EA2332	Mechanical storage - rotational energy	[iii]		0
EA2339	Mechanical storage - Other technologies and unallocated	[iii]		0
EA2399	Power storage - Miscellaneous	[iii]		0
EA2411	Transmission System Components	[iii]		0
EA2412	Transmission system - network planning	[iii]		0
EA2413	Transmission system - operational management	[iii]		0
EA2419	Transmission system - Other technologies and not allocated	[iii]		0
EA2421	Distribution network - components	[iii]		0
EA2422	Distribution network - Network planning	[iii]		0
EA2423	Distribution network - operational management	[iii]		0
EA2429	Distribution network - Other technologies and not allocated	[iii]		0
EA2499	Transport of electricity - Miscellaneous	[iii]		0
EA2511	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2512	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2519	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		1
EA2521	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2523	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2529	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2531	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2532	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2533	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2534	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2541	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2542	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2543	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2551	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2552	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2553	NIP - Special markets - Storage technology vehicles	[iii]		0

EA2554	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2556	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2561	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2562	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2563	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2565	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2566	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2567	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA2581	National Innovation Programme Hydrogen and Fuel Cell Technology (NIP)	[iii]		0
EA3010	Competitive tenders for electricity efficiency STEP up! individual projects	[iii]		0
EA3201	Energy-saving industrial processes - Heat exchangers	[iii]		0
EA3202	Energy saving industrial processes - heat pumps, refrigerants	[iii]		0
EA3203	Energy-saving industrial processes - Heat transformers / ORC systems	[iii]		0
EA3204	Energy-saving industrial processes - Industrial furnaces	[iii]		0
EA3205	Energy saving industrial processes - Power engines with external combustion	[iii]		0
EA3206	Energy saving industrial processes - Shredding of solids	[iii]		0
EA3207	Energy-saving industrial processes - Drying processes	[iii]		0
EA3208	Energy-saving industrial processes - mechanical and thermal separation processes	[iii]		1
EA3209	Energy-saving industrial processes - electrolytic separation processes	[iii]		0
EA3215	Energy-saving industrial processes - Chemical industry, Production of plastic and rubber goods	[iii]		0
EA3220	Energy-saving industrial processes - Quarrying and processing of stone and earth, fine ceramics, glass	[iii]		0
EA3230	Energy-saving industrial processes - Iron and steel industry	[iii]		0
EA3240	Energy-saving industrial processes - Non-ferrous metal industry	[iii]		0
EA3250	Energy-saving industrial processes - mechanical engineering, vehicle construction, electrical engineering, precision mechanics, optics, EBM goods	[iii]		0
EA3260	Energy-saving industrial processes - Wood, paper and printing	[ii]	MIX	3
EA3270	Energy saving industrial processes - Leather, textile and clothing	[iii]		0
EA3280	Energy-saving industrial processes - Food and beverage industry	[ii]	MIX	0
EA3285	Energy-saving industrial processes - General and others	[ii]	MIX	11
EA3299	Other horizontal tasks in the context of the rational use of energy	[iii]		0
EA3310	Cross-cutting tasks - system analysis	[iii]		2
EA3320	Cross-cutting tasks - Information processing	[iii]		0
EA3330	Cross-cutting issues - IEA	[iii]		0
EA3391	Cross-cutting tasks - project supervisors and external individual experts	[iii]		0
EA3399	Cross-cutting tasks - Miscellaneous	[iii]		0
EA3410	Energy-efficient and climate-friendly production processes Individual projects	[iii]		0
EA3490	Energy-efficient and climate-friendly production processes Project staff costs	[iii]		0
EA4111	Passive solar energy use - studies and basic research	[iii]		0
EA4112	Passive solar energy use - development of components	[iii]		0
EA4113	Passive use of solar energy - windows, double glazing	[iii]		0
EA4114	Passive use of solar energy - translucent thermal insulation	[iii]		0
EA4115	Passive use of solar energy - Use of daylight	[iii]		0
EA4116	Passive use of solar energy - Room air flows	[iii]		0
EA4117	Passive use of solar energy - buildings as structural and energy engineering units, residential buildings	[iii]		0
EA4118	Passive use of solar energy - buildings as structural and energy engineering units, commercially used buildings	[iii]		0
EA4121	Active use of solar energy - solar collectors, absorbers, heat pipes, inspection and test procedures	[iii]		0
EA4122	Active use of solar energy - selective coating	[iii]		0
EA4123	Active use of solar energy - solar water heating for sports facilities and swimming pools	[iii]		0
EA4124	Active use of solar energy - solar water heating for households	[iii]		0
EA4125	Active use of solar energy - solar hot water preparation for small-scale consumption	[iii]		0
EA4131	Heat pumps - electric	[iii]		0
EA4132	Heat pumps - internal combustion engine driven	[iii]		0

EA4133		Heat pumps - Absorption	[iii]		0
EA4151		Rational use of energy in households and small-scale consumption - conventional thermal insulation, inspection and test procedures	[iii]		0
EA4152		Rational use of energy in households and small-scale consumption - controlled ventilation, heat recovery	[iii]		0
EA4153		Rational use of energy in households and small-scale consumption - Energy-saving household appliances	[iii]		0
EA4154		Rational use of energy in households and small-scale consumption - Improving conventional heating systems	[iii]		0
EA4155		Rational use of energy in households and small-scale consumption - Advisory, information and forecasting systems	[iii]		0
EA4159		Rational use of energy in households and small-scale consumption - comprehensive measures, status seminars	[iii]		0
EA4181		Preparatory project funding for the funding measure SOLARTHERMIE-2000	[iii]		0
EA4182		Accompanying project funding for the SOLARTHERMIE-2000 funding measure	[iii]		0
EA4200		NA	[iii]		0
EA4300		Solar-optimized building	[iii]		5
EA4400		Energy-optimised improvement of the building fabric	[iii]		0
EA5010		Lead project \Energy generation and storage for decentralized and mobile use\" - Coordination phase	[iii]		0
EA5020		Lead project \Energy generation and storage for decentralized and mobile use\" - Implementation phase	[iii]		0
EA6010		Basic energy research	[ii]	E&F	186
EB1011	EB - Renewable Energies	Crystalline silicon base material	[iii]		0
EB1012		Crystalline silicon cell development	[iii]		0
EB1013		Crystalline silicon module technology	[iii]		0
EB1014		Crystalline silicon Overall development	[iii]		0
EB1021		Thin-film technologies Silicon; photovoltaics - amorphous silicon	[iii]		0
EB1022		Thin Film Technologies Chalcopyrite	[iii]		0
EB1023		Thin film technologies CdTe	[iii]		0
EB1024		Thin film technologies OPV	[ii]	P&M	3
EB1028		Thin-film technologies Other materials/technologies	[iii]		0
EB1029		Thin-film technologies General questions	[iii]		0
EB1031		Concentrating Photovoltaics (CPV) Cell development	[iii]		0
EB1032		Concentrating photovoltaics (CPV) Module technology	[iii]		0
EB1033		Concentrating Photovoltaic (CPV) system	[iii]		0
EB1041		Quality assurance, reliability, long-term stability Components	[iii]		0
EB1042		Photovoltaics - other structures - other; quality assurance, reliability, long-term stability Systems	[iii]		0
EB1051		System technology network coupling	[iii]		0
EB1052		Systems engineering island systems	[iii]		0
EB1053		Systems engineering Application and demonstration	[iii]		0
EB1054		Photovoltaics - application and demonstration - stand-alone operation	[iii]		0
EB1059		Systems engineering Other	[iii]		0
EB1060		Accompanying project funding for the Bund-Länder-1000-Dächer-1000-Photovoltaik-Programm	[iii]		0
EB1070		Photovoltaics - devices and small systems	[iii]		0
EB1080		Research infrastructure	[iii]		0
EB1099		Photovoltaics - cross-cutting and other investigations	[iii]		0
EB1210		Wind turbine development, R&D	[iii]		0
EB1211		wind turbines - rotors, rotor blades	[iii]		0
EB1212		Wind turbines - Drive train	[iii]		0
EB1213		Wind turbines - power transmission, gears, bearings	[iii]		0
EB1214		Wind turbines - generator, electrical components	[iii]		0
EB1215		Wind turbines - other components	[iii]		0
EB1220		Wind energy - Onshore	[iii]		0
EB1230		Wind energy - Offshore	[iii]		1
EB1231		Wind energy offshore - foundations, foundations	[iii]		0
EB1240		Wind energy - wind physics, meteorology	[iii]		0
EB1250		Logistics, plant installation, maintenance and operational management	[iii]		1
EB1260		Environmental aspects of wind energy, accompanying ecological research	[iii]		0
EB1261		Sound minimization, sound insulation	[iii]		0
EB1280		Other in the context of wind energy	[iii]		0
EB1300		Support measure 100/250 MW wind	[iii]		0
EB1411		Thermal use in agriculture - Development of air collectors	[iii]		0

