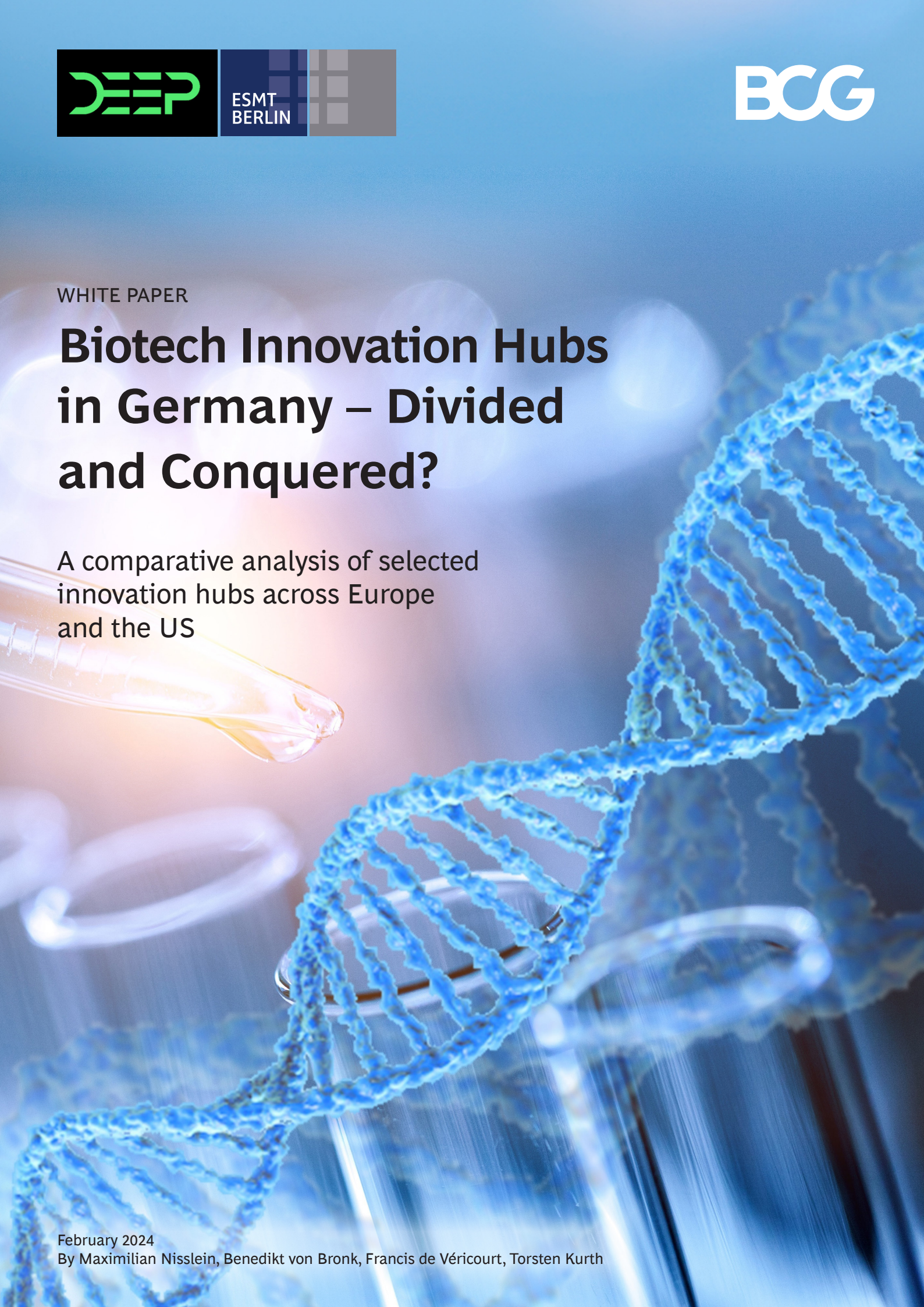
WHITE PAPER

Biotech Innovation Hubs in Germany – Divided and Conquered?

A comparative analysis of selected innovation hubs across Europe and the US



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Content

SUMMARY:

Our study introduces a new index to assess and compare the efficiency of various biotech innovation hubs in Europe and the US, with a particular emphasis on Germany. Our findings reveal that European hubs are significantly trailing their US counterparts in every aspect of the innovation process, except for the quality of academic research.

Our analysis further shows that Germany's biotech hubs perform on par with each other and possess highly complementary strengths. The country, however, fails to capitalize on these synergies, resulting in an overall performance that falls short of other European biotech hubs, such as London or Paris.

Our analysis leads to recommendations designed to improve collaboration among complementary hubs, aiming to enhance biotech innovation capabilities in both Germany and Europe.

1 Context

Biotech innovation, the process of turning life science discoveries into practical solutions that improve quality of life, is essential for driving sustainable prosperity and economic growth (de Véricourt, 2023). Regions or nations that have effectively leveraged this approach have historically secured a dominant position in the global economy and significantly increased their population's life expectancy (Lipsey, Carlaw, & Bekar, 2006). With the current escalating role of biotechnology in global economic and scientific progress (European Medicines Agency, 2023), enhancing innovation capabilities in this field is increasingly vital.

Yet, there is a noticeable disparity in how urgently European regions are tackling this challenge compared to their US counterparts (Vieira, 2016). This difference prompts a key question: What are the underlying factors causing the observed variations in the innovation ecosystems of Europe and the US, especially within the biotechnology sector?

To explore this issue and offer practical insights, we introduce the "Biotech Innovation Hub Index" (BIHI), a novel, objective metric assessing the critical success factors enabling an innovation hub to foster biotech start-ups. These hubs are epicenters of scientific and technological development (CIDEG at Tsinghua University, 2023), which facilitate the exchange of resources like knowledge, data, talent, and funding among firms and institutions within a geographic area.

Employing the BIHI, our study conducts an extensive comparison, examining the dynamics of US innovation hubs and contrasting them with their European counterparts, including those in France and the UK. Additionally, our study delves into the intricacies and potential trade-offs of decentralized systems. We specifically focus on Germany, assessing the unique benefits and challenges of hubs in cities like Berlin, Munich, and Heidelberg.

This analysis yields actionable insights for decision makers, researchers, and industry professionals to pave the way for a new normal in biotech innovation in Europe and specifically Germany.

2 The Biotech Innovation Hub Index

The Biotech Innovation Hub Index (BIHI) is a measure to assess different innovation ecosystems (i.e., metropolitan areas) regarding their ability to develop emerging biotechnology companies. We compared several of the most important hubs along their capabilities to foster biotech innovation using BIHI, which is further described in excursion box 1. The capabilities are thereby benchmarked along four critical aspects of the innovation ecosystem and a sub-score for each aspect as well as the total is calculated.

Excursion box 1

THE BIOTECH INNOVATION HUB INDEX (BIHI)

The Biotech Innovation Hub Index (BIHI) encompasses 20 Key Performance Indicators (KPI) that each reflect a critical factor contributing to the successful translation of research into biotech start-ups and products. The BIHI categorizes its normalized KPIs into four sub-indices, each representing a distinct aspect of the biotech innovation ecosystem. Detailed descriptions of each KPI can be found in Appendix. These KPIs are calculated by normalizing raw data values (for details see Appendices 6.2 and 6.4) across hubs (i.e., a KPI value of 1.2 means 20% better performance compated to average value 1.0). After normalization, KPIs are combined into each sub-index and the sub-indices into the BIHI, through averaging.

BIHI consists of 4 sub-indices:

1. Public Infrastructure: 4 KPIs
   (Total graduates – Undergraduate degrees & Graduate degrees, Number of hospitals, avg. Number of hospital beds)

2. Business environment & Entrepreneurship: 5 KPIs
   (Ease of doing business ranking, R&D as % of GDP, FDI as a % of GDP, Start-up activity (companies founded since 2018) – Overall, Companies funded by Angel investors)

3. Biotech R&D: 6 KPIs
   (Scientific output in biologics: Quantity, Times cited, average number of citations; Patents in biologics: Quantity & Quality; Number of clinical trials)

4. Biotech venturing: 5 KPIs
   (Start-up activity in biologics (founded since 2018), Private funding events last 5 years for biologics, Private funding last 5 years for biologics, Freshness of private funding (% since 2020) for biologics (based on # funding events), Total number of investors for biologics)

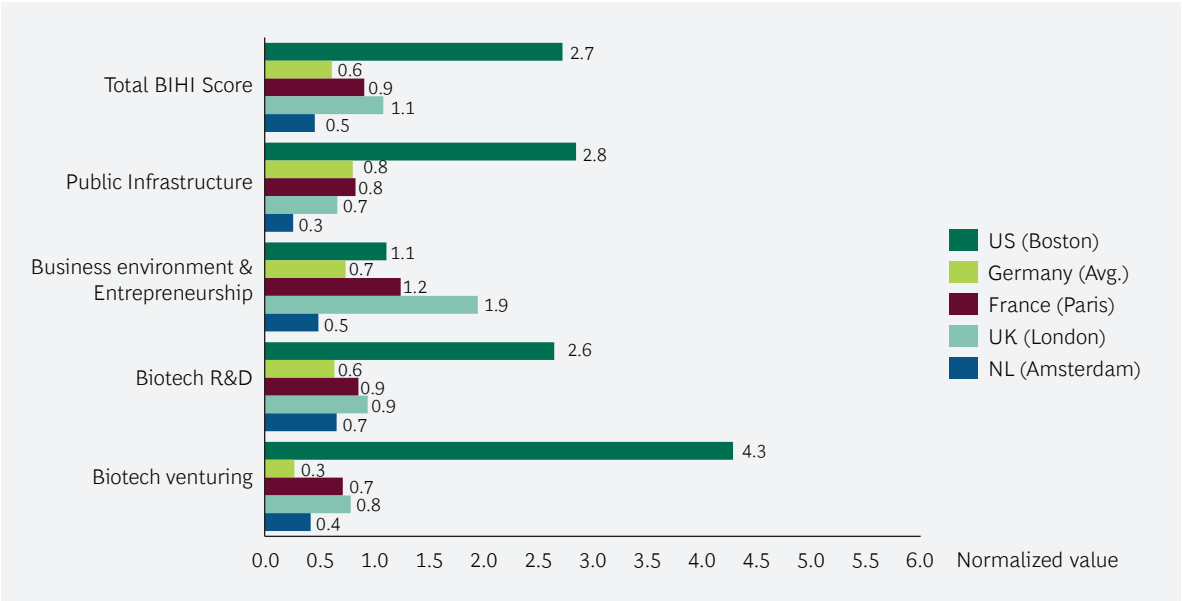
3 Findings

Our comprehensive study reveals insightful trends and discrepancies in biotech innovation hubs, comparing European Hubs in the UK (London), the Netherlands (Amsterdam), Germany (Average of individual hubs Berlin, Munich, Heidelberg) and France (Paris), as well as in the United States (Boston) – see Appendix 6.5 for rationale on hub selection. Germany represents a decentralized system with three hubs per country, we considered the average for the three German hubs as the value for an integrated German hub. For the other countries, we only considered the most prominent biotech hub for each country.

THE GAP BETWEEN EUROPEAN HUBS AND BOSTON ACROSS BIHI KPIS IS SIGNIFICANT.

The first application of our study involved a comparative analysis of the most prominent biotech hubs in all 5 countries along the 4 dimensions of the BIHI. Boston consistently outperformed all other hubs from Europe in all sub-indices except for Business environment & Entrepreneurship, as depicted in exhibit 1. This dominance is significant, as Boston's BIHI is nearly three times greater than that of London (2.7 vs. 1.1) and 4.5 times larger than Germany's (2.7 vs. 0.6).

Exhibit 1 | Total BIHI score and sub-index scores per country



Source: BCG analysis

Boston's excellence in public infrastructure, is primarily due to its world-class educational institutions like Harvard and MIT (see exhibit S1 in Appendix 6.1). These institutions enhance the city's capabilities in hospital infrastructure and produce a skilled graduate pool, contributing significantly to its leading position in biotech innovation.

Concerning business environment and entrepreneurship, the study found an equitable playing field in terms of ease of doing business and public R&D investment across the hubs (see exhibit S2 in the Appendix 6.1). However, London stood out for its high rate of company creation, likely influenced by its status as a global financial hub. This trend highlights the impact of financial ecosystems on fostering biotech innovations.

Examining the quality of scientific Biotech research and development, European hubs generally match the quality of research outputs and, to a lesser degree, the quality of their patents. However, Boston surpasses these European hubs in terms of the quantity of both research outputs, patents and clinical trials (see exhibit S3 in Appendix 6.1). This finding points to a challenge in Europe's biotech sector: effectively turning research into market-ready innovations. Interestingly, despite challenges in translating the research into a large number of patents, Germany leads in clinical trials compared to other European nations (see exhibit S3 in Appendix 6.1).

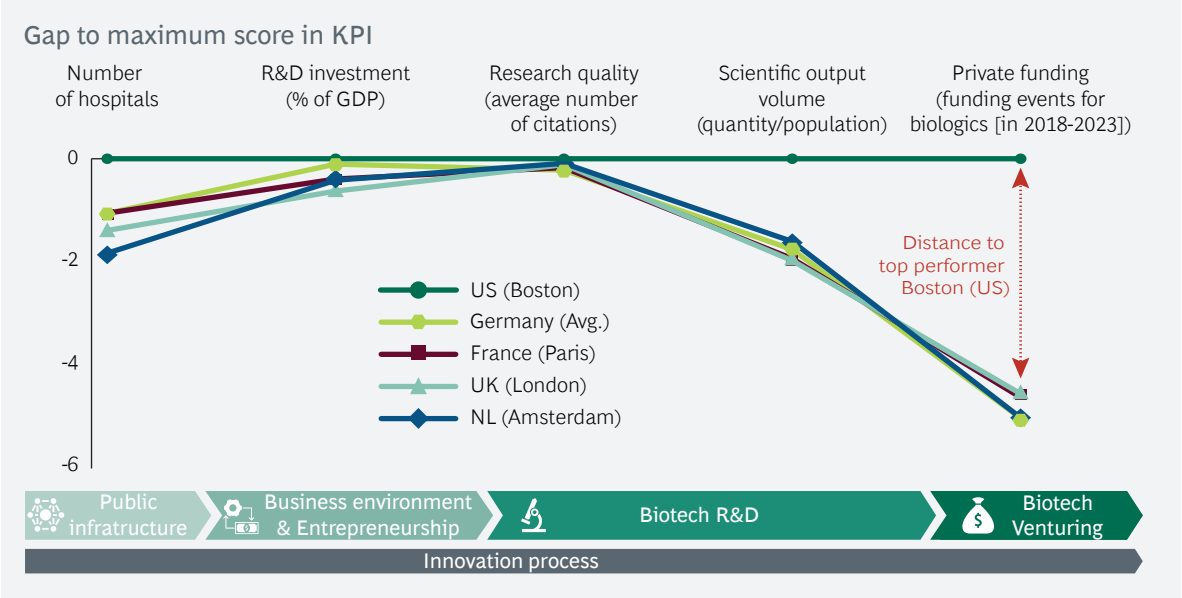
Boston's dominance is underscored in biotech venturing, which outperforms its European counterparts by a factor between 14 (when compared to Germany) and 5 (when compared to London). Boston's outstanding superiority is attributed to a strong presence of entrepreneurial activities and significant venture funding availability (see exhibit S4 in Appendix 6.1).

Overall, these findings underscore the gap between European hubs and Boston across BIHI KPIs. While European hubs demonstrate strong scientific capabilities, there remains a big challenge in translating these into commercial successes. Boston's exemplary performance across various dimensions, particularly in biotech venturing should serve as a learning opportunity. Therefore, we investigated the gap between European hubs and Boston more specifically along the innovation process.

THE GAP BETWEEN EUROPEAN HUBS AND BOSTON FIRST IMPROVES BUT THEN WORSEN ALONG THE INNOVATION PROCESS.

The innovation process within a Biotech hub involves transforming scientific research into successful Biotech ventures. The upstream part of this process focuses on creating the right infrastructure and business environment to facilitate this transformation. The downstream process is primarily about generating research of both high quality and quantity, which in turn enables the funding of Biotech Ventures. The different KPIs we measure for BIHI enables us to track the gap in performance along this process as illustrated in Exhibit 2.

Exhibit 2 | Gap along the translation process per country.



Source: BCG analysis

The data reveals that the most significant disparities exist at the outermost stages of this process. Although R&D investment as a percentage of GDP and research quality are somewhat comparable, the gaps in public infrastructure, volume of scientific output, and particularly in private funding events are substantial.

HETEROGENEOUS LANDSCAPE IN GERMANY AS DECENTRALIZED SYSTEM

A distinctive characteristic of Germany, compared to countries like France and England, is its high level of decentralization. In this section, we examine the nature of this decentralization by assessing the relative strengths and weaknesses of each of its three major biotech innovation hubs.

Our first observation is that the overall BIHI values for the three German hubs are quite similar (Berlin at 0.62, Munich at 0.64, and Heidelberg at 0.57, as shown in Exhibit 3 and Table 2 in Appendix 6.3). Despite this proximity in scores, each of these cities - Berlin, Munich, and Heidelberg - exhibits distinct strengths and weaknesses in biotech innovation, as elaborated in Exhibit 3. In this sense, the capacity to transform research into biotech innovation is fairly evenly dispersed across Germany. Yet, despite the closeness in scores, the unique strengths and weaknesses of each hub are significantly distinct, as detailed in Exhibit 3.

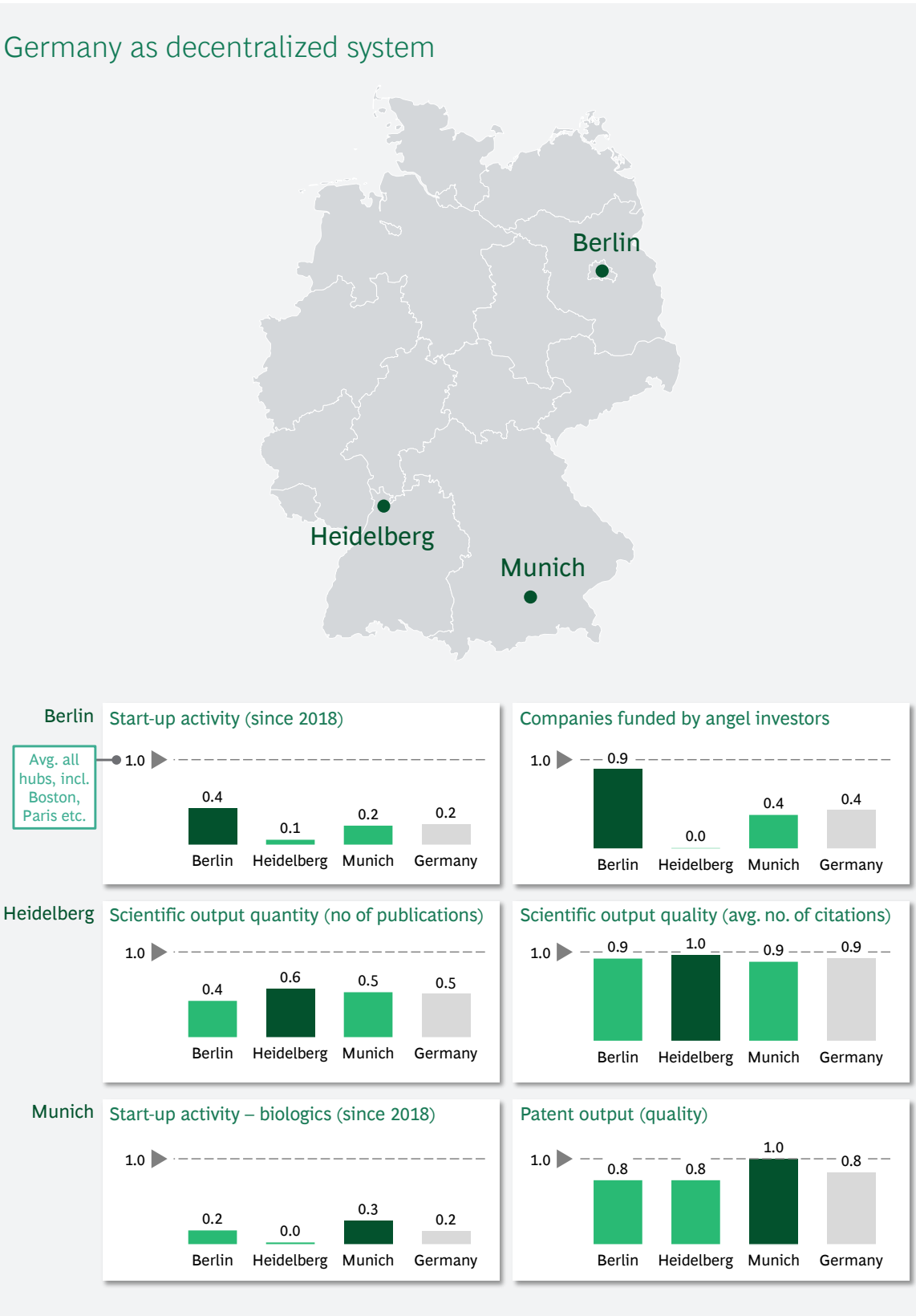
More specifically, Berlin stands out for its strength in the category business environment and entrepreneurship (0.87) compared to Munich (0.73) and Heidelberg (0.62), e.g., driven by the considerably higher number of companies funded by angel investors compared to other German hubs (see exhibit 3 top right) and close to the international average.

Heidelberg, on the other hand, is renowned for its strong scientific output and prestige but only a small lead compared to Munich and Berlin in terms of scientific output quantity (0.57 compared to 0.53 & 0.43) and quality (0.96 compared to 0.89 & 0.93). The city's reputation and achievements in scientific research contribute significantly to its standing in the biotech community, although this rarely translates into commercial success.

Munich emerges as a leader in biotech venturing within Germany (0.37 compared to 0.23 in Berlin and 0.21 in Heidelberg). The city's ecosystem is particularly favorable to the growth and development of biotech startups. This is remarkable because the overall start up activity is clearly behind Berlin (0.23 compared to 0.43). This high degree of translation capabilities indicates a strong alignment of resources and support for bringing scientific innovations to the market potentially also a driver behind leading in patent output quality (Munich 1.0 compared to 0.75 each for Berlin & Heidelberg).

Collectively, these findings suggest that the Berlin, Heidelberg, and Munich hubs exhibit strong complementarity. However, Germany does not capitalize on these synergistic potentials. Indeed, the combined BIHI of these three hubs is 30% lower than Paris's score (0.6 vs. 0.9) and 45% lower than London's (0.6 vs. 1.1) as shown in Exhibit 1.

Exhibit 3 | Comparison of core strengths in German hubs



Source: BCG analysis

4 Implications for the German Biotech innovation system

The results of this study call for a wake-up call, particularly for Europe, and more specifically for Germany. The findings are stark: Europe's performance in biotech innovation is suboptimal, with Germany displaying particularly concerning outcomes This requires a reevaluation and reinvention of Germany's approach to collaboration and innovation in the biotech sector.

A key issue identified in our study is the lack of translational capabilities in the German biotech sector. This shortfall can be attributed to several factors, with fragmentation playing a significant role. Fragmented innovation landscapes are characterized by numerous local but sub-scale initiatives, and potentially insufficient exchange of best practices between innovation hubs hindering translation. The Biotech Innovation Hub Index (BIHI) shows how the fragmented German system has a notable gap to more centralized systems like Paris or London (see exhibit 1), e.g., in the number of biotech startups (24% lower, see exhibit S4) and funding levels (18% lower, see exhibit S4).

In addition, German's sub-par performance could stem from the traditional reluctance among scientists and physicians to engage with the business side of their discoveries (Ho, 2022). It could be one driver that hinders the transition of scientific breakthroughs into business-oriented biotech ventures. This challenge is compounded by the traditional risk aversion of institutional investors (Fixsen, 2016) especially with biotech ventures that often require long-term investment. This cautiousness, coupled with the scientists' distance from entrepreneurship in the German eco-system, creates a difficult environment for nurturing biotech innovations, as it limits the conversion of research into successful business ventures.

TO ADDRESS THESE CHALLENGES, OUR STUDY PROPOSES SEVERAL ACTIONABLE STEPS:

1. Establish Cross-Hub Collaboration: A crucial action is the establishment of cross-hub collaboration through regional or national catalyst organizations. These entities would serve as centers for upskilling and exchanging knowledge among scientific personnel. For instance, national mentorship programs could be initiated to foster collaborations between scientists and business professionals beyond local spheres. Consequently, hubs could benefit from each other's strengths to achieve a better performance on country-level.

One way to enable this collaboration is via cross-hub catalysts. Independent academic centers like the European School of Management and Technology (ESMT) or universities such as the Technological University of Munich (TUM) could play a pivotal role in acting as independent catalysts for Germany's biotech innovation ecosystem. For example, this could be accomplished by offering specialized programs and forums for exchange between scientists and entrepreneurs to foster a more integrated approach between scientific research and commercial enterprises.

2. Harmonize Biotech Innovation Approach: Leveraging these cross-hub catalysts can create a more unified approach to biotech innovation in Germany. This would involve orchestrating various parts of the innovation process like research, IP, and venturing across the major German hubs, utilizing each city's strengths. The aim would be to avoid the dilution of efforts and resources in capital-intensive but sub-scale local initiatives.