EB1412	Thermal use in agriculture - solar drying	[i]	A&F	2
EB1413	Thermal use in agriculture - Greenhouses	[i]	A&F	0
EB1419	Thermal use in agriculture - Other	[iii]		0
EB1420	Thermal utilization in the high temperature range for the supply of process heat	[iii]		0
EB1425	Solar seawater desalination and brackish water treatment	[iii]		0
EB1430	Solar powered water pump	[iii]		0
EB1435	Solar cooling	[iii]		0
EB1445	Component development for solar thermal power generation	[iii]		0
EB1451	Solar thermal power plants from 100 kW - SSPS	[iii]		0
EB1455	Small solar thermal power plants	[iii]		0
EB1458	Solar thermal power plants - paraboloids	[iii]		0
EB1480	Cooperation projects (renewable energies)	[iii]		0
EB1481	Cooperation projects (renewable energies) - Eldorado Sun 2	[iii]		0
EB1482	Cooperation projects (renewable energies) - Eldorado Wind	[iii]		0
EB1484	Cooperation projects (renewable energies) - NCRD/Israel	[iii]		0
EB1485	Cooperation projects (renewable energies) - solar village REI/Indonesia	[iii]		0
EB1486	Cooperation projects (renewable energies) - Lykovrissi/Greece	[iii]		0
EB1489	Cooperation projects (renewable energies) - Other	[iii]		0
EB1511	Molecular biological investigations to increase photosynthetic substance production in plants	[i]	E&F	0
EB1512	Biological hydrogen production	[i]	E&F	0
EB1520	Energy use of plants (completed in 1992)	[i]	E&F	0
EB1611	Prospection and exploration of geothermal energy	[iii]		1
EB1612	Hot water and steam deposits	[iii]		0
EB1613	Hot Dry Rock (hot deep rock)	[iii]		0
EB1619	Other in the context of geothermal energy	[iii]		1
EB1710	Promotion within the framework of the EU Renewable Energies Directive	[iii]		0
EB1721	Biomass and waste - direct combustion (completed)	[i]	E&F	0
EB1722	Biomass and waste - thermal conversion (completed)	[i]	E&F	0
EB1723	Biomass and waste - Biogas (completed)	[i]	E&F	0
EB1729	Biomass and waste - other (completed)	[i]	E&F	3
EB1730	Hydropower	[iii]		0
EB1790	Project staff costs	[iii]		0
EB1795	Studies (renewable energy sources)	[ii]	E&F	2
EB1796	Conferences, status seminars (renewable energy sources)	[ii]	SEF	0
EB1797	Measurement programs, test stands (renewable energy sources)	[iii]		0
EB1799	Other in the context of renewable energy sources	[ii]	E&F	29
EB1810	Energy Storage	[iii]		0
EB1820	Networks	[iii]		1
EB1821	smart grids, load management	[iii]		1
EB1822	System services	[iii]		0
EB1830	Combined cycle power plants, virtual power plants	[iii]		0
EB1840	Forecasts, predictions	[iii]		0
EB1841	Feed-in forecasts	[iii]		0
EB1850	Mobility	[iii]		0
EB1860	Integration of renewable energies and renewable energy supply systems, other	[iii]		0
EB1920	Energetic use of biomass	[i]	E&F	262
EB1930	NA	[iii]		0
EB1953	NA	[iii]		0
EB2011	Collector concepts, collector development	[iii]		0
EB2012	Optimization of production processes	[iii]		0
EB2013	Materials Technologies	[iii]		0
EB2014	Building integration and combined use	[iii]		0
EB2021	Optimized water storage tanks	[iii]		0
EB2023	New high energy density storage devices	[ii]	E&F	5
EB2024	Seasonal heat storage in heating networks	[iii]		0
EB2030	System technology solar heating and WW- preparation for large plants	[iii]		0
EB2031	Solar heating, solar active building	[iii]		0
EB2032	Planning tools, control and hydraulic concepts, heat transport	[iii]		0
EB2033	Monitoring, functional control and yield assessment	[iii]		0
EB2041	Components for solar thermal driven refrigeration processes	[iii]		0

EB2042		System technology solar cooling	[iii]	0
EB2043		Monitoring of pilot and demonstration plants	[iii]	0
EB2050		Solar process heat	[iii]	0
EB2051		Process Integration	[iii]	0
EB2052		Systems engineering and standardization	[iii]	0
EB2053		Monitoring of pilot and demonstration plants	[iii]	0
EB2060		accompanying research, measuring programs	[iii]	0
EB2070		Pilot and demonstration plants	[iii]	0
EB2111		Tower power plants Receiver	[iii]	0
EB2112		Tower power plants Heliostats / field design / control	[iii]	0
EB2113		Tower power plants Overall system	[iii]	0
EB2121		Parabolic trough technology Collector / field / control	[iii]	0
EB2122		Parabolic Trough Technology Receiver	[iii]	0
EB2123		Parabolic trough technology Overall system	[iii]	0
EB2131		Fresnel technology collector / field / control	[iii]	0
EB2132		Fresnel Technology Receiver	[iii]	0
EB2133		Fresnel technology Overall system	[iii]	0
EB2140		Setup, logistics, operation, O&M measures	[iii]	0
EB2150		Quality assurance, certification, standardization	[iii]	0
EB2160		Studies and concepts for solar thermal power generation	[iii]	0
EB2170		Memory	[iii]	0
EB2180		Other technologies	[iii]	0
EB6010		Basic energy research	[iii]	14
EC1100	EC - Nuclear safety and disposal	Breeder reactors (SBR) - Compact sodium-cooled nuclear reactor plant (KNK II)	[iii]	0
EC1210		Breeder reactors (SBR) - SNR 300 - Construction (including plutonium)	[iii]	0
EC1220		Breeder reactors (SBR) - SNR 300 - Project supervisor	[iii]	0
EC1230		Breeder reactors (SBR) - SNR 300 - Research and development related to construction, commissioning and operation	[iii]	0
EC1310		Breeder reactors (SBR) - further development - safety-related work	[iii]	0
EC1330		Breeder reactors (SBR) - further development - R&D within the framework of European cooperation	[iii]	0
EC1400		Breeder reactors (SBR) - Fuel cycle	[iii]	0
EC2100		THTR 300 (including project support)	[iii]	0
EC2211		HTR combined heat and power generation - studies, expert opinions	[iii]	0
EC2212		HTR cogeneration - technology, safety	[iii]	0
EC2220		HTR fuel cycle	[iii]	0
EC2231		HTR process heat - studies, expertises	[iii]	0
EC2232		HTR Process Heat - Nuclear Heat Generation System (NWS)	[iii]	0
EC2233		HTR process heat - components, methods	[iii]	0
EC2234		HTR process heat - planning	[iii]	0
EC2299		Other in the context of the further development of HTR	[iii]	0
EC3010		Niederaichbach nuclear power plant (completed)	[iii]	0
EC3020		Hot steam reactors (closed)	[iii]	0
EC3030		Light water reactors (closed)	[iii]	0
EC3040		Research reactors (especially MPR 30 - Indonesia)	[iii]	0
EC3050		Studies and expert reports in the context of other reactor development	[iii]	0
EC4110		uranium exploration and mining	[iii]	0
EC4130		Uranium hexafluoride conversion process	[iii]	0
EC4140		Fuel element development	[iii]	0
EC4150		Enrichment reduction for research and material test reactors	[iii]	0
EC4190		Project staff costs	[iii]	0
EC4191		Project supervisors and external individual experts (PB,RE)	[iii]	0
EC4210		Gasultra centrifuge process	[iii]	0
EC4211		2000 annual URENCO programme	[iii]	0
EC4220		Laser processes in the context of uranium enrichment	[iii]	0
EC4230		Other new uranium enrichment processes	[iii]	0
EC5110		Radioecology	[iii]	0
EC5120		reprocessing (including Eurochemic)	[iii]	0
EC5130		Return of fuels from reprocessing	[iii]	0
EC5140		Transport of radioactive materials	[iii]	0
EC5150		Fissile material monitoring	[iii]	0
EC5200		Treatment and conditioning of radioactive waste; fission product and actinide conversion	[iii]	0

EC6000			Basic research energy/nuclear safety research	[iii]		8
EC6111			Final disposal - basic work Salt	[iii]		0
EC6112			Disposal - Basic work for geological formations other than salt, e.g. sea beds	[iii]		0
EC6113			Disposal - Basic research Safety analysis and assessment	[iii]		0
EC6120			Final disposal - other disposal techniques	[iii]		0
EC6130			Final disposal - Konrad project	[iii]		0
EC6140			Final disposal - Gorleben project	[iii]		0
EC6150			Interim and final storage of spent fuel elements from research reactors	[iii]		0
EC6200			Research projects for the decommissioning of nuclear facilities	[iii]		0
EC6300			Financial contribution to the expiring EU supplementary HFR-Petten programme	[iii]		0
EC6910			Analyses and concepts for disposal	[iii]		0
EC6999			Other in the context of disposal	[iii]		0
EC8110			Loss of coolant, emergency cooling, containment, accident management measures	[iii]		0
EC8120			Container failure (reactor safety)	[iii]		0
EC8130			External events (reactor safety)	[iii]		0
EC8140			Component safety (reactor safety)	[iii]		0
EC8210			Reactor safety - Breeder reactors (SBR)	[iii]		0
EC8220			Reactor Safety - High Temperature Reactors (HTR)	[iii]		0
EC8230			Reactor safety - inherently safe reactor systems	[iii]		0
EC8310			Core melts, fission product transport and radiation exposure, hydrogen generation and behaviour	[iii]		0
EC8320			Quality assurance (reactor safety), non-destructive testing methods	[iii]		0
EC8330			Interaction of man and machine (reactor safety)	[iii]		0
EC8340			Risk and reliability (reactor safety)	[iii]		0
EC8350			Reactor safety studies at HDR	[iii]		0
EC8360			Analytical activities, international cooperation, other reactor safety research activities	[iii]		0
EC8380			International Atomic Energy Agency (IAEA)	[iii]		0
EC8490			Project staff costs	[iii]		0
ED1000		ED - Disposal of nuclear installations	Removal of nuclear installations	[iii]		4
ED2000			Backfilling and securing nuclear repositories	[iii]		0
ED5000			Nuclear energy risk sharing	[iii]		1
EF6000		EF - Fusion energy research	Basic research energy/fusion research	[iii]		0
FA0410	F - Climate, environment, sustainability	FA - Climate, climate protection; global change	Climate protection, climate protection law	[iii]		0
FA0480			Adaptation to the effects of climate change	[iii]		0
FA0490			----	[iii]		0
FA1010			Climate Forecast	[iii]		0
FA1011			Climate Processes	[iii]		5
FA1012			Climate monitoring	[iii]		0
FA1020			Climate protection in business and society	[iii]		0
FA1021			Mitigation	[ii]	CEP	46
FA1022			Climate Adaptation	[iii]		21
FA1030			Integrated assessment and knowledge transfer	[iii]		0
FA1031			Competence Centres Climate Change and Adapted Land Management in Africa	[iii]		1
FA1032			Air conditioning services	[iii]		0
FA1033			Economics, governance and finance	[iii]		1
FA1060			Instruments and methods	[iii]		0
FA1080			Atmospheric processes	[iii]		0
FA1081			airborne trace substances / - pollutants	[iii]		5
FA1082			Effects of air pollutants on ecosystems and material goods	[iii]		0
FA1083			Biological effects of increased UV radiation	[ii]	MIX	0
FA1085			Ozone research	[iii]		0
FA1099			Other activities in the field of climate and atmospheric research	[iii]		0
FA1901			KSI - Starter package for energy saving models in KSJSS	[iii]		0
FA1902			KSI - Climate Protection Investments in KSJSS	[iii]		0
FA1904			KSI - National Competition Climate Protection in Cycling	[iii]		0
FA1906			KSI - Climate Protection Investments in Data Centre Infrastructures	[iii]		0
FA1911			KSI - Creation of climate protection concepts	[iii]		0
FA1912			KSI - Consulting support for climate protection concepts	[iii]		0
FA1913			KSI - Climate protection technologies in electricity use	[iii]		0
FA1914			KSI - Model projects for climate protection	[iii]		0

FA1915		KSI Master Plan 100%	[iii]		1
FA1916		KSI- measure within the framework of the advisory monitoring	[iii]		1
FA1917		KSI - Invest Mobility	[iii]		0
FA1918		KSI - Investment landfills	[iii]		0
FA1919		KSI - Consulting for beginner communities	[iii]		0
FA1930		KSI - Supporting programme	[iii]		0
FA1940		KSI - Evaluation of the national part of the Climate Protection Initiative of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	[iii]		0
FA1950		KSI - Promotion of climate protection projects in the fields of business, consumers and education within the framework of the National Climate Protection Initiative of the Federal Ministry for the Environment	[iii]		0
FA1951		KSI - Individual projects - Grants	[iii]		1
FA1952		KSI - Further Development	[iii]		0
FA1953		KSI - Individual projects - Contracts	[iii]		0
FA3010		Biodiversity dynamics and ecological processes	[i]	CEP	17
FA3012		Forecasts	[ii]	CEP	0
FA3020		Biodiversity in economy and society	[i]	CEP	13
FA3021		Ecosystem services	[ii]	CEP	6
FA3022		Economy and Governance	[ii]	CEP	4
FA3023		Nature conservation research	[i]	CEP	19
FA3030		Integrated assessment and knowledge transfer	[i]	CEP	127
FA3031		Ecological concepts in regions	[i]	CEP	28
FA3060		Instruments and methods	[ii]	CEP	3
FA3061		Data management	[ii]	CEP	6
FA3099		Other activities in the field of biodiversity and ecosystems	[i]	CEP	7
FA5010		Sustainable land use	[i]	CEP	12
FA5011		Land use and climate change	[i]	CEP	31
FA5012		Land use and ecosystems	[i]	CEP	40
FA5013		Land use in river basins	[i]	CEP	83
FA5014		Land use and desertification	[iii]		0
FA5021		Megacities and metropolitan areas	[iii]		0
FA5060		Instruments, methods, platforms and networks	[iii]		0
FA5099		Other activities in the field of globalised habitats	[iii]		1
FA9010		Participation in national and international research programmes and advisory bodies	[iii]		0
FA9090		Project staff costs	[iii]		0
FA9093		Technical accompanying measure(s)	[iii]		0
FA9094		Administrative accompanying measure(s)	[iii]		0
FA9099		Other in the area of global change	[iii]		0
FB1010	FB - Coastal, marine and polar research, earth sciences	Global systems research	[ii]	CEP	81
FB1020		impact research (e.g. ocean/atmosphere interaction)	[iii]		1
FB2010		Regional systems research (Baltic Sea, North Sea, deep sea, polar regions, etc.)	[ii]	CEP	97
FB2020		Impact research (e.g. pollutant flows and effects)	[ii]	CEP	30
FB3010		Identification and investigation of marine natural products	[i]	P&M	75
FB3020		Other marine resources	[ii]	A&F	1
FB4010		Technology/infrastructure development and provision (monitoring systems, research accompanying monitoring, innovative technology and equipment carriers)	[iii]		4
FB5010		Integrated coastal zone management	[iii]		0
FB5020		Ecosystem research	[i]	CEP	20
FB6010		Construction of a medium-sized ship	[iii]		0
FB6020		Instrument pool for marine research	[iii]		0
FB6030		Large, medium-sized research vessels; ship pool	[iii]		0
FB7010		Marine aquaculture	[i]	A&F	10
FB8010		Recording and forecasting natural conditions in coastal areas	[iii]		0
FB8020		Interactions sea / coastal structure	[iii]		0
FB8099		Coastal engineering, Other	[iii]		0
FB8592		Advisory bodies (SK)	[iii]		0
FB8599		Other in the framework of marine and polar research	[iii]		0
FB8620		Surface and underground exploration	[iii]		0
FB8630		technical and economic feasibility studies	[iii]		0
FB8710		Geo-processes of the continental and oceanic lithosphere	[iii]		0
FB8720		Scientific drilling in marine, terrestrial and polar areas (IODP; ICDP; NAD)	[iii]		0

FB8810		Processes of the Earth's interior; mapping and exploration of resource and risk capital	[iii]		0
FB8820		Acquisition of the System Earth from space	[iii]		0
FB8840		Gas hydrates: energy source and climate factor	[iii]		3
FB8850		Natural disasters: Early warning systems in earth management	[iii]		0
FB8860		Geo-Information Systems in Earth Management	[iii]		0
FB8870		Continental margins	[iii]		0
FB8880		Use and protection of the underground space	[iii]		3
FB8885		Mineral Surfaces	[ii]	WBT	17
FB8894		Tomography of the usable underground	[iii]		0
FB8999		Other in the context of geosciences	[iii]		0
FB9010		Continental deep drilling program (KTB)	[iii]		0
FB9020		Scientific investigations within the scope of deep drilling	[iii]		0
FB9030		Processing KTB	[iii]		0
FB9510		Mining Technology	[iii]		0
FB9520		Processing of mineral raw materials	[iii]		0
FB9530		Depositology	[iii]		0
FB9540		Exploration methods	[iii]		0
FB9611		Ore processing	[iii]		0
FB9612		Ore processing by bacterial leaching	[i]	WBT	0
FB9620		Metal production	[iii]		0
FB9630		Recovery of valuable metals	[iii]		0
FC0160	FC - Environmental and sustainability research	Social science environmental issues, social and (youth) cultural change; environment, tourism and sport	[iii]		0
FC1011		Space management	[iii]		4
FC1013		Ecological concepts for cities	[iii]		1
FC1014		Cross-cutting themes on soil research, urban and industrial soils	[ii]	CEP	25
FC1020		Rural areas	[iii]		55
FC1021		Ecological concepts for agricultural soils	[i]	CEP	18
FC1022		Agroecosystem research at representative locations	[i]	CEP	16
FC1023		Other ecological research for agricultural landscapes	[i]	CEP	10
FC1034		Ecological concepts for industrial landscapes, e.g. post-mining landscapes	[i]	CEP	32
FC1040		Recording and evaluation of contaminated sites	[ii]	CEP	18
FC1099		Other on ecological research for urban-industrial landscapes	[iii]		0
FC2010		Rivers and lakes	[ii]	CEP	4
FC2011		Ecological concepts for river and lake landscapes	[ii]	CEP	16
FC2013		Water protection technologies	[ii]	CEP	50
FC2020		Sustainable use of water resources	[iii]		16
FC2021		Planning instruments for sustainable water management	[iii]		0
FC2022		Development of sustainable water technologies	[ii]	WBT	36
FC2023		Flood management	[iii]		0
FC2024		Integrated water resources management	[iii]		4
FC2025		Decentralised water supply and sanitation	[ii]	WBT	15
FC2026		Valuable substances from water treatment	[iii]		0
FC2027		Unconventional water extraction	[iii]		0
FC3010		Water supply	[ii]	WBT	66
FC3020		Water reuse	[iii]		4
FC3030		Municipal wastewater	[ii]	WBT	20
FC3040		Industrial waste water	[ii]	WBT	40
FC3050		Sewage sludge	[ii]	WBT	9
FC3060		Analytics - sensors, measuring methods and models	[ii]	WBT	78
FC3070		Basics, forecasts, planning of waste management	[iii]		0
FC3080		waste management	[ii]	WBT	52
FC3085		Underground storage	[iii]		1
FC3099		Overarching and other water/waste treatment projects	[iii]		2
FC4010		Social-ecological research	[iii]		43
FC4020		Reporting systems on sustainability	[iii]		0
FC4040		Other on social-ecological sustainability research	[iii]		0
FC5010		Dissemination strategies	[iii]		0
FC5011		International measures	[iii]		8
FC5012		Further development for sustainability strategies	[iii]		0
FC5013		Legal framework	[iii]		0
FC5014		Security research and technology	[iii]		0