3. Channel Government Funding into Later Stages of Innovation: Our data indicates that R&D is not the bottleneck in the innovation process. Therefore, we suggest redirecting more government funding towards later stages of the innovation process, specifically in supporting hubs and science-to-business translation programs. This would be a more cost-effective strategy than investing heavily in R&D.

In conclusion, our study analyses the performance of innovation hubs using the herein proposed Biotech Innovation Hub Index (BIHI), highlights the gap in translation of scientific discoveries into marketable innovations between Europe, and especially Germany, compared to the US, and deducts actionable insights for German scientists, policymakers, and other stakeholders in the biotech sector.

If Germany as a decentralized state can successfully navigate and resolve its challenges, it could provide a roadmap for the rest of Europe on how to enhance biotech competitiveness on a global scale. Europe itself is fragmented and could greatly profit from increased leverage of synergies. Joint European cross-hub catalysts such as the Creative Destruction Lab (CDL) with European locations in Berlin, Paris, Oxford, and Estonia could create these synergies, e.g., through mentorship programs.

The integrated orchestration of innovation could transcend national boundaries, strengthening Europe's scientific and technological position globally. The vision we foresee is not separated capitals of nations but a robust network of interconnected and collaborative biotech hubs.

5 Bibliography

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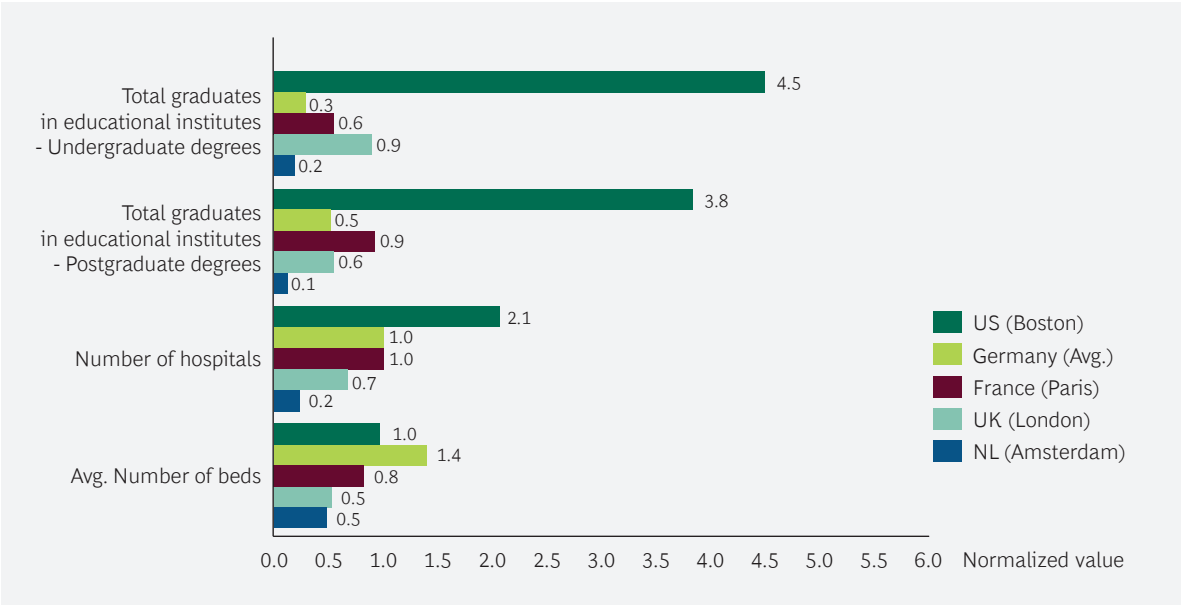
6 Appendix

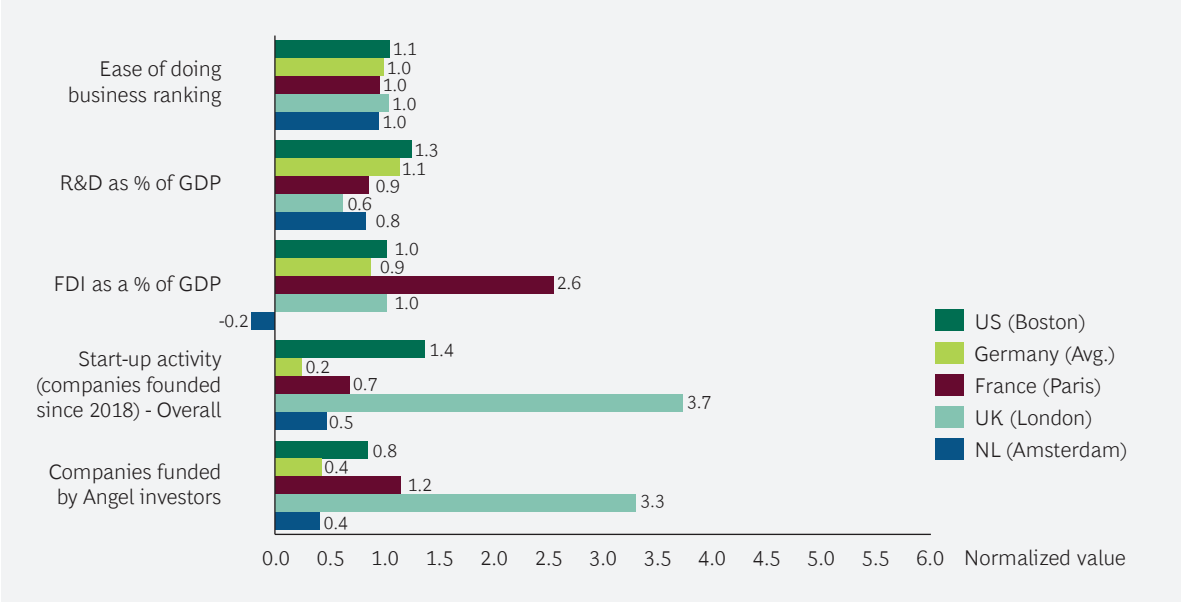
6.1 DETAILED SUB-INDEX SCORE PER COUNTRY

Exhibit S1 | KPIs for sub-index 1 "public infrastructure" per country



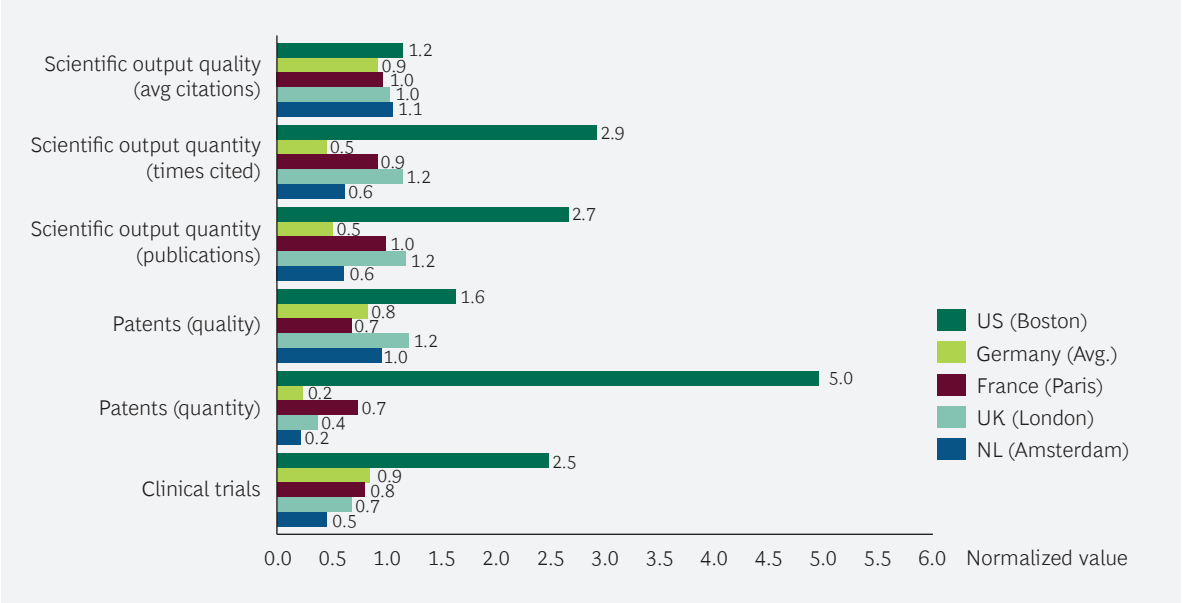
Source: BCG analysis

Exhibit S2 | KPIs for sub-index 2 "business environment and entrepreneurship" per country



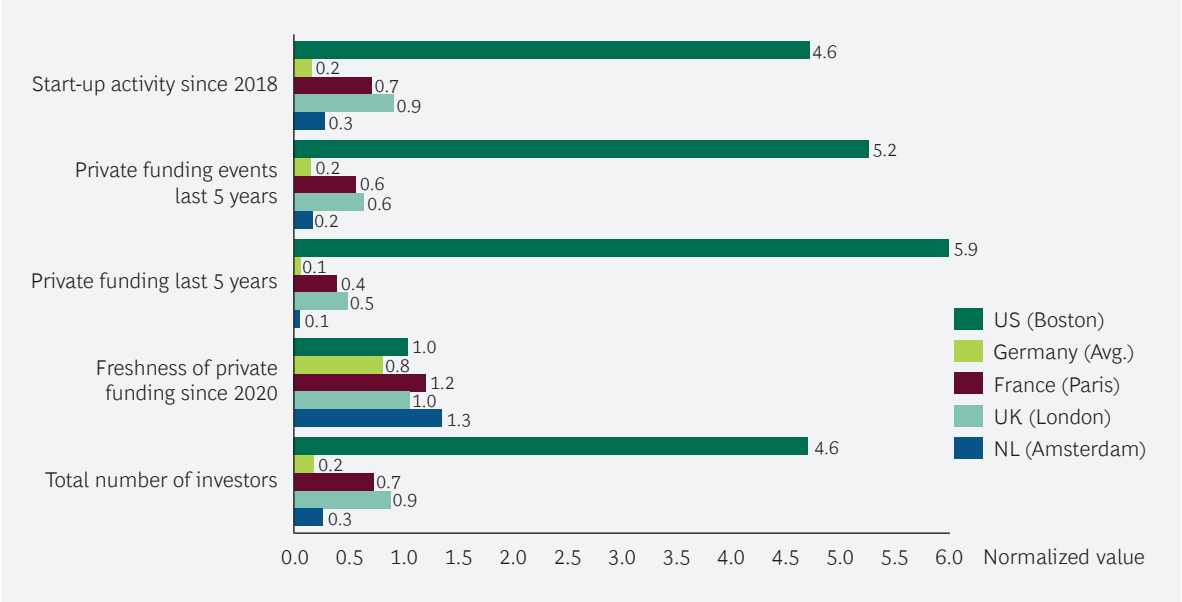
Source: BCG analysis

Exhibit S3 | **KPIs for sub-index 3 "biotech R&D" per country**



Source: BCG analysis

Exhibit S4 | **KPIs for sub-index 4 "biotech venturing" per country**



Source: BCG analysis

6.2 DEFINITION OF SUB-INDICES AND KPIS

Table 1 | Variables

Sub-index	ID	KPI	Description	Source	Search parameter	Year	Data category	Country/ City level
Public infrastructure	1	Total graduates - Undergraduate degrees	Number of graduates in undergraduate, bachelor's or equivalent level for 'Natural sciences, mathematics and statistics' and 'Health and welfare'.	OECD.Stat (https://stats.oecd.org/Index.aspx?DataSetCode=EDU_GRAD_FIELD)	Geo: countries of hubs	2020	Primary data	Country
	2	Total graduates - Postgraduate degrees	Number of graduates in post graduate, master's or equivalent level for 'Natural sciences, mathematics and statistics' and 'Health and welfare'.	OECD.Stat (https://stats.oecd.org/Index.aspx?DataSetCode=EDU_GRAD_FIELD)	Geo: countries of hubs	2020	Primary data	Country
	3	Number of hospitals	Number of hospitals available in the country including publicly owned, not-for-profit privately owned hospitals, for-profit privately owned hospitals.	OECD (https://stats.oecd.org/index.aspx?queryid=30182)	Geo: countries of hubs	2021	Primary data	Country
	4	Avg. Number of beds	Number of hospital beds available in the country in publicly owned, not-for-profit privately owned and for-profit privately owned hospitals.	OECD (https://stats.oecd.org/index.aspx?queryid=30182)	Geo: countries of hubs	2021	Primary data	Country
Business environment & Entrepreneurship	5	Ease of doing business ranking	Index across 10 topics (Starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting minority investors, paying taxes, trading across borders, enforcing contracts, and resolving insolvency). Economies are ranked on their ease of doing business, from 1–190. A high ease of doing business ranking means the regulatory environment is more conducive to the starting and operation of a local firm. The rankings are determined by sorting the aggregate distance to frontier scores on 10 topics, each consisting of several indicators, giving equal weight to each topic. The rankings for all economies are benchmarked to June 2016.	World Bank (http://www.doingbusiness.org/rankings https://openknowledge.worldbank.org/server/api/core/bitstreams/75ea67f9-4bcb-5766-ada6-6963a992d64c/content)		2020	External ranking	Country
	6	R&D as % of GDP	Research and development expenditure (% of GDP). Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. Covers basic and applied research, and experimental development.	World Bank, United Nations (https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?view=chart)	Geo: countries of hubs	2020	Primary data	Country
	7	FDI as a % of GDP	Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors, and is divided by GDP.	World Bank (https://data.worldbank.org/indicator/BX.KLT.DINV.WD.GD.ZS)	Geo: countries of hubs	2022	Primary data	Country
	8	Start-up activity (companies founded since 2018) - Overall	Number of companies founded in the last 5 years located in given locations. Only companies that are included in the CapitalIQ and Crunchbase databases are included.	QUID, Capital IQ, Crunchbase	Geo: see Table 3, column "start-up"	2018-2023	Primary data	City
	9	Companies funded by Angel investors	Number of companies funded by angel investors in the last 5 years.	Pitchbook	Geo: see Table 3, column "start-up"	2018-2023	Primary data	City
Biotech R&D	10	Scientific output quantity in biologics: Publications	Number of scientific literature published since 2018 related to biologics on hub level.	Web of Science	Geo: see Table 3, column "scientific literature"	2018-2023		City
	11	Scientific output quantity in biologics: Times cited	Number of times the identified scientific literature was cited by another publication on hub level.	Web of Science	Geo: see Table 3, column "scientific literature" Bio: see Table 4, column "scientific literature"	2018-2023	Primary data	City
	12	Scientific output quality in biologics: Average number of citations	Average number of citations for the identified publications on hub level.	Web of Science	Geo: see Table 3, column "scientific literature" Bio: see Table 4, column "scientific literature"	2018-2023	Primary data	City
	13	Patents in biologics: Quantity	Number of patents filed since 2018 related to biologics on hub level.	Derwent Innovation	Geo: see Table 3, column "patents" Bio: see Table 4, column "patents"	2017-2023	Primary data	City

Sub-index	ID	KPI	Description	Source	Search parameter	Year	Data category	Country/ City level
	14	Patents in biologics: Quality	Quality of patents filed since 2018 related to biologics on hub level. The age adjusted forward citations, breadth of patent claims and backward citations are used to calculate a quality score.	BCG Quality Index	Geo: see Table 3, column "patents" Bio: see Table 4, column "patents"	2017-2023	Primary data	Country
	15	Number of clinical trials	Number of trials listed in the WHO International Clinical Trials Registry Platform (ICTRP) is reported.	WHO (https://www.who.int/observatories/global-observatory-on-health-research-and-development/monitoring/number-of-clinical-trials-by-year-country-who-region-and-income-group)	Geo: countries of hubs	2018-2022	Primary data	Country
Biotech Venturing	16	Start-up activity (companies founded since 2018) - biologics	Number of companies founded in the last 5 years related to biologics located in given locations. Only companies that are included in the CapitalIQ and Crunchbase databases are included.	QUID, Capital IQ, Crunchbase	Geo: see Table 3, column "start-up" Bio: see Table 4, column "start-up"	2018-2023	Primary data	City
	17	Private funding events last 5 years (2018-2023) for biologics	Number of private investment events received by companies in the biologics space in the last 5 years. Investment events are identified and mapped to locations of interest based on distance. Only investment events that are included in the CapitalIQ and Crunchbase database are included.	QUID, Capital IQ, Crunchbase	Geo: see Table 3, column "start-up" Bio: see Table 4, column "start-up"	2018-2023	Primary data	City
	18	Private funding last 5 years ($, 2018-2023) for biologics	Funding received through private investment across the biologics space in the last 5 years. Investment dollars are tied to the investment events above. Does not include funding from private investment events that are undisclosed.	QUID, Capital IQ, Crunchbase	Geo: see Table 3, column "start-up" Bio: see Table 4, column "start-up"	2018-2023	Primary data	City
	19	Freshness of private funding (% since 2020) for biologics (based on # funding events)	Percent of private investment events identified above that was received from 2021-2023 compared to 2018-2020 to identify locations where there are disproportionately more funding in recent years.	QUID, Capital IQ, Crunchbase	Geo: see Table 3, column "start-up" Bio: see Table 4, column "start-up"	2018-2023	Primary data	City
	20	Total number of investors for biologics	Number of unique investors across all sectors	QUID, Capital IQ, Crunchbase	Geo: see Table 3, column "start-up" Bio: see Table 4, column "start-up"	2018-2023	Primary data	City
Other Variables	101	Population	Population data available for the respective city	World Population Review (https://worldpopulationreview.com)	Geo: city name	2023	Primary data	City
	102	Number of hospital beds	Number of hospital beds available in the country in publicly owned, not-for-profit privately owned and for-profit privately owned hospitals.	OECD (https://stats.oecd.org/index.aspx?queryid=30182)	Geo: countries of hubs	2021	Primary data	Country

6.3 VALUE TABLE

Table 2 | Values

	Metric	Score/ Absolute value							
		Berlin	Munich	Heidel-berg	Germany	Paris	London	Amster-dam	Boston
	BIHI Score	0.62	0.64	0.57	0.61	0.91	1.08	0.46	2.72
Sub-Index	KPI								
Business environment & Entrepre-neurship	Sub-Index average	0.87	0.73	0.62	0.74	1.24	1.95	0.49	1.11
	Ease of doing business ranking	1.00	1.00	1.00	1.00	0.96	1.04	0.95	1.05
	R&D as % of GDP	1.14	1.14	1.14	1.14	0.86	0.62	0.83	1.26
	FDI as a % of GDP	0.88	0.88	0.88	0.88	2.55	1.02	-0.22	1.02
	Start-up activity (companies founded since 2018) - Overall	0.43	0.23	0.06	0.24	0.69	3.74	0.47	1.38
	Companies funded by Angel investors	0.89	0.38	0.01	0.43	1.15	3.31	0.41	0.85
Biotech R&D	Sub-Index average	0.59	0.67	0.64	0.64	0.85	0.94	0.65	2.65
	Scientific output in biologics: Quantity	0.43	0.53	0.57	0.51	1.00	1.18	0.62	2.67
	Scientific output in biologics: Times cited	0.38	0.45	0.52	0.45	0.93	1.16	0.62	2.94
	Scientific output in biologics: Average number of citations	0.93	0.89	0.96	0.93	0.97	1.03	1.06	1.15
	Patents in biologics: Quantity	0.17	0.32	0.20	0.23	0.74	0.37	0.22	4.98
	Patents in biologics: Quality	0.75	1.00	0.75	0.84	0.68	1.21	0.96	1.64
	Number of clinical trials	0.85	0.85	0.85	0.85	0.80	0.68	0.46	2.49
Biotech Venturing	Sub-Index average	0.23	0.37	0.21	0.27	0.71	0.78	0.42	4.28
	Start-up activity (companies founded since 2018) - biologics	0.17	0.28	0.03	0.16	0.70	0.90	0.28	4.65
	Private funding events last 5 years (2018-2023) for biologics	0.24	0.16	0.07	0.15	0.56	0.63	0.17	5.19
	Private funding last 5 years ($, 2018-2023) for biologics	0.10	0.07	0.01	0.06	0.39	0.49	0.05	5.90
	Freshness of private funding (% since 2020) for biologics (based on # funding events)	0.40	1.10	0.90	0.80	1.19	1.05	1.34	1.03
	Total number of investors for biologics	0.26	0.23	0.03	0.17	0.72	0.87	0.26	4.64
Public infra-structure	Sub-Index average	0.80	0.80	0.80	0.80	0.83	0.66	0.26	2.85
	Total graduates in educational institutes - Undergraduate degrees	0.29	0.29	0.29	0.29	0.55	0.89	0.19	4.50
	Total graduates in educational institutes - Postgraduate degrees	0.52	0.52	0.52	0.52	0.92	0.55	0.13	3.85
	Number of hospitals	1.01	1.01	1.01	1.01	1.01	0.67	0.23	2.07
	Avg. Number of beds	1.40	1.40	1.40	1.40	0.83	0.53	0.48	0.97

6.4 METHODOLOGY OF CALCULATIONS

The hereby presented "Biotech Innovation Hub Index" (BIHI) allows for the objective assessment of different innovation hubs (i.e., metropolitan areas) regarding their suitability to foster emerging biotechnology companies.

A medical biotechnology company is herein defined as active in the field of creating biological therapies for medical treatment. Examples include mAbs, cell therapy, gene therapy or oncolytic viruses. Companies developing diagnostic tools are excluded, as well as digital health players, as their innovation journeys tend to follow different paths and often stem from other academic disciplines, rather than pure biosciences.

Combining hub- & country-level datapoints allows for a detailed view on regional characteristics and their impact on biotech innovation, without disregarding the overall environment, e.g., healthcare infrastructure.

Each KPI $\bar{x}^{\text{Hub}}_{\text{KPI}}$ per hub is normalized by the average value of the raw KPI values across hubs, with N_{Hubs} being the number of hubs:

$$\bar{x}^{\text{Hub}}_{\text{KPI}} = \frac{x^{\text{Hub}}_{\text{KPI}}}{\sum_{i \in \{\text{Hubs}\}} x^{i}_{\text{KPI}} / N_{\text{Hubs}}}$$

The value for the sub-index $\bar{x}^{\text{Hub}}_{\text{sub-index}}$ in turn is calculated by averaging the respective KPI values for a given sub-index per hub, with $N_{\text{KPI per sub-index}}$ the number of KPIs per sub-index:

$$\bar{x}^{\text{Hub}}_{\text{sub-index}} = \frac{\sum_{\text{KPI} \in \{\text{sub-index}\}} \bar{x}^{\text{Hub}}_{\text{KPI}}}{N_{\text{KPI per sub-index}}}$$

The BIHI per hub BIHI^{Hub} is then calculated with an equal weighting of the 4 sub-indices:

$$\text{BIHI}^{\text{Hub}} = \frac{\sum_{\text{sub-index} \in \{\text{sub-indices}\}} \bar{x}^{\text{Hub}}_{\text{sub-index}}}{4}$$

Values for Germany as aggregated hub combined of Berlin, Heidelberg and Munich were calculated by summing up the absolute numbers for all 3 hubs together and treating it as one hub before normalizing.

6.5 HUB SELECTION

Objective of the study design is to achieve a granular view while combining differences in geographies (US vs. Europe) and concentration of innovation (centralized / de-centralized systems).

The 7 hubs in Germany (Berlin, Munich, Heidelberg), France (Paris), UK (London), Netherlands (Amsterdam) and United States (Boston) were determined as followed:

- Boston acts as example for central US hub, given high accumulation of academia, ventures & investors (biotech invest >34% of total US biotech invest)
- Hubs in France, Netherlands & UK were chosen as centralized structures in EU capitals.
- Due to focus on Germany, we made decision to look at 3 main biotech research hubs in Germany, as de-centralized system. Top 3 hubs in Germany were identified by ranking top 10 university cities in Germany, according to number of students, and then sorting these by quantity of biotech publications.