FC5015			Other sustainability issues	[iii]		0
FC9010			Noise reduction	[iii]		0
FC9020			Air pollution control method	[ii]	WBT	2
FC9030			Measuring method for air pollutants	[ii]	WBT	0
FC9050			Detection and control of oil/chemical pollution at sea	[iii]		0
FC9099			Other in the context of regional environmental aspects	[iii]		0
FD0800		FD - Ecology, nature conservation, sustainable use	Fundamental issues of nature conservation policy	[iii]		1
FD0820			National and international species protection	[i]	CEP	0
FD0830			National and international protection of ecosystems and habitats (Natura 2000, forests, wilderness, seas, etc.)	[i]	CEP	1
FD0850			Nature conservation and society	[i]	CEP	1
FD0860			Nature conservation accompanying research on energy system transformation	[iii]		0
FD0870			---	[iii]		0
FD1010			Field of need nutrition	[ii]	F&F	19
FD1040			Field of need Recreation/living	[iii]		0
FD2011			Research for future-oriented forestry	[i]	A&F	179
FD2012			Forest Ecosystem Research Solling, Research Centre Göttingen	[ii]	CEP	4
FD2013			Forest damage research, clarification of the causes	[i]	CEP	0
FD2040			Material efficiency in raw material-intensive production processes	[ii]	WBT	57
FD3010			Key technological innovations	[ii]	WBT	37
FD3020			Key non-technological innovations	[iii]		0
FD4010			Internal and external business processes	[iii]		0
FD4020			Product strategies	[iii]		0
FD5010			BIOKON Bionics Competence Network	[iii]		0
FD5020			Bionic developments	[iii]		10
FD6010			Technologies for sustainability and climate protection	[ii]	MIX	10
FD7010			Framework conditions for innovations for sustainable management	[iii]		1
FD7020			Economic principles of sustainability	[iii]		0
FD8010			Integrated environmental protection in the timber and furniture industry	[i]	P&M	56
FD8020			Integrated environmental protection in the area of agriculture and food	[i]	F&F	118
FD8030			Integrated environmental protection in the field of chemicals and plastics	[iii]		4
FD8040			Integrated environmental protection in the textile and leather industry	[ii]	P&M	24
FD8050			Integrated environmental protection in the metal producing and metal processing industry	[iii]		1
FD8060			Integrated environmental protection in the electrical/electronics industry	[iii]		0
FD8070			Integrated environmental protection in the construction, glass and ceramics industries	[iii]		0
FD8081			Integrated environmental protection in vehicle construction	[iii]		0
FD8082			Integrated environmental protection in the pulp and paper industry	[i]	P&M	8
FD8083			Integrated environmental protection in the packaging industry	[iii]		3
FD8084			Integrated environmental protection in the health sector	[iii]		0
FD8085			Integrated environmental protection in other industries/thematic fields	[ii]	P&M	21
FD9031			Overarching themes on ecotoxicology	[ii]	CEP	8
FD9032			Environmental pollution Health	[iii]		3
FD9040			Security research and security technology	[iii]		0
FD9080			Radiation exposure, radiation measurement methods and equipment (completed)	[iii]		0
FD9092			NA	[iii]		0
FD9099			Other cross-sectional activities for integrated environmental protection, environmental technology	[iii]		1
GA1010	G - Information and communication technologies	GA - Software systems; knowledge technologies	Development of software methods and tools	[iii]		3
GA1011			Embedded systems	[iii]		0
GA1012			Integrated application systems	[iii]		0
GA1013			Services	[iii]		0
GA1040			Correctness and redundancy in information systems	[iii]		0
GA1050			Manipulation security of information systems	[iii]		0
GA1060			Security in data processing networks	[iii]		0
GA1080			Other within the scope of software technology	[iii]		0
GA2010			Parallel architectures	[iii]		0
GA2020			Parallel Software	[iii]		0
GA2030			Mathematical foundations of scientific computer applications	[iii]		0
GA2040			Modelling / Simulation	[iii]		0

GA2050		Visualization	[iii]		0
GA2060		GRID	[iii]		2
GA2080		Other in the context of supercomputing	[iii]		0
GA3010		Evolutionary Algorithms	[iii]		0
GA3080		Other biological solutions in information processing	[iii]		0
GA4010		Neural networks and their applications	[iii]		0
GA4020		Neuroprosthetics	[iii]		3
GA4030		Recognition and understanding of writing and images	[iii]		0
GA4040		Knowledge processing/expert systems	[iii]		0
GA4080		Other in the context of intelligent systems	[iii]		0
GA5010		Recognition, understanding and translation of language	[iii]		0
GA5020		Intelligent methods of human-machine communication	[iii]		4
GA5030		Virtual reality / Augmented reality	[iii]		0
GA5080		Other in the context of language technology and man-machine communication	[iii]		0
GA6010		Project proposals/preliminary studies	[iii]		0
GA6011		Applied research and experimental development	[iii]		0
GA9010		Analyses, forecasts and evaluations Informatics	[iii]		0
GA9020		International cooperation in the context of information processing, if not assigned to the individual topics	[iii]		0
GA9077		Software design (completed DV program)	[iii]		0
GA9078		Basic software (completed DV program)	[iii]		0
GA9079		System design (completed DV program)	[iii]		0
GA9080		Molecular Bioinformatics (completed DV programme)	[ii]	RBT	1
GA9081		Data processing systems and technologies (completed DV-Progr.)	[iii]		0
GA9082		DV applications, information systems (completed DV-Progr.)	[iii]		0
GA9083		Database software (completed DV-Progr.)	[iii]		0
GA9084		Data processing in education (completed DV-progr.)	[iii]		0
GA9085		Information technology for office and administration, data security technology (completed DV-Progr.)	[iii]		0
GA9086		Regional computer centres (completed DV-Progr.)	[iii]		0
GA9087		Supra-regional research program in computer science (completed DV-Progr.)	[iii]		0
GA9088		Nuclear DV (completed DV-Progr.)	[iii]		0
GA9089		Other DV (completed DV-Progr.)	[iii]		0
GA9099		Other (also standardization) within the scope of informatics	[iii]		2
GB1010	GB - Communication technologies and services	IT Security Work Programme	[iii]		0
GB1011		Secure Cloud Computing	[iii]		0
GB1012		IT security in critical infrastructures	[iii]		0
GB1013		High-tech for IT security	[iii]		0
GB1070		Quantum Information Technology	[iii]		0
GB1080		Privacy in the digital world	[iii]		0
GB1099		Miscellaneous in the context of IT security	[iii]		0
GB2010		Network-based services in medicine	[iii]		0
GB2011		Network-based services in transport	[iii]		0
GB2099		Other in the context of network-based services	[iii]		0
GB5010		Optoelectronics	[iii]		0
GB5020		Photonics	[iii]		0
GB5040		Network technologies	[iii]		0
GB6111		Terminals (without ISDN)	[iii]		0
GB6112		ISDN terminals	[iii]		0
GB6113		Broadband ISDN terminals	[iii]		0
GB6119		Other within the scope of the terminal equipment of communication systems	[iii]		0
GB6121		Video technology	[iii]		0
GB6122		Video recording procedure	[iii]		0
GB6123		High definition television	[iii]		0
GB6131		Mobile radio	[iii]		0
GB6132		Digital Mobile Communications	[iii]		0
GB6139		Other in the context of radio technology	[iii]		0
GB6140		Radio-based network technologies	[iii]		0
GB6210		Picture technology	[iii]		0
GB6220		Flat screen	[ii]	WBT	24
GB6299		Other within the scope of display technology	[iii]		0
GB7010		German Research Network (DFN) - completed, see I51010 -	[iii]		0

GB7020		Local area networks (LAN) - locked -	[iii]		0
GB7030		Open networks, standards - closed, see I51020 -	[iii]		0
GB7099		Other in the context of data communication - closed, see I51099 -	[iii]		0
GB8010		Development and investigation of novel materials and manufacturing processes	[iii]		0
GB8020		Integration technology with compound semiconductors (e.g. quantum structure components)	[iii]		0
GB8030		Integrated circuits with superconducting, magnetic and organic materials (especially molecular electronics)	[iii]		1
GB8040		Internet Technologies	[iii]		0
GB8099		Other in the field of new materials and component structures	[iii]		0
GB9010		Systems engineering, circuit technologies for broadband networks (optical communications engineering)	[iii]		0
GB9020		Components Broadband networks (fiber optics, laser, photodiodes)	[iii]		0
GB9099		Other in the context of communication technology (including cross-sectional studies)	[iii]		0
GC1010	GC - Electronics and electronic systems	Nanolithography process	[iii]		0
GC1020		Computer-aided chip design (EDA)	[iii]		1
GC1030		New materials and process technologies	[iii]		0
GC1040		New analysis and test methods for nanostructures	[iii]		0
GC1050		Cooperation projects, research networks (AMTC, CNT, NaMLab, ASSID)	[iii]		0
GC1055		magnetolectronics, spintronics	[iii]		0
GC1065		1D and 2D electronics	[iii]		0
GC2010		Devices and structures for the sub-100 nm range	[iii]		5
GC2012		Microelectronic integration for transdisciplinary applications	[iii]		0
GC2020		Assembly and connection technology, 3D integration	[iii]		0
GC2025		Chip-based security for digitization	[iii]		0
GC2030		Power Electronics	[iii]		0
GC2035		Novel microelectronic components and sensor-based electronic systems	[iii]		1
GC2040		Automotive electronics, IAE, E/ENOVA	[iii]		0
GC2060		Organic electronics	[i]	WBT	1
GC3010		Battery system research	[iii]		0
GC3020		Complete electric vehicle system (with focus on vehicle electronics and energy management, vehicle concepts and manufacturing processes)	[iii]		0
GC3040		NA	[iii]		0
GC3050		Automotive electronics, IAE, E/ENOVA	[iii]		0
GC4010		Cross-cutting activities (in particular analysis, prognosis, impact research; also cross-cutting for the entire field of information technology)	[iii]		0
GC4040		Measures to accompany innovation	[iii]		0
GC4050		Training and further training measures	[iii]		0
GC4070		Cross-cutting activities (e.g. Joint Secretariat for Electric Mobility of the Federal Government	[iii]		0
GC5010		New power electronic converters and integrable components	[iii]		0
GC5020		Intelligent energy management systems and systems for grid quality/grid stability	[iii]		0
GC5030		New manufacturing and AVT concepts and materials for power electronic systems	[iii]		0
GD1110	GD - Microsystems Technology	Application of microelectronics (without microperipherals) - Project funding	[iii]		0
GD1200		Application of microelectronics (without microperipherals) - indirect specific funding	[iii]		0
GD2110		Microperipheric - Power components	[iii]		0
GD2120		Microperiphery - Final control elements	[iii]		0
GD2130		Microperipheric - Indicators, large area displays	[iii]		0
GD2140		Microperiphery - Semiconductor sensors	[iii]		0
GD2150		Microperiphery - microoptical sensors	[iii]		0
GD2160		microperipheric - chemical sensors	[ii]	WBT	0
GD2170		Microperipheric - micromechanical sensors	[iii]		0
GD2180		Microperiphery - Connection technologies	[iii]		0
GD2199		Other within the scope of microperiphery	[iii]		0
GD2200		Microperipherals (especially sensors and actuators) - indirect-specific funding	[iii]		0
GD3110		System Capability	[iii]		0
GD3120		manageability of microsystems technology for small and medium-sized enterprises	[iii]		0
GD3130		Systems engineering development	[iii]		0
GD3140		Model solutions in microsystems technology	[iii]		0
GD3150		Microtechnologies for service providers	[iii]		0