6.6 SEARCH PARAMETERS FOR VARIABLES

Table 3 | Search parameters by categories and by city for geography search

City	Start-up	Patent	Scientific Literature
Berlin	(city:("Berlin" OR "Berlin" OR "Bernau" OR "Biesenthal" OR "Birkenwerder" OR "Blankenfelde-Mahlow" OR "Eberswalde" OR "Erkner" OR "Hennigsdorf" OR "Hennigsdorf" OR "Kleinmachnow" OR "Luckenwalde" OR "Marienwerder" OR "Neuenhagen" OR "Potsdam" OR "Schoenefeld" OR "Schoeneiche" OR "Schonefeld" OR "Schönefeld" OR "Schoneiche" OR "Teltow" OR "Wildau" OR "Zossen") AND country:("Germany"))	((INAD=("Berlin" OR "Berlin" OR "Bernau" OR "Biesenthal" OR "Birkenwerder" OR "Blankenfelde-Mahlow" OR "Eberswalde" OR "Erkner" OR "Hennigsdorf" OR "Hennigsdorf" OR "Kleinmachnow" OR "Luckenwalde" OR "Marienwerder" OR "Neuenhagen" OR "Potsdam" OR "Schoenefeld" OR "Schoeneiche" OR "Schonefeld" OR "Schönefeld" OR "Schoneiche" OR "Teltow" OR "Wildau" OR "Zossen")) AND (INAD=(Germany) OR PAOD=(Germany))) OR ((INAD=("Berlin" OR "Berlin" OR "Bernau" OR "Biesenthal" OR "Birkenwerder" OR "Blankenfelde-Mahlow" OR "Eberswalde" OR "Erkner" OR "Hennigsdorf" OR "Hennigsdorf" OR "Kleinmachnow" OR "Luckenwalde" OR "Marienwerder" OR "Neuenhagen" OR "Potsdam" OR "Schoenefeld" OR "Schoeneiche" OR "Schonefeld" OR "Schönefeld" OR "Schoneiche" OR "Teltow" OR "Wildau" OR "Zossen") OR PAOD=("Berlin" OR "Berlin" OR "Bernau" OR "Biesenthal" OR "Birkenwerder" OR "Blankenfelde-Mahlow" OR "Eberswalde" OR "Erkner" OR "Hennigsdorf" OR "Hennigsdorf" OR "Kleinmachnow" OR "Luckenwalde" OR "Marienwerder" OR "Neuenhagen" OR "Potsdam" OR "Schoenefeld" OR "Schoeneiche" OR "Schonefeld" OR "Schönefeld" OR "Schoneiche" OR "Teltow" OR "Wildau" OR "Zossen")) AND PRC=("DE"))	(CI=("Berlin" OR "Berlin" OR "Bernau" OR "Biesenthal" OR "Birkenwerder" OR "Blankenfelde-Mahlow" OR "Eberswalde" OR "Erkner" OR "Hennigsdorf" OR "Hennigsdorf" OR "Kleinmachnow" OR "Luckenwalde" OR "Marienwerder" OR "Neuenhagen" OR "Potsdam" OR "Schoenefeld" OR "Schoeneiche" OR "Schonefeld" OR "Schönefeld" OR "Schoneiche" OR "Teltow" OR "Wildau" OR "Zossen") AND CU=("Germany"))
Munich	(city:("Aschheim" OR "Augsburg" OR "Dachau" OR "Eching" OR "Erding" OR "Feldkirchen" OR "Finning" OR "Forstinning" OR "Freising" OR "Garching" OR "Gauting" OR "Geretsried" OR "Germering" OR "Gilching" OR "GrAfelfing" OR "Grafing" OR "Grafrath" OR "Greifenberg" OR "Grobenzell" OR "Grunwald" OR "Haag in Oberbayern" OR "Haar" OR "Halfing" OR "Herrsching" OR "Hohenkirchen-Siegertsbrunn" OR "Holzkirchen" OR "Ismaning" OR "Jetzendorf" OR "Karlsfeld" OR "Kirchdorf" OR "Kirchseeon" OR "Landsberg am Lech" OR "Langenbach" OR "M?Â¬nchen" OR "Merching" OR "Miesbach" OR "Muenchen" OR "Munchen" OR "München" OR "Munich" OR "Munich" OR "Neubiberg" OR "Oberding" OR "Oberhaching" OR "Odelzhausen" OR "Ottobrunn" OR "Penzberg" OR "Pfaffenhofen" OR "Planegg" OR "Planegg" OR "Poing" OR "Puchheim" OR "Pullach" OR "Rohrdorf" OR "Rosenheim" OR "Seefeld" OR "Starnberg" OR "Stephanskirchen" OR "Sulzemoos" OR "Taufkirchen" OR "Unterfoehring" OR "Unterhaching" OR "Vaterstetten" OR "Warngau" OR "Webling" OR "Weilheim in Oberbayern") AND country:("Germany"))	((INAD=("Aschheim" OR "Augsburg" OR "Dachau" OR "Eching" OR "Erding" OR "Feldkirchen" OR "Finning" OR "Forstinning" OR "Freising" OR "Garching" OR "Gauting" OR "Geretsried" OR "Germering" OR "Gilching" OR "GrAfelfing" OR "Grafing" OR "Grafrath" OR "Greifenberg" OR "Grobenzell" OR "Grunwald" OR "Haag in Oberbayern" OR "Haar" OR "Halfing" OR "Herrsching" OR "Hohenkirchen-Siegertsbrunn" OR "Holzkirchen" OR "Ismaning" OR "Jetzendorf" OR "Karlsfeld" OR "Kirchdorf" OR "Kirchseeon" OR "Landsberg am Lech" OR "Langenbach" OR "M?Â¬nchen" OR "Merching" OR "Miesbach" OR "Muenchen" OR "Munchen" OR "München" OR "Munich" OR "Munich" OR "Neubiberg" OR "Oberding" OR "Oberhaching" OR "Odelzhausen" OR "Ottobrunn" OR "Penzberg" OR "Pfaffenhofen" OR "Planegg" OR "Planegg" OR "Poing" OR "Puchheim" OR "Pullach" OR "Rohrdorf" OR "Rosenheim" OR "Seefeld" OR "Starnberg" OR "Stephanskirchen" OR "Sulzemoos" OR "Taufkirchen" OR "Unterfoehring" OR "Unterhaching" OR "Vaterstetten" OR "Warngau" OR "Webling" OR "Weilheim in Oberbayern")) AND (INAD=(Germany) OR PAOD=(Germany))) OR ((INAD=("Aschheim" OR "Augsburg" OR "Dachau" OR "Eching" OR "Erding" OR "Feldkirchen" OR "Finning" OR "Forstinning" OR "Freising" OR "Garching" OR "Gauting" OR "Geretsried" OR "Germering" OR "Gilching" OR "GrAfelfing" OR "Grafing" OR "Grafrath" OR "Greifenberg" OR "Grobenzell" OR "Grunwald" OR "Haag in Oberbayern" OR "Haar" OR "Halfing" OR "Herrsching" OR "Hohenkirchen-Siegertsbrunn" OR "Holzkirchen" OR "Ismaning" OR "Jetzendorf" OR "Karlsfeld" OR "Kirchdorf" OR "Kirchseeon" OR "Landsberg am Lech" OR "Langenbach" OR "M?Â¬nchen" OR "Merching" OR "Miesbach" OR "Muenchen" OR "Munchen" OR "München" OR "Munich" OR "Munich" OR "Neubiberg" OR "Oberding" OR "Oberhaching" OR "Odelzhausen" OR "Ottobrunn" OR "Penzberg" OR "Pfaffenhofen" OR "Planegg" OR "Planegg" OR "Poing" OR "Puchheim" OR "Pullach" OR "Rohrdorf" OR "Rosenheim" OR "Seefeld" OR "Starnberg" OR "Stephanskirchen" OR "Sulzemoos" OR "Taufkirchen" OR "Unterfoehring" OR "Unterhaching" OR "Vaterstetten" OR "Warngau" OR "Webling" OR "Weilheim in Oberbayern") OR PAOD=("Aschheim" OR "Augsburg" OR "Dachau" OR "Eching" OR "Erding" OR "Feldkirchen" OR "Finning" OR "Forstinning" OR "Freising" OR "Garching" OR "Gauting" OR "Geretsried" OR "Germering" OR "Gilching" OR "GrAfelfing" OR "Grafing" OR "Grafrath" OR "Greifenberg" OR "Grobenzell" OR "Grunwald" OR "Haag in Oberbayern" OR "Haar" OR "Halfing" OR "Herrsching" OR "Hohenkirchen-Siegertsbrunn" OR "Holzkirchen" OR "Ismaning" OR "Jetzendorf" OR "Karlsfeld" OR "Kirchdorf" OR "Kirchseeon" OR "Landsberg am Lech" OR "Langenbach" OR "M?Â¬nchen" OR "Merching" OR "Miesbach" OR "Muenchen" OR "Munchen" OR "München" OR "Munich" OR "Munich" OR "Neubiberg" OR "Oberding" OR "Oberhaching" OR "Odelzhausen" OR "Ottobrunn" OR "Penzberg" OR "Pfaffenhofen" OR "Planegg" OR "Planegg" OR "Poing" OR "Puchheim" OR "Pullach" OR "Rohrdorf" OR "Rosenheim" OR "Seefeld" OR "Starnberg" OR 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Heidelberg	(city:("Adelsheim" OR "Bad Schonborn" OR "Brackenheim" OR "Bretten" OR "Bruchsal" OR "Darmstadt" OR "Darmstadt," OR "Deidesheim" OR "Dieburg" OR "Durmersheim" OR "Eggenstein-Leopoldshafen" OR "Erbach im Odenwald" OR "Ettlingen" OR "Fischbachtal" OR "Frankenthal" OR "Griesheim" OR "Heidelberg" OR "Heilbronn" OR "Herxheim" OR "Ispringen" OR "Karlsruhe" OR "Karlsruhe" OR "Kirchardt" OR "Knittlingen" OR "Landau" OR "Lauffen am Neckar" OR "Ludwigshafen" OR "Ludwigshafen am Rhein" OR "Mannheim" OR "Mannheim" OR "Maxdorf" OR "Neckarsulm" OR "Osterburken" OR "Pfinztal" OR "Pforzheim" OR "Pfungstadt" OR "Reinheim" OR "Rheinstetten" OR "Rulzheim" OR "Sankt Leon-Rot" OR "Schifferstadt" OR "Speyer" OR "Stutensee" OR "Vaihingen an der Enz" OR "WaghAusel" OR "Waibstadt" OR "Walldorf" OR "Weinheim" OR "Weiterstadt" OR "Worms" OR "Zwingenberg") AND country:("Germany"))	((INAD=("Adelsheim" OR "Bad Schonborn" OR "Brackenheim" OR "Bretten" OR "Bruchsal" OR "Darmstadt" OR "Darmstadt," OR "Deidesheim" OR "Dieburg" OR "Durmersheim" OR "Eggenstein-Leopoldshafen" OR "Erbach im Odenwald" OR "Ettlingen" OR "Fischbachtal" OR "Frankenthal" OR "Griesheim" OR "Heidelberg" OR "Heilbronn" OR "Herxheim" OR "Ispringen" OR "Karlsruhe" OR "Karlsruhe" OR "Kirchardt" OR "Knittlingen" OR "Landau" OR "Lauffen am Neckar" OR "Ludwigshafen" OR "Ludwigshafen am Rhein" OR "Mannheim" OR "Mannheim" OR "Maxdorf" OR "Neckarsulm" OR "Osterburken" OR "Pfinztal" OR "Pforzheim" OR "Pfungstadt" OR "Reinheim" OR "Rheinstetten" OR "Rulzheim" OR "Sankt Leon-Rot" OR "Schifferstadt" OR "Speyer" OR "Stutensee" OR "Vaihingen an der Enz" OR "WaghAusel" OR "Waibstadt" OR "Walldorf" OR "Weinheim" OR "Weiterstadt" OR "Worms" OR "Zwingenberg")) AND (INAD=(Germany) OR PAOD=(Germany))) OR ((INAD=("Adelsheim" OR "Bad Schonborn" OR "Brackenheim" OR "Bretten" OR "Bruchsal" OR "Darmstadt" OR "Darmstadt," OR "Deidesheim" OR "Dieburg" OR "Durmersheim" OR "Eggenstein-Leopoldshafen" OR "Erbach im Odenwald" OR "Ettlingen" OR "Fischbachtal" OR "Frankenthal" OR "Griesheim" OR "Heidelberg" OR "Heilbronn" OR "Herxheim" OR "Ispringen" OR "Karlsruhe" OR "Karlsruhe" OR "Kirchardt" OR "Knittlingen" OR "Landau" OR "Lauffen am Neckar" OR "Ludwigshafen" OR "Ludwigshafen am Rhein" OR "Mannheim" OR "Mannheim" OR "Maxdorf" OR "Neckarsulm" OR "Osterburken" OR "Pfinztal" OR "Pforzheim" OR "Pfungstadt" OR "Reinheim" OR "Rheinstetten" OR "Rulzheim" OR "Sankt Leon-Rot" OR "Schifferstadt" OR "Speyer" OR "Stutensee" OR "Vaihingen an der Enz" OR "WaghAusel" OR "Waibstadt" OR "Walldorf" OR "Weinheim" OR "Weiterstadt" OR "Worms" OR "Zwingenberg") OR PAOD=("Adelsheim" OR "Bad Schonborn" OR "Brackenheim" OR "Bretten" OR "Bruchsal" OR "Darmstadt" OR "Darmstadt," OR "Deidesheim" OR "Dieburg" OR "Durmersheim" OR "Eggenstein-Leopoldshafen" OR "Erbach im Odenwald" OR "Ettlingen" OR "Fischbachtal" OR "Frankenthal" OR "Griesheim" OR "Heidelberg" OR "Heilbronn" OR "Herxheim" OR "Ispringen" OR "Karlsruhe" OR "Karlsruhe" OR "Kirchardt" OR "Knittlingen" OR "Landau" OR "Lauffen am Neckar" OR "Ludwigshafen" OR "Ludwigshafen am Rhein" OR "Mannheim" OR "Mannheim" OR "Maxdorf" OR "Neckarsulm" OR "Osterburken" OR "Pfinztal" OR "Pforzheim" OR "Pfungstadt" OR "Reinheim" OR "Rheinstetten" OR "Rulzheim" OR "Sankt Leon-Rot" OR "Schifferstadt" OR "Speyer" OR "Stutensee" OR "Vaihingen an der Enz" OR "WaghAusel" OR "Waibstadt" OR "Walldorf" OR "Weinheim" OR "Weiterstadt" OR "Worms" OR "Zwingenberg")) AND PRC=("DE"))	(CI=("Adelsheim" OR "Bad Schonborn" OR "Brackenheim" OR "Bretten" OR "Bruchsal" OR "Darmstadt" OR "Darmstadt," OR "Deidesheim" OR "Dieburg" OR "Durmersheim" OR "Eggenstein-Leopoldshafen" OR "Erbach im Odenwald" OR "Ettlingen" OR "Fischbachtal" OR "Frankenthal" OR "Griesheim" OR "Heidelberg" OR "Heilbronn" OR "Herxheim" OR "Ispringen" OR "Karlsruhe" OR "Karlsruhe" OR "Kirchardt" OR "Knittlingen" OR "Landau" OR "Lauffen am Neckar" OR "Ludwigshafen" OR "Ludwigshafen am Rhein" OR "Mannheim" OR "Mannheim" OR "Maxdorf" OR "Neckarsulm" OR "Osterburken" OR "Pfinztal" OR "Pforzheim" OR "Pfungstadt" OR "Reinheim" OR "Rheinstetten" OR "Rulzheim" OR "Sankt Leon-Rot" OR "Schifferstadt" OR "Speyer" OR "Stutensee" OR "Vaihingen an der Enz" OR "WaghAusel" OR "Waibstadt" OR "Walldorf" OR "Weinheim" OR "Weiterstadt" OR "Worms" OR "Zwingenberg") AND CU=("Germany"))
London (Considered only London but not the surrounding regions since the data is too high if we add those.)	(city:("London") AND country:("united kingdom"))	((INAD=("London") OR PAOD=("London")) AND (INAD=("United Kingdom" OR "England") OR PAOD=("United Kingdom" OR "England"))) OR ((INAD=("London") OR PAOD=("London")) AND PRC=("GB"))	(CI=("London") AND CU=("united kingdom" OR "England" OR "Great Britain"))