GD3161		Microsystems technology - cross-cutting issues	[iii]	0
GD3162		Microsystems technology - Qualification	[iii]	0
GD3163		Microsystems technology - Quality assurance	[iii]	0
GD3170		Basic industrial research in microsystems technology	[iii]	0
GD3181		Further development of system technologies	[iii]	42
GD3182		Development of standard components of microsystems	[iii]	9
GD3183		Development of prototypes of advanced microsystem solutions	[iii]	17
GD3184		Development of production technology for microsystems	[iii]	0
GD3185		Scientific principles for microsystems technology	[iii]	7
GD3199		Other in project funding for microsystems technology	[iii]	36
GD3210		Development of microsensors	[iii]	0
GD3220		Development of microactuators	[iii]	0
GD3230		Development of miniaturized sensor elements	[iii]	0
GD3240		Development of miniaturized actuator elements	[iii]	0
GD3250		Development of signal processing components	[iii]	0
GD3260		Development of micro components using combinations of micro techniques	[iii]	0
GD3299		Other in the indirect specific funding of microsystems technology	[iii]	0
GD3320		Technology transfer (MST) - Dissemination of information	[iii]	0
GD3340		Technology transfer (MST) - Promotion of demonstration centres	[iii]	0
GD3380		Technology transfer (MST) - evaluation and assessment	[iii]	0
GD3399		Technology Transfer (MST) - Other	[iii]	0
GD3410		Industrial diffusion of microsystems technology	[iii]	0
GD3420		Technology assessment for microsystem solutions	[iii]	0
GD3430		Exchange of scientists	[iii]	0
GD3440		Education and training networks	[iii]	0
GE1010	GE - Multimedia - Development of convergent ICT	German Research Network (DFN)	[iii]	0
GE1099		Other in the context of multimedia data communication	[iii]	0
GE2010		Digital process chain, information technology value added services	[iii]	0
GE2020		Telecooperation within and between organisations	[iii]	0
GE2030		e-government, virtual city	[iii]	0
GE2040		Virtual Networks	[iii]	0
GE2050		Other strategic projects	[iii]	0
GE2060		Safety and ease of use through technology	[iii]	0
GE2070		Internet of Things	[iii]	0
GE2080		Internet of Services	[iii]	0
GE2081		Internet-based knowledge infrastructure	[iii]	0
GE2083		Internet of Energy	[iii]	0
GE2084		Qualification through multimedia	[iii]	0
GE2085		eStandards	[iii]	0
GE2086		Usability	[iii]	0
GE2087		eCompetence network for companies	[iii]	0
GE2088		Mobile Internet	[iii]	0
GE2094		Medium-sized businesses 4.0 - Agencies	[iii]	0
GE2095		Medium-sized businesses 4.0 - Competence centres	[iii]	0
GE4010		Teleworking and SMEs (completed)	[iii]	0
GE4020		Multimedia business start-ups	[iii]	0
GE4030		Multimedia competence centres (completed)	[iii]	0
GE4095		Other in Multimedia (completed)	[iii]	0
GE5090		Project staff costs	[iii]	0
GE7010		Innovative forms of teaching and learning at universities	[iii]	3
GE7020		Notebook University concepts	[iii]	0
GE7030		Virtual university	[iii]	0
GE7040		Institutes for Information Technology	[iii]	0
GE7050		Non-university research in the field of information and communication technology	[iii]	0
GE9011		Fact banks - Chemistry	[iii]	0
GE9012		Fact banks - Energy, physics, mathematics	[iii]	0
GE9013		Fact banks - Space and construction	[iii]	0
GE9019		Fact banks - other	[iii]	0
GE9021		Reference banks - Chemistry	[iii]	0
GE9022		Reference banks - Energy, physics, mathematics	[iii]	0
GE9023		Reference banks - Space and construction	[iii]	0

GE9024			Reference banks - Social sciences	[iii]	0
GE9029			reference banks - other	[iii]	0
GE9030			Full text banks - Patents	[iii]	0
GE9110			Electronic publishing - completed, see I53010 and I53020 -	[iii]	0
GE9120			Information network (specialist information data centres)	[iii]	0
GE9180			Other through the use of new technologies in the field of technical information	[iii]	0
GE9210			New specialist information services	[iii]	0
GE9220			Information provision - completed, see I53030 -	[iii]	0
GE9230			Literature supply	[iii]	0
GE9240			Other services within the scope of the technical information	[iii]	0
GE9310			Basic research and applied research within the framework of specialist information	[iii]	0
GE9320			International cooperation within the framework of professional information	[iii]	0
GE9330			Other subject-specific projects within the framework of the technical information	[iii]	0
GE9360			Improvement of performance in the field of professional information, information awareness	[iii]	0
GE9365			Standardization (technical information)	[iii]	0
GE9370			Education, further education (technical information)	[iii]	0
GE9380			Other within the scope of the scientific information	[iii]	0
GE9420			Preliminary phases of institutional funding within the framework of specialist information	[iii]	0
HA1000	H - Vehicle and transport technologies, including maritime technologies	HA - Vehicle and transport technologies	Mobility in urban areas (lead projects)	[iii]	0
HA1010			Traffic Management 2010 (Leitvision)	[iii]	0
HA1030			Innovative transport infrastructures and modes of operation	[iii]	0
HA2010			Long distance rail transport	[iii]	0
HA2020			Local and regional transport	[iii]	0
HA2031			Maglev - System development (until 1996)	[iii]	0
HA2032			Maglev - TRANSRAPID Test Facility (TVE) in Emsland (until 1996)	[iii]	0
HA2040			Intermodal transport	[iii]	0
HA2050			Control and information systems for road traffic	[iii]	0
HA2060			Control and information systems for rail-guided traffic	[iii]	0
HA3010			Combined transport and transhipment systems	[iii]	0
HA3020			Logistics and transport chains	[iii]	0
HA3030			Rail freight transport 2010 (guiding vision)	[iii]	0
HA3040			General and bulk transport	[iii]	0
HA4010			Emission reduction and energy saving in road transport	[iii]	0
HA4011			Alternative drive technologies	[iii]	0
HA4020			Quiet traffic	[iii]	0
HA4030			Protection of the environment and resources in other traffic	[iii]	0
HA5010			road safety	[iii]	0
HA5020			Safety in rail-guided traffic	[iii]	0
HA6000			Better understanding of mobility and transport	[iii]	0
HA8010			Standardization and certification	[iii]	0
HA8020			Cross-cutting technologies	[iii]	0
HA8030			International research cooperations	[iii]	0
HA8040			ICT	[iii]	0
HA8050			Vehicle integration of electrified powertrains (especially drive management, integration into safety systems)	[iii]	0
HA8060			Electromobility showcase	[iii]	0
HB1010		HB - Maritime technologies	Marine resources - Prospection and exploration (completed)	[iii]	0
HB1020			Marine Raw Materials - Materials Handling (completed)	[iii]	0
HB2010			Offshore technology for hydrocarbons - Fundamentals (completed)	[iii]	0
HB2020			Offshore hydrocarbon engineering - prospection and exploration (completed)	[iii]	0
HB2030			Offshore technology for hydrocarbons - Production engineering (completed)	[iii]	0
HB2040			Transport and storage technology -Pipeline, sea transport, storage-	[iii]	0
HB2050			Process plants, energy conversion offshore (completed)	[iii]	0
HB2060			Service facilities -supply vessels, surveillance- (completed)	[iii]	0
HB2070			Underwater technology (completed)	[iii]	0
HB3010			Fundamentals of marine engineering (completed)	[iii]	0
HB3020			Maritime transport systems, special ships (completed)	[iii]	0
HB3030			Marine ice breaking technology (completed)	[iii]	0
HB3040			Ship propulsion systems (locked)	[iii]	0

HB3050			Ship Operation Technology (completed)	[iii]		0
HB3060			Shipbuilding technology (completed)	[iii]		0
HB4010			Ship Technology	[iii]		0
HB4020			Production of maritime systems	[iii]		0
HB4030			Shipping	[iii]		0
HB4040			Inland navigation	[iii]		0
HB5000			Marine Technology	[iii]		5
HB9010			Recording and forecasting natural conditions in coastal areas	[iii]		0
HB9020			Interactions sea/coastal structure	[iii]		0
HB9090			Project staff costs	[iii]		0
HB9099			Other in the context of marine technology	[iii]		0
IA1011	I - Aviation and space travel	IA - Aviation	Commercial aircraft - Megaliner	[iii]		0
IA1012			Commercial aircraft - Eurojet	[iii]		0
IA1013			Commercial aircraft - Regioprop	[iii]		0
IA1019			Commercial Aircraft - General	[iii]		0
IA1020			General aviation aircraft	[iii]		0
IA1030			Helicopter	[iii]		0
IA1040			Environmentally friendly drive	[iii]		0
IA2010			Air traffic control / ground systems / navigation	[iii]		0
IA2020			Avionics / Equipment	[iii]		0
IA3010			Wind tunnels	[iii]		0
IA3020			Other experimental facilities	[iii]		0
IA4010			Hypersonic aircraft	[iii]		0
IA4020			Hypersonic drive	[iii]		0
IA4030			Other concept studies	[iii]		0
IA5010			Air jet propulsion	[iii]		0
IA5020			ramjet drives	[iii]		0
IA6010			Aerothermodynamics	[iii]		0
IA6020			Materials / Construction	[iii]		0
IA6030			Subsystems/equipment	[iii]		0
IA7010			Drive test stands	[iii]		0
IA7020			Hypersonic wind tunnels	[iii]		0
IA9010			Technological basis Aviation research and hypersonic technology	[iii]		0
IA9020			Cross-sectional tasks free of guiding concepts	[iii]		0
IA9030			Structural technology / materials	[iii]		0
IA9080			Manufacturing Technologies	[iii]		0
IA9099			Other in the context of aeronautical research and hypersonic technology	[iii]		0
IB1010		IB - National space research and space technology	Atmospheric Physics	[iii]		1
IB1020			Exploration of the solar system	[iii]		0
IB1030			Astronomy and Astrophysics	[iii]		1
IB1040			Technology developments for extraterrestrial missions	[iii]		0
IB1060			Cross-cutting and other issues in the context of space exploration	[iii]		0
IB1080			Studies in the context of space exploration	[iii]		0
IB1091			Project supervisors and external individual experts (PB,RE)	[iii]		0
IB2000			Earth Observation	[iii]		0
IB2011			Research projects - application-oriented basic research (signatures)	[iii]		15
IB2012			Research projects - methodological studies on data processing in the context of earth observation	[iii]		1
IB2013			Research projects - pilot and demonstration projects	[iii]		1
IB2021			Development and use of equipment - Land, ocean and sea observation	[iii]		0
IB2022			Equipment development and use - Physics of the solid earth	[iii]		0
IB2023			Equipment development and use - trace gas concentrations in the atmosphere, radiation balance	[iii]		0
IB2060			Cross-cutting and miscellaneous Earth observation	[iii]		0
IB2080			Studies in the context of Earth observation	[iii]		0
IB3010			Research under space conditions - Materials science	[iii]		2
IB3020			Research under space conditions - Life sciences and medicine	[ii]	MIX	79
IB3030			Research under space conditions - development and construction of experimental facilities	[iii]		0
IB3040			Research under space conditions - Flight programmes	[iii]		0
IB3060			Cross-cutting and miscellaneous in the context of research under space conditions	[iii]		0
IB3080			Studies in the context of research under space conditions	[iii]		0
IB3091			Project supervisors and external individual experts (PB,RE)	[iii]		0

IB4010			Drive Technology	[iii]	0
IB4020			Structures, construction methods and fuel tanks	[iii]	0
IB4030			Reentry technology for reusable carrier systems	[iii]	0
IB4040			Vehicle System Concepts	[iii]	0
IB4060			General and miscellaneous space transportation	[iii]	0
IB4080			Studies in the field of space transport	[iii]	0
IB5010			D2 - Space mission performance	[iii]	0
IB5020			Multidisciplinary space mission services	[iii]	0
IB5030			Exploration	[iii]	0
IB5060			General and Miscellaneous in the field of space station and manned space flight	[iii]	1
IB5080			Studies in the field of space station and manned space flight	[iii]	0
IB6010			Payload developments and technologies including antennas in the context of satellite communications	[iii]	0
IB6020			Bus developments and technologies in the context of satellite communication	[iii]	0
IB6060			Overarching and miscellaneous satellite communications	[iii]	0
IB6080			Studies in the context of satellite communications	[iii]	0
IB7010			System studies and technology for satellite navigation	[iii]	0
IB7020			Pilot and demonstration projects for satellite navigation applications	[iii]	0
IB7030			Receiver and antenna technology for satellite navigation	[iii]	0
IB7060			General and other aspects of satellite navigation	[iii]	0
IB7080			Studies in the context of satellite navigation	[iii]	0
IB8010			Technology for space systems	[iii]	1
IB8015			Robotics for space systems	[iii]	0
IB8020			Product assurance in the context of space research and space technology	[iii]	0
IB8030			SME programme and commercialisation in the context of space research and space technology	[iii]	1
IB8040			Operating systems in the context of space research and space technology	[iii]	0
IB8050			School and youth projects	[iii]	0
IB8070			Plants of the Industrieanlagen-Betriebsgesellschaft (IABG)	[iii]	0
IB8080			Strategic studies in the framework of space research and space technology	[iii]	0
IB8091			Project supervisors and external individual experts (PB,RE)	[iii]	0
IB8092			Advisory bodies (SK)	[iii]	0
IB8098			Continuing education in space research and space technology (completed)	[iii]	0
IB8099			Other in the framework of space research and space technology	[iii]	0
JA1002	J - Research and development to improve working conditions and in the service sector	JA - Research to improve working conditions	Reduction and defence of harmful and annoying working materials	[iii]	0
JA1003			Reduction of vibrations and shocks	[iii]	0
JA1004			Improvement of the climate situation at the workplace	[iii]	0
JA1007			Research and reduction of combined loads	[iii]	0
JA1008			Examination of mental and nervous stress; stress	[iii]	0
JA1009			Improvement of occupational safety and accident prevention	[iii]	0
JA1010			Reduction of noise pollution	[iii]	0
JA1011			Noise reduction in sheet metal processing	[iii]	0
JA1012			Noise reduction in the textile industry	[iii]	0
JA1020			Reduction and defence of loads during welding	[iii]	0
JA1021			Reduction and prevention of pollution in the packaging industry	[iii]	0
JA1040			Working conditions and health of the workforce	[iii]	0
JA1041			Cancer risks in the workplace	[iii]	0
JA1042			Allergic reactions and diseases	[iii]	0
JA1050			Occupational health and safety 2000	[iii]	0
JA2010			Humane application of new technologies in the office and administration	[iii]	0
JA2011			Protection of health at work with new information and communication technologies	[iii]	0
JA2020			Humane application of new technologies in production	[iii]	0
JA2021			Protection of health when new techniques are used in production	[iii]	0
JA2022			Humane application of new technologies in series assembly	[iii]	0
JA2050			Services of the future	[iii]	0
JA2060			Pilot projects for job-creating/employment-generating innovations	[iii]	0
JA2099			Humane application of new technologies in other areas	[iii]	0
JA3001			Implementation through information tools and materials	[iii]	0
JA3002			Implementation through consulting	[iii]	0
JA3003			Implementation through qualification	[iii]	0

JA3004			Development and testing of extended methods of economic efficiency calculation	[iii]		0
JA3009			Implementation research; other	[iii]		0
JA4001			Humane design of working conditions in mining	[iii]		0
JA4002			Improving working conditions in forestry and agriculture	[iii]		0
JA4003			Humane design of working conditions in the foundry industry	[iii]		0
JA4004			Humane design of working conditions in the forging industry	[iii]		0
JA4009			Improvement of working conditions in other metalworking industries	[iii]		0
JA4010			Improvement of working conditions in the electrical industry	[iii]		0
JA4019			Improvement of working conditions in other metalworking industries	[iii]		0
JA4020			Improvement of working conditions in the carpentry and furniture industry	[iii]		0
JA4021			Improvement of working conditions in the textile industry	[iii]		0
JA4022			Improving working conditions in the garment industry	[iii]		0
JA4023			Humane design of working conditions in the construction industry	[iii]		0
JA4030			Humane application of new technologies in the printing industry	[iii]		0
JA4039			Improvement of working conditions in other sectors of the manufacturing and processing industry	[iii]		0
JA4040			Improving working conditions in the hotel and catering sector	[iii]		0
JA4041			improving working conditions in the social and health services	[iii]		0
JA4042			Humane organisation of working conditions in road freight transport	[iii]		0
JA4049			improvement of working conditions in the field of passenger and other freight transport	[iii]		0
JA4059			Improving working conditions in other service sectors	[iii]		0
JA5010			Innovative design of work organisation	[iii]		1
JA5030			Labour Research	[iii]		0
JA5040			Prevention	[iii]		0
JA5060			Working, learning, competence development / in-company training	[iii]		0
JA5080			Basic and cross-sectional questions on innovative work design	[iii]		0
JA8001			Industrial science	[iii]		0
JA8002			Occupational Medicine	[iii]		0
JA8003			Sociology of work and work psychology	[iii]		0
JA8004			Study and improvement of the working conditions of special groups of people	[iii]		0
JA8050			Demographic consequences for gainful employment in the future	[iii]		0
JA8081			Development and testing of new work structures in production	[iii]		0
JA8082			Development and testing of new working structures in the office and administration sector	[iii]		0
JA8099			Other cross-cutting issues	[iii]		0
JB6010		JB - Research in the service sector	Knowledge-intensive services	[iii]		0
JB6020			Design of service companies and work	[iii]		1
JB6040			skilled service work	[iii]		0
JB6050			Services for the 21st century	[iii]		0
JB6060			Services Demography and technology	[iii]		0
JB6080			Basic and cross-sectional issues concerning innovative services	[iii]		0
KA1010	K – Nano-technologies and materials technologies	KA – Nano-technologies	Lead innovation NanoMobil	[iii]		1
KA1020			Lead innovation NanoLux	[iii]		0
KA1030			Lead innovation NanoForLife	[ii]	RBT	4
KA1040			Lead innovation NanoTex	[ii]	WBT	21
KA1050			Lead innovation NanoChem	[iii]		4
KA1060			Lead Innovation NanoTecture	[iii]		0
KA1080			Further lead innovations	[iii]		0
KA1110			Process technology and nanoanalytics	[ii]	MIX	14
KA1120			Process Technology	[ii]	MIX	6
KA1130			Ultra-thin layers	[ii]	WBT	4
KA1210			Nanobiotechnology	[i]	MIX	100
KA1220			Nanomedicine	[ii]	RBT	152
KA1310			Nanostructure materials	[ii]	MIX	27
KA1320			Nanocomposites	[iii]		0
KA1330			Carbon NanoTubes	[iii]		0
KA1340			Nano Centres	[ii]	MIX	2
KB2010		KB - Materials technologies	Resource-efficient materials	[ii]	WBT	15
KB2110			Lightweight construction	[ii]	M&P	6
KB2210			Electromagnetic materials	[iii]		0
KB2220			Li-ion batteries	[iii]		0
KB2310			Intelligent materials	[ii]	MIX	10