City	Start-up	Patent	Scientific Literature
Paris	(city:("Antony" OR "Arcueil" OR "Asnieres sur Seine" OR "Asnieres-sur-Seine" OR "Asnières-sur-Seine" OR "Aubervilliers" OR "Avon" OR "Bagneux" OR "Bagnolet" OR "Bailly" OR "Beaumont sur oise" OR "Bezons" OR "Bievres" OR "Bois-Colombes" OR "Boissise-la-Bertrand" OR "Boissy-l'Aillerie" OR "Bondoufle" OR "Bougival" OR "Boulogne Billancourt" OR "Boulogne-Billancourt" OR "Bourg la Reine" OR "Boussy-Saint-Antoine" OR "Brie-Comte-Robert" OR "Bry-sur-Marne" OR "Cachan" OR "Cergy" OR "Cergy Pontoise" OR "Champigny-sur-Marne" OR "Champlan" OR "Champs Sur Marne" OR "Champs-sur-Marne" OR "Chantilly" OR "Charenton Le Pont" OR "Charenton-le-Pont" OR "Chatenay-Malabry" OR "Chatillon" OR "Chatou" OR "Chavenay" OR "Chaville" OR "Chevreuse" OR "Chilly-Mazarin" OR "Clamart" OR "Clichy" OR "Colombes" OR "Corbeil Essonnes" OR "Courbevoie" OR "Creteil" OR "Croissy Beaubourg" OR "Croissy Sur Seine" OR "Croissy-Beaubourg" OR "Eaubonne" OR "Elancourt" OR "Epinay sur Seine" OR "Eragny-sur-Oise" OR "Evry" OR "Évry" OR "Fontenay aux Roses" OR "Fontenay sous bois" OR "Fontenay-aux-Roses" OR "Fontenay-le-Fleury" OR "Fresnes" OR "Garches" OR "Gennevilliers" OR "Gentilly" OR "Gif Sur Yvette" OR "Gif-sur-Yvette" OR "Gonesse" OR "Grigny" OR "Guyancourt" OR "Houdan" OR "Igny" OR "ile-de-France" OR "Issy Les Moulineaux" OR "Issy-les-Moulineaux" OR "Itteville" OR "Ivry-sur-Seine" OR "Jouy en Josas" OR "Juvisy sur Orge" OR "La Courneuve" OR "La Garenne-Colombes" OR "La Plaine Saint Denis" OR "La Plaine Saint-Denis" OR "La Verriere" OR "La-Plaine-Saint-Denis" OR "Le Blanc-Mesnil" OR "le Bourget" OR "le Chesnay" OR "Le Kremlin Bicetre" OR "Le Kremlin-Bicetre" OR "Le Mesnil Le Roi" OR "Le Pecq" OR "Le Perreux-sur-Marne" OR "Le Plessis Robinson" OR "Le Pre Saint Gervais" OR "Le Thillay" OR "Le Vesinet" OR "Les Halles" OR "Les Mureaux" OR "Les Ulis" OR "Levallois Perret" OR "Levallois-Perret" OR "Lisses" OR "Longjumeau" OR "Louveciennes" OR "Magny les Hameaux" OR "Maisons Laffitte" OR "Maisons-Alfort" OR "Maisons-Laffitte" OR "Malakoff" OR "Mantes-La-Ville" OR "Marly le Roi" OR "Marly-Le-roi" OR "Marne La Vallee" OR "Marne-la-Vallée" OR "Massy" OR "Maurepas" OR "Melun" OR "Meudon" OR "Meudon La Foret" OR "Mitry-Mory" OR "Moissy-Cramayel" OR "Montataire" OR "Montesson" OR "Montfermeil" OR "Montigny Le Bretonneux" OR "Montigny-le-Bretonneux" OR "Montmorency" OR "Montreuil" OR "Montrouge" OR "Morangis" OR "Nangis" OR "Nanterre" OR "Neuilly Plaisance" OR "Neuilly sur Seine" OR "Neuilly-sur-Seine" OR "Nogent" OR "Nogent-sur-Marne" OR "Noisiel" OR "Noisy-le-Grand" OR "Noisy-le-Sec" OR "Orsay" OR "Osny" OR "Palaiseau" OR "Pantin" OR "Paray-Vieille-Poste" OR "Paris" OR "Paris " OR "PARIS 8" OR "Paris Cedex 02" OR "Pierrelaye" OR "Plailly" OR "Plaisir" OR "Poissy" OR "Pr?? 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Saint Gervais" OR "PrAe Saint Gervais" OR "Puteaux" OR "Rambouillet" OR "Rocquencourt" OR "Roissy-en-France" OR "Romainville" OR "Rueil Malmaison" OR "Rueil-Malmaison" OR "Rungis" OR "Saint Cloud" OR "Saint Germain en Laye" OR "Saint Maur des Fosses" OR "Saint Nom la Breteche" OR "Saint Ouen" OR "Saint-Cloud" OR "Saint-Denis" OR "Saint-Fargeau-Ponthierry" OR "Saint-Mande" OR "Saint-Maur-des-Fosses" OR "Saint-Ouen" OR "Sartrouville" OR "Savigny le Temple" OR "St Ouen" OR "St. Ouen" OR "Suresnes" OR "Toussus-le-Noble" OR "V??lizy-Villacoublay" OR "Vanves" OR "Velizy Villacoublay" OR "Vélizy-Villacoublay" OR "Versailles" OR "Villebon-sur-Yvette" OR "Ville-dAvray" OR "Villejuif" OR "Villejust" OR "Villeneuve-sous-Dammartin" OR "Villepinte" OR "Villers Saint Paul" OR "Villetaneuse" OR "Vincennes" OR "Vitry-sur-Seine" OR "Voisins le Bretonneux" OR "Wissous") AND CU=("France"))