KB2410			Bionic materials	[iii]		3
KB2510			Layers and interfaces	[ii]	MIX	3
KB2610			Virtual material development	[ii]	MIX	1
KB2710			Materials in the border area	[iii]		0
KB2810			OLED	[i]	WBT	29
KB2820			Organic photovoltaics	[i]	WBT	33
KB3010			New catalytic process routes	[ii]	WBT	15
KB3020			Microreaction technology	[ii]	WBT	3
KB3110			Materials for life sciences	[ii]	WBT	21
KB4010			SMEs including NanoChance	[ii]	WBT	63
KB4020			Promotion of young talent	[ii]	WBT	15
KB4030			education and training	[ii]	WBT	2
KB4040			Measures to support innovation	[iii]		0
KB4210			Events	[iii]		0
KB8805			Other specialized topics of chemical technologies	[iii]		2
KB8810			Basic funding of the ACA	[iii]		0
KB8820			Old projects Chemical technologies	[iii]		2
KB9099			Other activities and cross-sectional activities Materials research, other	[iii]		0
KB9901			Old projects materials research	[iii]		0
KB9902			Old projects Materials for future technologies	[iii]		17
L01110	L - Optical technologies	L - Optical technologies	Optical technologies for information and communication	[iii]		1
L01120			Optical technologies for lighting and environmental protection	[ii]	MIX	137
L01130			Optical technologies for life sciences and health	[ii]	MIX	181
L01140			Optical technologies for production	[iii]		5
L01150			Optical technologies for mobility and traffic	[iii]		0
L01160			Optical technologies: Cross-application technology field development	[iii]		20
L01170			Optical technologies: Accompanying measures for site development	[iii]		0
L02011			Development of systems, equipment and processes - Surface technologies	[iii]		0
L02012			Development of systems, devices and processes - Microstructure techniques	[iii]		0
L02019			Development of systems, equipment and processes - cross-cutting and other developments	[iii]		0
L02021			New analytical methods and measuring techniques - Surface techniques	[iii]		0
L02022			New analytical methods and measurement techniques - Microstructure techniques	[iii]		0
L02030			New surface materials and layers, especially applications	[iii]		0
L02080			Other, in particular technology transfer in the context of surface and microstructure technology	[iii]		0
L03000			Plasma technology (without fusion)	[iii]		18
L04010			Superconducting materials	[iii]		0
L04020			Magnet construction	[iii]		0
L04030			New applications of superconductivity	[iii]		0
L04031			Power Engineering	[iii]		0
L04032			Sensors	[iii]		0
L04033			Electronics, HF technology	[iii]		0
L04040			Cryogenics	[iii]		0
L05010			Lateral nanostructures	[iii]		0
L05020			Nano-Optoelectronics	[iii]		0
L05030			X-ray technology	[iii]		0
L05070			Ultra Precision Machining	[iii]		0
L05110			Lateral nanostructures	[iii]		0
L05170			Ultra Precision Machining	[iii]		1
L05199			Other nanotechnologies and cross-sectional activities (competence centres, expert and strategy circle)	[iii]		0
L06010			Electronic correlation and magnetism/magnetoelectronics	[iii]		0
L06020			Non-linear dynamics	[iii]		0
L06030			Photonic crystals	[iii]		0
L06070			Other new activities in the field of physical technologies	[iii]		8
L06080			Technology transfer and other cross-cutting activities	[iii]		0
L07510			Electronic image technology	[iii]		0
L07520			Sensor technology (as far as lead time for physical technologies)	[iii]		0
L07533			Adaptronics	[iii]		0
L07534			Bionics	[iii]		0

L07560			Expiring measures in the framework of physical technologies	[iii]	0
L07561			Key components of physical technologies	[iii]	0
L07562			Measurement and analysis technology	[iii]	0
L07563			control and feedback control systems	[iii]	0
L07564			Electron Microscopy	[iii]	0
L07565			Applied electron and ion optics	[iii]	1
L07566			Components and methods of optics and precision mechanics	[iii]	0
L07567			Material development for components of physical technologies	[iii]	0
M01010	M - Production technologies	M - Production technologies	Computer aided development, design and manufacturing - CAD/CAM	[iii]	0
M01015			Computer Integrated Manufacturing (CIM)	[iii]	0
M01020			Flexible manufacturing systems	[iii]	0
M01030			Industrial robots, assembly and handling systems	[iii]	0
M01040			Material flow, information flow, concatenation	[iii]	0
M01050			Manufacturing processes and technologies	[iii]	0
M01060			Quality assurance, early damage detection and diagnosis	[iii]	0
M01070			Analyses, preparatory investigations and evaluations Production engineering, if not assigned to the individual areas	[iii]	0
M01075			International Cooperation Production Engineering, if not allocated to the individual areas	[iii]	0
M01081			Process control with computer systems (completed)	[iii]	0
M01099			Other, cross-sectional activities (production engineering)	[iii]	0
M02010			Computer aided development, design and manufacturing - CAD/CAM	[iii]	0
M02020			Industrial robots, handling systems including intelligent periphery	[iii]	0
M02030			Computer Integrated Manufacturing (CIM)	[iii]	0
M03000			Production engineering - standardization	[iii]	0
M05010			Technology transfer production engineering	[iii]	0
M05020			Technology transfer manufacturing technology with foreign countries	[iii]	0
M05030			Technology assessment, impact research, accompanying research in the social, labour and economic sciences within the framework of production technology	[iii]	0
M07010			Basic research in the context of quality assurance	[iii]	0
M07020			Application-oriented research within the framework of quality assurance	[iii]	0
M07030			Technology transfer within the framework of quality assurance	[iii]	0
M07040			Standardization within the scope of quality assurance	[iii]	0
M08010			Strategies and methods for product planning	[iii]	6
M08020			Manufacturing technologies and production equipment	[iii]	38
M08030			New forms of cooperation between enterprises	[iii]	0
M08040			Specialist and managerial staff for production	[iii]	0
M08099			Research for production - other projects	[iii]	7
M08110			Analyses, preliminary studies, programme evaluation	[iii]	0
M08120			Priority actions (UA) for the preparation of fields of action	[iii]	0
M09010			Product development methods and production processes	[iii]	0
M09020			Economic activity in cycles	[iii]	0
M09030			Logistics for production	[iii]	0
M09040			Information technology for production	[iii]	0
M09050			Production in a turbulent environment	[iii]	0
M09060			Overarching themes for the Production 2000 framework concept	[iii]	0
M09100			Production 2000 framework concept: standardization research accompanying development	[iii]	0
M09200			Production 2000 framework concept: technology transfer, technology design, qualification, analyses	[iii]	0
NB1010	N - Regional planning and urban development; building research	NB - Building research	Rational construction methods (prefabrication and site fabrication)	[iii]	0
NB1020			modernisation, rehabilitation and upgrading of transport infrastructure	[iii]	0
NB1030			Reduction of primary energy/raw material consumption and susceptibility to damage in the production and use of building materials, elements and composite components	[iii]	0
NB1040			Computer-aided optimization of construction planning and execution control	[iii]	0
NB1051			Reduction/repair of construction and environmental damage and disturbance loads during construction, on buildings (especially monuments) and their surroundings	[iii]	0
NB1052			Construction in existing buildings (renovation, modernisation, repair)	[iii]	0
NB1053			New construction methods and technologies for space-saving, dense urban construction	[iii]	0
NB1060			Preventive structural building fire protection	[iii]	0

NB1070			Measures with specific objectives (e.g. basic research, knowledge transfer and qualification, test facilities and experiments, e.g. overall system optimisation, research into the preservation of historical monuments)	[iii]		0
NB1099			Other within the scope of building research and technology	[iii]		0
NB2010			Sustainable urban and spatial development	[iii]		0
NB2020			housing research (e.g. consequences of structural developments for housing needs and demand)	[iii]		0
OB0400	O - Innovations in education	OB - Research in education	Support for disadvantaged persons	[iii]		0
OB0500			Monitoring	[iii]		1
OB0600			Programme \Early recognition of qualification requirements\""	[iii]		0
OB1001			Transfer of innovation to adapt vocational training practice to technical and structural requirements	[iii]		0
OB1002			further development of vocational training, in particular new qualification structures	[iii]		0
OB1003			Equivalence of vocational education and training to general education	[iii]		0
OB1004			improving vocational training for the disadvantaged	[iii]		0
OB1005			Improving opportunities for women	[iii]		0
OB1010			Departmental research, scientific conferences, exchange of experience in the field of vocational training, other	[iii]		0
OB1050			Experimental and model facilities and programmes in the field of vocational training	[iii]		0
OB1100			Qualification of vocational training personnel	[iii]		0
OB1710			Training place developer incl. Regiokom-Ost	[iii]		0
OB1720			STARegio Program	[iii]		0
OB1730			Training offensive	[iii]		0
OB1740			Job starter program	[iii]		0
OB5000			Programme Future Education	[iii]		0
OB5100			Educational Research	[iii]		2
OB5200			Innovative development programmes	[iii]		0
OB5300			Cultural education	[iii]		0
OB5400			Programme School-Economy/Working Life	[iii]		0
OB6000			Other in the field of educational research (excluding vocational training or tertiary education)	[iii]		0
OB7000			Reform and implementation strategies for lifelong learning in national and international contexts	[iii]		0
OB7100			Quality development and structural improvement of general continuing education	[iii]		0
OB7200			Promotion of continuing education at universities	[iii]		0
OB7300			Modernisation and quality assurance in continuing vocational training	[iii]		0
OB7400			Research on continuing vocational training in enterprises	[iii]		0
OB8020			Demonstration Programme \Internationally Oriented Study Programmes\""	[iii]		0
OB8510			European Schools	[iii]		0
OB9000			Other in tertiary education	[iii]		0
PA1010	P - Humanities; economic and social sciences	PA - Humanities research	Research in the Humanities - Project Funding	[iii]		6
PB2010		PB - Social science research	Social sciences - project funding, international activities	[iii]		0
PB2030			Science Research - Project Funding	[iii]		0
PB2510			German Foundation for Peace Research	[iii]		0
PB2599			Other activities in the field of research for a policy of peace-building	[iii]		1
PD1010		PD - Infrastructure	NA	[iii]		0
PD3000			\"Brain gain" instead of "brain drain."	[iii]		0
PD3100			Research centres at universities and improvement of research infrastructure	[iii]		2
PD4100			NA	[iii]		1
PD4370			NA	[iii]		2
PD4380			NA	[iii]		0
QA2050	Q - Promotion of innovation by small and medium-sized enterprises	QA - Start-up support	Technology centres in the new federal states	[iii]		0
QA2060			Technology-oriented business start-ups in the new federal states (TOU-NBL)	[iii]		0
QB4010		QB - Technology promotion of medium-sized companieses	Research cooperation in the medium-sized economy (Foko)	[iii]		1
QB4090			Project staff costs	[iii]		0
QB4110			Central Innovation Programme for SMEs (ZIM) - Cooperation Promotion	[iii]		0
QD2010		QD - Research infrastructure medium-sized businessesktur	Contract research and development for commercial enterprises	[iii]		0
RB0510			Strategy funds	[ii]	MIX	19

RB0520	R - Innovation-related framework conditions and other cross-sectional activities	RB - Structural cross-sectional activities	Promotion of measures to improve the international visibility of science and research	[iii]		0
RB0530			Problem-oriented technology assessment	[iii]		1
RB0550			Development and testing of new concepts in the entire education system and in research	[iii]		2
RB0570			Technology Transfer University - Economy / Public-Private-Partnership; EXIST	[ii]	MIX	107
RB0580			Utilization offensive	[iii]		7
RB0581			Technology transfer through standardization	[iii]		0
RB0591			Project supervisors and external individual experts (PB,RE)	[iii]		0
RB0592			Advisory bodies (SK)	[iii]		0
RB1510			Planning; analyses; educational, scientific and research data	[iii]		0
RB2010			Promotion of additional R&D personnel capacity	[iii]		0
RB2510			Promotion of women's research/gender research in the fields of education, science and research	[iii]		0
RB2520			measures to promote equal opportunities for women in science, research and technology	[ii]	SEF	34
RB2530			Innovative study and networking concepts	[iii]		0
RB2540			Women in the Information Society	[iii]		0
RB2550			Measures to improve the training and professional development opportunities for women	[iii]		0
RB2560			Developing and testing effective strategies to enforce equal opportunities and promote a change in awareness	[iii]		0
RB2570			Specialist events	[iii]		0
RB2580			Improving the further training of women and expanding the range of professions	[iii]		0
RB3010			Promotion of innovation in the new Länder	[ii]	MIX	564
RB3091			Project supervisors and external individual experts (PB,RE)	[iii]		0
RB6010			Promotion of innovative networks -Inno-Net-	[ii]	SEF	69
RB8015			Costs for pilot projects to increase efficiency in the federal administration	[iii]		0
RB8020			Competitions and prizes	[ii]	MIX	0
RB8030			Exhibitions and conferences (if not in other areas)	[iii]		0
RB8040			Promotion of the exchange of scientists; scholarships	[iii]		0
RB8050			Scientific cooperation with other countries (if not in other areas)	[iii]		0
RB8075			Construction, refurbishment and purchase of equipment for non-university research centres (Chapter 60 03 Title 893 01)	[iii]		0
RB8082			Investment grants for non-institutionally funded institutions outside the universities (completed funding)	[iii]		0
RB8099			Cross-cutting structural activities, other	[iii]		0
RB9000			High-Tech Strategy	[ii]	MIX	15
RB9010			Research premium I	[ii]	MIX	29
RB9020			Research premium II	[ii]	MIX	16
RB9030			Cluster competition	[ii]	MIX	268
RB9040			New instruments and model projects in knowledge and technology transfer	[ii]	MIX	22
RB9050			KMU-innovative	[ii]	MIX	7
RB9051			Hightech-Strategie: Biotechnology (SMEs)	[i]	MIX	119
RB9100			Innovative medium-sized businesses	[iii]		0
RB9510			Digital change	[iii]		6
RC1010		RC - Demographic change	Human-technology interaction for demographic change	[iii]		33
RE1010		RE - Miscellaneous	Research at universities of applied sciences	[ii]	MIX	176
RE8015			Costs for pilot projects to increase efficiency in the federal administration	[ii]	SEF	15
RE8020			Competitions and prizes	[iii]		0
RE8030			Exhibitions and conferences (if not in other areas)	[iii]		0
RE8040			Promotion of the exchange of scientists; scholarships	[ii]	SEF	109
RE8050			Scientific cooperation with other countries (if not in other areas)	[ii]	SEF	242
RE8060			Cooperation with foreign research institutes (if not in other areas)	[ii]	SEF	77
RE8099			Innovation-related framework conditions and other cross-sectional activities, other	[ii]	SEF	48
TB0500	T - Funding organisations, restructuring of research in the accession area; higher education construction and special programmes mainly related to higher education	TB - Miscellaneous	Restructuring of research in the Accession Area	[iii]		0
TB0700			Promotion of top universities	[iii]		0
TB6010			Higher Education Pact 2020	[iii]		0
TB7000			Teaching quality pact	[iii]		0

U01011	U - Large-scale equipment for basic research	U - Large-scale equipment for basic research	Structure and interaction of fundamental particles - Activities at CERN	[iii]		0
U01012			Structure and interaction of fundamental particles - Activities at DESY	[iii]		0
U01013			Structure and interaction of fundamental particles - Activities at CERN and DESY	[iii]		0
U01014			Structure and interaction of fundamental particles - Activities at other centers	[iii]		0
U01019			Structure and interaction of fundamental particles - Miscellaneous	[iii]		0
U02021			Hadron and nuclear physics - activities at CERN	[iii]		0
U02022			Hadron and nuclear physics - activities at SIN/PSI	[iii]		0
U02023			Hadron and nuclear physics - activities at other international accelerators	[iii]		0
U02024			Hadron and nuclear physics - applications of nuclear physics methods	[iii]		2
U02025			Hadron and nuclear physics - activities at COSY	[iii]		0
U02026			Hadron and nuclear physics - activities at FAIR	[iii]		0
U02032			Hadron and nuclear physics - activities at GSI	[iii]		0
U02033			Hadron and nuclear physics - activities at the ILL	[iii]		0
U02034			hadron and nuclear physics - high-density matter	[iii]		0
U02035			Hadron and nuclear physics - activities at several accelerators	[iii]		0
U02039			Hadron and nuclear physics - Other	[iii]		0
U03041			Atomic and molecular physics - Synchrotron radiation	[iii]		0
U03042			Atomic and molecular physics - particle beams	[iii]		0
U03049			Atomic and molecular physics - Other	[iii]		0
U03051			Research of condensed matter - neutron scattering	[iii]		6
U03052			Condensed Matter Research - Synchrotron Radiation	[ii]	MIX	61
U03053			Condensed matter research - particle beams	[iii]		0
U03054			Research of condensed matter - with other methods	[iii]		5
U03059			Condensed Matter Research - Other	[iii]		0
U03060			Nuclear chemistry (completed)	[iii]		0
U04065			Selected fields of mathematics	[iii]		7
U04066			Selected fields of astrophysics	[iii]		0
U04067			Selected fields of particle astrophysics	[iii]		0
U05071			Apparatus development - Light sources	[iii]		0
U05072			Apparatus development - particle sources	[iii]		0
U05073			Equipment development - accelerator technology	[iii]		0
U05079			Equipment development - other	[iii]		0
U06003			SNQ , ESS	[iii]		0
U06004			Research reactor Munich II (FRM II)	[iii]		0
U06005			BESSY	[iii]		0
U06011			X-ray free-electron laser XFEL	[iii]		0
U06021			Accelerator facility FAIR	[iii]		0
U06031			Large Hadron Collider (LHC)	[iii]		0
U06099			Other within the framework of large-scale facilities for basic research	[iii]		1
U07080			Other within the framework of research on large-scale facilities for basic research	[iii]		0
U07085			Cooperation with the United Institute for Nuclear Research (VIK) in Dubna	[iii]		1
U07088			Investigations in plasma physics (completed)	[iii]		0
U07089			Radionuclide technology (completed)	[iii]		0
U08000			Application of scientific methods in the humanities	[ii]	MIX	0
U08500			Fusion research	[iii]		0
YB1000	Y - no classification	YB -	exchanges with other countries in the field of vocational training and scholarships	[iii]		0
YB2000			Promotion of gifted young people in vocational education and training	[iii]		0
YB3000			Inter-company vocational training centres	[iii]		0
YB3500			Measures to improve career guidance	[iii]		0
YB5000			Other specific programmes in the field of vocational training	[iii]		0
YB9000			Other non-R&D expenditure on vocational training	[iii]		0
YC2000		YC -	Grant to the association "Villa Vigoni" Conversion and extension measures".	[iii]		0
YC3000			Grants to student support organizations	[iii]		0
YC4030			Return of German scientists and young researchers from abroad	[iii]		0
YC5010			Establishment of a Center of Advanced European Studies and Research (CAESAR), foundation share of the federal government	[iii]		0
YC5040			Other science and education-related compensatory measures of the Federal Government for the Bonn region	[iii]		0

YC7000			Promotion of the exchange of students and scientists as well as the international cooperation of scientists	[iii]		0
YC7100			Promotion of university-related central measures by student associations and other organisations	[iii]		0
YC9000			Other education expenditure not related to R&D	[iii]		0
YC9025			Mainly university-related individual activities of the former BMBW (outside the LP funding priorities A5 / A6 / S2)	[iii]		0
ZMAN	Z -	ZM -	for all clients	[ii]	MIX	655

DECLARATION OF ACADEMIC HONESTY

Eigenständigkeitserklärung

Hiermit erkläre ich, dass diese Arbeit bisher von mir weder an der Mathematisch-Naturwissenschaftlichen Fakultät der Universität Greifswald noch einer anderen wissenschaftlichen Einrichtung zum Zwecke der Promotion eingereicht wurde.

Ferner erkläre ich, dass ich diese Arbeit selbstständig verfasst und keine anderen als die darin angegebenen Hilfsmittel und Hilfen benutzt und keine Textabschnitte eines Dritten ohne Kennzeichnung übernommen habe.

Greifswald, den 07. Oktober 2020