City	Start-up	Patent	Scientific Literature
Amsterdam	(city:("Aalsmeer" OR "Alkmaar" OR "Almere" OR "Amstelveen" OR "Amsterdam" OR "Amsterdam" OR "Ankeveen" OR "Austerlitz" OR "Baarn" OR "Badhoevedorp" OR "Beverwijk" OR "Bilthoven" OR "Blaricum" OR "Bovenkarspel" OR "Breukelen" OR "Bunschoten" OR "De Ronde Venen" OR "Diemen" OR "Doorn" OR "Driebergen" OR "Driebergen-Rijsenburg" OR "Duivendrecht" OR "Eemnes" OR "Grootebroek" OR "Haarlem" OR "Heemstede" OR "Hilversum" OR "Hoevelaken" OR "Hoofddorp" OR "Huis ter Heide" OR "Huizen" OR "Langbroek" OR "Laren" OR "Lelystad" OR "Leusden" OR "Lijnden" OR "Maarsbergen" OR "Maarssen" OR "Maarssen" OR "Middenmeer" OR "Mijdrecht" OR "Naarden" OR "Naarden" OR "Nieuwegein" OR "Putten" OR "Schiphol" OR "Schiphol-Rijk" OR "Soest" OR "Soesterberg" OR "Urk" OR "Utrecht" OR "Utrecht" OR "Weesp" OR "Wormerveer" OR "Zaandam" OR "Zeist" OR "Zuidoostbeemster") AND country:("Netherlands"))	((INAD=("Aalsmeer" OR "Alkmaar" OR "Almere" OR "Amstelveen" OR "Amsterdam" OR "Amsterdam" OR "Ankeveen" OR "Austerlitz" OR "Baarn" OR "Badhoevedorp" OR "Beverwijk" OR "Bilthoven" OR "Blaricum" OR "Bovenkarspel" OR "Breukelen" OR "Bunschoten" OR "De Ronde Venen" OR "Diemen" OR "Doorn" OR "Driebergen" OR "Driebergen" OR "Driebergen-Rijsenburg" OR "Duivendrecht" OR "Eemnes" OR "Grootebroek" OR "Haarlem" OR "Heemstede" OR "Hilversum" OR "Hoevelaken" OR "Hoofddorp" OR "Huis ter Heide" OR "Huizen" OR "Langbroek" OR "Laren" OR "Lelystad" OR "Leusden" OR "Lijnden" OR "Maarsbergen" OR "Maarssen" OR "Maarssen" OR "Middenmeer" OR "Mijdrecht" OR "Naarden" OR "Naarden" OR "Nieuwegein" OR "Putten" OR "Schiphol" OR "Schiphol-Rijk" OR "Soest" OR "Soesterberg" OR "Urk" OR "Utrecht" OR "Utrecht" OR "Weesp" OR "Wormerveer" OR "Zaandam" OR "Zeist" OR "Zuidoostbeemster")) AND (INAD=(Netherlands) OR PAOD=(Netherlands))) OR ((INAD=("Aalsmeer" OR "Alkmaar" OR "Almere" OR "Amstelveen" OR "Amsterdam" OR "Amsterdam" OR "Ankeveen" OR "Austerlitz" OR "Baarn" OR "Badhoevedorp" OR "Beverwijk" OR "Bilthoven" OR "Blaricum" OR "Bovenkarspel" OR "Breukelen" OR "Bunschoten" OR "De Ronde Venen" OR "Diemen" OR "Doorn" OR "Driebergen" OR "Driebergen" OR "Driebergen-Rijsenburg" OR "Duivendrecht" OR "Eemnes" OR "Grootebroek" OR "Haarlem" OR "Heemstede" OR "Hilversum" OR "Hoevelaken" OR "Hoofddorp" OR "Huis ter Heide" OR "Huizen" OR "Langbroek" OR "Laren" OR "Lelystad" OR "Leusden" OR "Lijnden" OR "Maarsbergen" OR "Maarssen" OR "Maarssen" OR "Middenmeer" OR "Mijdrecht" OR "Naarden" OR "Naarden" OR "Nieuwegein" OR "Putten" OR "Schiphol" OR "Schiphol-Rijk" OR "Soest" OR "Soesterberg" OR "Urk" OR "Utrecht" OR "Utrecht" OR "Weesp" OR "Wormerveer" OR "Zaandam" OR "Zeist" OR "Zuidoostbeemster") OR PAOD=("Aalsmeer" OR "Alkmaar" OR "Almere" OR "Amstelveen" OR "Amsterdam" OR "Amsterdam" OR "Ankeveen" OR "Austerlitz" OR "Baarn" OR "Badhoevedorp" OR "Beverwijk" OR "Bilthoven" OR "Blaricum" OR "Bovenkarspel" OR "Breukelen" OR "Bunschoten" OR "De Ronde Venen" OR "Diemen" OR "Doorn" OR "Driebergen" OR "Driebergen" OR "Driebergen-Rijsenburg" OR "Duivendrecht" OR "Eemnes" OR "Grootebroek" OR "Haarlem" OR "Heemstede" OR "Hilversum" OR "Hoevelaken" OR "Hoofddorp" OR "Huis ter Heide" OR "Huizen" OR "Langbroek" OR "Laren" OR "Lelystad" OR "Leusden" OR "Lijnden" OR "Maarsbergen" OR "Maarssen" OR "Maarssen" OR "Middenmeer" OR "Mijdrecht" OR "Naarden" OR "Naarden" OR "Nieuwegein" OR "Putten" OR "Schiphol" OR "Schiphol-Rijk" OR "Soest" OR "Soesterberg" OR "Urk" OR "Utrecht" OR "Utrecht" OR "Weesp" OR "Wormerveer" OR "Zaandam" OR "Zeist" OR "Zuidoostbeemster")) AND PRC=("NL"))	(CI=("Aalsmeer" OR "Alkmaar" OR "Almere" OR "Amstelveen" OR "Amsterdam" OR "Amsterdam" OR "Ankeveen" OR "Austerlitz" OR "Baarn" OR "Badhoevedorp" OR "Beverwijk" OR "Bilthoven" OR "Blaricum" OR "Bovenkarspel" OR "Breukelen" OR "Bunschoten" OR "De Ronde Venen" OR "Diemen" OR "Doorn" OR "Driebergen" OR "Driebergen" OR "Driebergen-Rijsenburg" OR "Duivendrecht" OR "Eemnes" OR "Grootebroek" OR "Haarlem" OR "Heemstede" OR "Hilversum" OR "Hoevelaken" OR "Hoofddorp" OR "Huis ter Heide" OR "Huizen" OR "Langbroek" OR "Laren" OR "Lelystad" OR "Leusden" OR "Lijnden" OR "Maarsbergen" OR "Maarssen" OR "Maarssen" OR "Middenmeer" OR "Mijdrecht" OR "Naarden" OR "Naarden" OR "Nieuwegein" OR "Putten" OR "Schiphol" OR "Schiphol-Rijk" OR "Soest" OR "Soesterberg" OR "Urk" OR "Utrecht" OR "Utrecht" OR "Weesp" OR "Wormerveer" OR "Zaandam" OR "Zeist" OR "Zuidoostbeemster") AND CU=("Netherlands"))
Boston	(city:("Acton" OR "Allston" OR "Amesbury" OR "Andover" OR "Andover" OR "Arlington" OR "Arlington" OR "Ashland" OR "Auburndale" OR "Bedford" OR "Beverly" OR "Beverly" OR "Billerica" OR "Billerica" OR "Boston" OR "Boston" OR "Boxborough" OR "Braintree" OR "Brighton" OR "Brookline" OR "Brookline" OR "Burlington" OR "Cambridge" OR "Canton" OR "Canton" OR "Carlisle" OR "Chelmsford" OR "Chelmsford" OR "Chelsea" OR "Chestnut Hill" OR "Concord" OR "Danvers" OR "Danvers" OR "Dedham" OR "Dedham" OR "Dorchester" OR "Dover" OR "East Taunton" OR "Fall River" OR "Fitchburg" OR "Foxborough" OR "Framingham" OR "Framingham" OR "Franklin" OR "Gloucester" OR "Hampton" OR "Holliston" OR "Holliston" OR "Hopkinton" OR "Hopkinton" OR "Jamaica Plain" OR "Lawrence" OR "Lawrence" OR "Lexington" OR "Lexington" OR "Lincoln" OR "Littleton" OR "Littleton" OR "Lowell" OR "Lowell" OR "Mansfield" OR "Marblehead" OR "Marlborough" OR "Marlborough" OR "Maynard" OR "Medfield" OR "Medfield" OR "Medford" OR "Medford" OR "Middleboro" OR "Milford" OR "Milford" OR "Millis" OR "Nashua" OR "Nashua" OR "Natick" OR "Natick" OR "Needham" OR "Needham" OR "Newburyport" OR "Newburyport" OR "Newton" OR "Newton" OR "Newton Center" OR "North Andover" OR "North Billerica" OR "North Billerica" OR "North Easton" OR "North Reading" OR "Norwell" OR "Norwell" OR "Norwood" OR "Peabody" OR "Plainville" OR "Plymouth" OR "Providence" OR "Quincy" OR "Raynham" OR "Raynham" OR "Reading" OR "Riverside" OR "Rockland" OR "Salem" OR "Saugus" OR "Sherborn" OR "Shirley" OR "Shrewsbury" OR "Somerville" OR "Somerville" OR "South Boston" OR "South Easton" OR "South Easton" OR "South Lancaster" OR "Southborough" OR "Southborough" OR "Sudbury" OR "Taunton" OR "Tewksbury" OR "Wakefield" OR "Waltham" OR "Waltham" OR "Watertown" OR "Watertown" OR "Wayland" OR "Wellesley" OR "Wellesley" OR "Wenham" OR "West Boylston" OR "West Bridgewater" OR "West Newton" OR "Westborough" OR "Westborough" OR "Westford" OR "Westford" OR "Weston" OR "Westwood" OR "Wilmington" OR "Wilmington" OR "Winchester" OR "Woburn" OR "Woburn" OR "Woonsocket" OR "Worcester" OR "Worcester" OR "Wrentham") AND country:("United States"))	((INAD=("Acton" OR "Allston" OR "Amesbury" OR "Andover" OR "Andover" OR "Arlington" OR "Arlington" OR "Ashland" OR "Auburndale" OR "Bedford" OR "Beverly" OR "Beverly" OR "Billerica" OR "Billerica" OR "Boston" OR "Boston" OR "Boxborough" OR "Boxborough" OR "Braintree" OR "Brighton" OR "Brookline" OR "Brookline" OR "Burlington" OR "Cambridge" OR "Canton" OR "Canton" OR "Carlisle" OR "Chelmsford" OR "Chelmsford" OR "Chelsea" OR "Chestnut Hill" OR "Concord" OR "Danvers" OR "Danvers" OR "Dedham" OR "Dedham" OR "Dorchester" OR "Dover" OR "East Taunton" OR "Fall River" OR "Fitchburg" OR "Foxborough" OR "Framingham" OR "Framingham" OR "Franklin" OR "Gloucester" OR "Hampton" OR "Holliston" OR "Hopkinton" OR "Hopkinton" OR "Jamaica Plain" OR "Lawrence" OR "Lawrence" OR "Lexington" OR "Lexington" OR "Lincoln" OR "Littleton" OR "Littleton" OR "Lowell" OR "Lowell" OR "Mansfield" OR "Marblehead" OR "Marlborough" OR "Marlborough" OR "Maynard" OR "Medfield" OR "Medfield" OR "Medford" OR "Medford" OR "Middleboro" OR "Milford" OR "Milford" OR "Millis" OR "Nashua" OR "Nashua" OR "Natick" OR "Natick" OR "Needham" OR "Needham" OR "Newburyport" OR "Newburyport" OR "Newton" OR "Newton" OR "Newton Center" OR "North Andover" OR "North Billerica" OR "North Billerica" OR "North Easton" OR "North Reading" OR "Norwell" OR "Norwell" OR "Norwood" OR "Peabody" OR "Plainville" OR "Plymouth" OR "Providence" OR "Quincy" OR "Raynham" OR "Raynham" OR "Reading" OR "Riverside" OR "Rockland" OR "Salem" OR "Saugus" OR "Sherborn" OR "Shirley" OR "Shrewsbury" OR "Somerville" OR "Somerville" OR "South Boston" OR "South Easton" OR "South Easton" OR "South Lancaster" OR "Southborough" OR "Southborough" OR "Sudbury" OR "Taunton" OR "Tewksbury" OR "Wakefield" OR "Waltham" OR "Waltham" OR "Watertown" OR "Watertown" OR "Wayland" OR "Wellesley" OR "Wellesley" OR "Wenham" OR "West Boylston" OR "West Bridgewater" OR "West Newton" OR "Westborough" OR "Westborough" OR "Westford" OR "Westford" OR "Weston" OR "Westwood" OR "Wilmington" OR "Wilmington" OR "Winchester" OR "Woburn" OR "Woburn" OR "Woonsocket" OR "Worcester" OR "Worcester" OR "Wrentham")) AND (INAD=("United States" OR "USA") OR PAOD=("United States" OR "USA"))) OR ((INAD=("Acton" OR "Allston" OR "Amesbury" OR "Andover" OR "Andover" OR "Arlington" OR "Arlington" OR "Ashland" OR "Auburndale" OR "Bedford" OR "Beverly" OR "Beverly" OR "Billerica" OR "Billerica" OR "Boston" OR "Boston" OR "Boxborough" OR "Boxborough" OR "Braintree" OR "Brighton" OR "Brookline" OR "Brookline" OR "Burlington" OR "Cambridge" OR "Canton" OR "Canton" OR "Carlisle" OR "Chelmsford" OR "Chelmsford" OR "Chelsea" OR "Chestnut Hill" OR "Concord" OR "Danvers" OR "Danvers" OR "Dedham" OR "Dedham" OR "Dorchester" OR "Dover" OR "East Taunton" OR "Fall River" OR "Fitchburg" OR "Foxborough" OR "Framingham" OR "Framingham" OR "Franklin" OR "Gloucester" OR "Hampton" OR "Holliston" OR "Hopkinton" OR "Hopkinton" OR "Jamaica Plain" OR "Lawrence" OR "Lawrence" OR "Lexington" OR "Lexington" OR "Lincoln" OR "Littleton" OR "Littleton" OR "Lowell" OR "Lowell" OR "Mansfield" OR "Marblehead" OR "Marlborough" OR "Marlborough" OR "Maynard" OR "Medfield" OR "Medfield" OR "Medford" OR "Medford" OR "Middleboro" OR "Milford" OR "Milford" OR "Millis" OR "Nashua" OR "Nashua" OR "Natick" OR "Natick" OR "Needham" OR "Needham" OR "Newburyport" OR "Newburyport" OR "Newton" OR "Newton" OR "Newton Center" OR "North Andover" OR "North Billerica" OR "North Billerica" OR "North Easton" OR "North Reading" OR "Norwell" OR "Norwell" OR "Norwood" OR "Peabody" OR "Plainville" OR "Plymouth" OR "Providence" OR "Quincy" OR "Raynham" OR "Raynham" OR "Reading" OR "Riverside" OR "Rockland" OR "Salem" OR "Saugus" OR "Sherborn" OR "Shirley" OR "Shrewsbury" OR "Somerville" OR "Somerville" OR "South Boston" OR "South Easton" OR "South Easton" OR "South Lancaster" OR "Southborough" OR "Southborough" OR "Sudbury" OR "Taunton" OR "Tewksbury" OR "Wakefield" OR "Waltham" OR "Waltham" OR "Watertown" OR "Watertown" OR "Wayland" OR "Wellesley" OR "Wellesley" OR "Wenham" OR "West Boylston" OR "West Bridgewater" OR "West Newton" OR "Westborough" OR "Westborough" OR "Westford" OR "Westford" OR "Weston" OR "Westwood" OR "Wilmington" OR "Wilmington" OR "Winchester" OR "Woburn" OR "Woburn" OR "Woonsocket" OR "Worcester" OR "Worcester" OR "Wrentham")) AND PRC=("US"))	(CI=("Acton" OR "Allston" OR "Amesbury" OR "Andover" OR "Andover" OR "Arlington" OR "Arlington" OR "Ashland" OR "Auburndale" OR "Bedford" OR "Beverly" OR "Beverly" OR "Billerica" OR "Billerica" OR "Boston" OR "Boston" OR "Boxborough" OR "Boxborough" OR "Braintree" OR "Brighton" OR "Brookline" OR "Brookline" OR "Burlington" OR "Cambridge" OR "Canton" OR "Canton" OR "Carlisle" OR "Chelmsford" OR "Chelmsford" OR "Chelsea" OR "Chestnut Hill" OR "Concord" OR "Danvers" OR "Danvers" OR "Dedham" OR "Dedham" OR "Dorchester" OR "Dover" OR "East Taunton" OR "Fall River" OR "Fitchburg" OR "Foxborough" OR "Framingham" OR "Framingham" OR "Franklin" OR "Gloucester" OR "Hampton" OR "Holliston" OR "Hopkinton" OR "Hopkinton" OR "Jamaica Plain" OR "Lawrence" OR "Lawrence" OR "Lexington" OR "Lexington" OR "Lincoln" OR "Littleton" OR "Littleton" OR "Lowell" OR "Lowell" OR "Mansfield" OR "Marblehead" OR "Marlborough" OR "Marlborough" OR "Maynard" OR "Medfield" OR "Medfield" OR "Medford" OR "Medford" OR "Middleboro" OR "Milford" OR "Milford" OR "Millis" OR "Nashua" OR "Nashua" OR "Natick" OR "Natick" OR "Needham" OR "Needham" OR "Newburyport" OR "Newburyport" OR "Newton" OR "Newton" OR "Newton Center" OR "North Andover" OR "North Billerica" OR "North Billerica" OR "North Easton" OR "North Reading" OR "Norwell" OR "Norwell" OR "Norwood" OR "Peabody" OR "Plainville" OR "Plymouth" OR "Providence" OR "Quincy" OR "Raynham" OR "Raynham" OR "Reading" OR "Riverside" OR "Rockland" OR "Salem" OR "Saugus" OR "Sherborn" OR "Shirley" OR "Shrewsbury" OR "Somerville" OR "Somerville" OR "South Boston" OR "South Easton" OR "South Easton" OR "South Lancaster" OR "Southborough" OR "Southborough" OR "Sudbury" OR "Taunton" OR "Tewksbury" OR "Wakefield" OR "Waltham" OR "Waltham" OR "Watertown" OR "Watertown" OR "Wayland" OR "Wellesley" OR "Wellesley" OR "Wenham" OR "West Boylston" OR "West Bridgewater" OR "West Newton" OR "Westborough" OR "Westborough" OR "Westford" OR "Westford" OR "Weston" OR "Westwood" OR "Wilmington" OR "Wilmington" OR "Winchester" OR "Woburn" OR "Woburn" OR "Woonsocket" OR "Worcester" OR "Worcester" OR "Wrentham") AND CU=("United States" OR "USA"))

Table 4 | Search parameters of variable category for biotechnology search

Category	Query
Start-up	(industry: ("Pharmaceuticals" OR "Biotechnology") AND desc: ("cell therapy" ~ 3 OR "cellular therapy" ~ 3 OR "gene therapy" ~ 3 OR "genetic therapy" ~ 3 OR "cell therapies" ~ 3 OR "cellular therapies" ~ 3 OR "gene therapies" ~ 3 OR "genetic therapies" ~ 3 OR "genes therapy" ~ 3 OR "genes therapies" ~ 3 OR "cell therapeutic" ~ 3 OR "cellular therapeutic " ~ 3 OR "gene therapeutic " ~ 3 OR "genetic therapeutic " ~ 3 OR "cell therapeutics" ~ 3 OR "cellular therapeutics" ~ 3 OR "gene therapeutics" ~ 3 OR "genetic therapeutics" ~ 3 OR "genes therapeutic" ~ 3 OR "genes therapeutics" ~ 3 OR "cell medicine" ~ 3 OR "cellular medicine" ~ 3 OR "gene medicine" ~ 3 OR "genetic medicine" ~ 3 OR "genome medicine" ~ 3 OR "genomic medicine" ~ 3 OR (("gene editing" ~ 3 OR "gene edit" ~ 3 OR "genome editing" ~ 3 OR "genome edit" ~ 3 OR "stem cell" * OR "pluripotent cell" * OR antibod * OR ADC OR mAB OR microbiom * OR oncolytic OR aptamer * OR "fusion protein" * OR "recombinant protein" * OR "drug conjugate" * OR "drug-conjugate" * OR "nucleic acid" * OR antisense OR iRNA OR iRNAs OR RNAi OR RNAis OR mRNA OR mRNAs OR lncRNA OR lncRNAs OR siRNA OR siRNAs OR miRNA OR miRNAs OR microRNA OR microRNAs OR tRNA OR tRNAs OR rRNA OR rRNAs OR piRNA OR piRNAs OR aRNA OR aRNAs OR asRNA OR asRNAs OR shRNA OR shRNAs OR ncRNA OR ncRNAs OR dsRNAs OR dsRNAs OR aptamer * OR transgene * OR "interfering RNA" OR "interfering RNAs" OR "RNA interference" OR "pre-mRNA" OR "pre-mRNAs" OR oligonucleotide * OR polynucleotide * OR oligopeptide * OR polypeptide * OR "Treg" * OR "T reg" *) AND (therap * OR immunotherap * OR immuno-therap * OR treatment * OR drug * OR "pharmaceutical" OR "biopharmaceutical" OR medicine *)) OR "genetic drug" ~ 3 OR "genetic drugs" ~ 3 OR "genome drug" ~ 3 OR "genome drugs" ~ 3 OR "genomic drug" ~ 3 OR "genomic drugs" ~ 3 OR "CAR-T" OR "CAR T" OR "chimeric antigen receptor T cell" OR "chimeric antigen receptor T cells" OR "CAR-NK" OR "CAR NK" OR "chimeric antigen receptor NK cell" OR "chimeric antigen receptor NK cells" OR "chimeric antigen receptor natural killer cell" OR "chimeric antigen receptor natural killer cells" OR "CAR-DC" OR "CAR DC" OR "chimeric antigen receptor DC cell" OR "chimeric antigen receptor DC cells" OR "chimeric antigen receptor dendritic cell" OR "chimeric antigen receptor dendritic cells" OR "CAR-NKT" OR "CAR NKT" OR "chimeric antigen receptor NKT cell" OR "chimeric antigen receptor NKT cells" OR "chimeric antigen receptor natural killer T cell" OR "chimeric antigen receptor natural killer T cells" OR "tumor infiltrating lymphocyte" OR "tumor infiltrating lymphocytes" OR "tumor-infiltrating lymphocyte" OR "tumour-infiltrating lymphocytes" OR "tumour infiltrating lymphocyte" OR "tumour infiltrating lymphocytes" OR "tumour-infiltrating lymphocyte" OR "tumour-infiltrating lymphocytes" OR "TIL cell" OR "TIL cells" OR "autologous cell" ~ 3 OR "allogeneic cell" ~ 3 OR "off-the-shelf cell" ~ 3 OR "autologous cells" ~ 3 OR "allogeneic cells" ~ 3 OR "off-the-shelf cells" ~ 3 OR "engineered cell" ~ 3 OR "engineered cells" ~ 3 OR "chimeric antigen receptor" * OR "DNA therapy" ~ 3 OR "RNA therapy" ~ 3 OR "DNA therapeutics" ~ 3 OR "RNA therapeutics" ~ 3 OR "DNA drug" * OR "DNA medicine" * OR "RNA drug" * OR "RNA medicine" * OR "DNA drug" ~ 3 OR "RNA drug" ~ 3 OR "DNA drugs" ~ 3 OR "RNA drugs" ~ 3 OR "protein therapy" ~ 3 OR "peptide therapy" ~ 3 OR "protein therapeutics" ~ 3 OR "peptide therapeutics" ~ 3 OR "protein drug" ~ 3 OR "peptide drug" ~ 3 OR "protein drugs" ~ 3 OR "peptide drugs" ~ 3 OR "proteins therapy" ~ 3 OR "peptides therapy" ~ 3 OR "proteins therapeutics" ~ 3 OR "peptides therapeutics" ~ 3 OR "proteins drug" ~ 3 OR "peptides drug" ~ 3 OR "proteins drugs" ~ 3 OR "peptides drugs" ~ 3 OR PROTAC OR "proteolysis targeting chimer" * OR "proteolysis-targeting chimer" * OR vaccine * OR "biologics" OR "cell transplant" * OR "cellular transplant" *))
Patent	(IPCSmart=(A61K 35/12, A61K 35/66, A61K 38, A61K 39, A61K 48) OR CPCSmart=(A61K 35/12, A61K 35/66, A61K 38, A61K 39, A61K 48, A61K2035, A61K2239) OR ((IPCSmart=(C07K, C08, C12N) OR CPCSmart=(C07K, C08, C12N, C12Y)) AND TitleAbstract=((((cell OR cells OR T-cell* OR cellular) NEAR3 *therap*) OR antibod* OR "mAb" OR immunoglobulin* OR *peptide* OR (protein* AND NOT (protein* NEAR3 inhibitor*)) OR microbiom* OR microbiot* OR microflor* OR "chimeric antigen receptor*" OR "nucleic acid*" OR RNA* OR antisense OR iRNA OR iRNAs OR RNAi OR RNAis OR mRNA OR mRNAs OR lncRNA OR lncRNAs OR siRNA OR siRNAs OR miRNA OR miRNAs OR microRNA OR microRNAs OR tRNA OR tRNAs OR rRNA OR rRNAs OR piRNA OR piRNAs OR aRNA OR aRNAs OR asRNA OR asRNAs OR shRNA OR shRNAs OR ncRNA OR ncRNAs OR dsRNAs OR dsRNAs OR aptamer* OR transgene* OR "interfering RNA" OR "interfering RNAs" OR "pre-mRNA" OR "pre-mRNAs" OR (gene ADJ silencing) OR (gene ADJ knockout) OR (gene ADJ knock-out) OR DNA* OR oligonucleotid* OR *nucleotide* OR ribonucleic acid* OR oligomer* OR oncolytic OR "proteolysis target* chimer*" OR antigen-binding* OR antigen binding* OR immunoglobulin* OR recombinant* OR (gene NEAR1 edit*) OR (genetic NEAR1 edit*) OR (genome NEAR1 engineer*) OR (genetic NEAR1 engineer*) OR (genomic NEAR1 engineer*) OR CRISPR OR (Clustered ADJ Regularly ADJ Interspaced ADJ Short ADJ palindromic ADJ Repeat*) OR cas9 OR gRNA OR gRNAs OR (guide ADJ RNA) OR (guide ADJ RNAs) OR TALEN OR TALENs OR (zinc ADJ finger ADJ nuclease*) OR ZFN OR ZFNs OR (transcription ADJ activator ADJ like ADJ effector ADJ based ADJ nuclease*) OR meganuclease* OR ((AAV OR (AAV ADJ based) OR rAAV OR adeno-associated virus* OR non-viral OR retrovir* OR adenovir* OR vaccinia OR (herpes ADJ simplex) OR lentivir* OR (viral NEAR2 vector*) OR (viral NEAR2 particle*) OR (virus NEAR2 vector*) OR (virus NEAR2 particle*)) NEAR5 (vector* OR delivery OR delivering)) OR PROTAC OR PROTACs OR "protein degrad*" OR "CAR-T" OR "CAR T" OR "chimeric antigen receptor T cell" OR "chimeric antigen receptor T cells" OR "CAR-NK" OR "CAR NK" OR "chimeric antigen receptor NK cell" OR "chimeric antigen receptor NK cells" OR "chimeric antigen receptor natural killer cell" OR "chimeric antigen receptor natural killer cells" OR "CAR-DC" OR "CAR DC" OR "chimeric antigen receptor DC cell" OR "chimeric antigen receptor DC cells" OR "chimeric antigen receptor dendritic cell" OR "chimeric antigen receptor dendritic cells" OR "CAR-NKT" OR "CAR NKT" OR "chimeric antigen receptor NKT cell" OR "chimeric antigen receptor NKT cells" OR "chimeric antigen receptor natural killer T cell" OR "chimeric antigen receptor natural killer T cells" OR "tumor infiltrating lymphocyte" OR "tumor infiltrating lymphocytes" OR "tumor-infiltrating lymphocyte" OR "tumour-infiltrating lymphocytes" OR "tumour infiltrating lymphocyte" OR "tumour infiltrating lymphocytes" OR "tumour-infiltrating lymphocyte" OR "tumour-infiltrating lymphocytes" OR "TIL cell" OR "TIL cells" OR ((engineered OR engineer* OR engineering OR allogeneic OR syngeneic OR off-the-shelf OR "off the shelf" OR autologous OR stem OR embryonic OR mesenchymal OR hematopoietic OR progenitor OR stem-cell OR stem-cells OR pluripotent OR multipotent OR neural ADJ stem OR stromal OR iPS OR iPSs OR iPSC OR iPSCs OR adoptive OR activated) NEAR3 (cell OR cells OR lymphocyte* OR "b cell" OR "b cells" OR "t cell" OR "t cells" OR "dendritic cell" OR "dendritic cells" OR "NK cell" OR "NK cells" OR "NKT cell" OR "NKT cells")) OR iPSC OR iPSCs OR stem-cell OR stem-cells OR "stem cell" OR "stem cells" OR (target* NEAR3 (protein* OR polypeptide*) NEAR3 (degrad* OR ubiquitin* OR proteasome* OR proteolysis)) OR vaccine* OR "Treg*" OR "T reg*" OR ((regulatory NEAR1 ("T cell*" OR "T-cell*")))))) AND (drug* OR pharmaceutical* OR *therap* OR treatment* OR medication* OR medicine*)) OR ((IPCSmart=(A61P) OR CPCSmart=(A61P)) AND TitleAbstract=((((cell OR cells OR T-cell* OR cellular) NEAR3 *therap*) OR antibod* OR "mAb" OR immunoglobulin* OR *peptide* OR (protein* AND NOT (protein* NEAR3 inhibitor*)) OR microbiom* OR microbiot* OR microflor* OR "chimeric antigen receptor*" OR "nucleic acid*" OR RNA* OR antisense OR iRNA OR iRNAs OR RNAi OR RNAis OR mRNA OR mRNAs OR lncRNA OR lncRNAs OR siRNA OR siRNAs OR miRNA OR miRNAs OR microRNA OR microRNAs OR tRNA OR tRNAs OR rRNA OR rRNAs OR piRNA OR piRNAs OR aRNA OR aRNAs OR asRNA OR asRNAs OR shRNA OR shRNAs OR ncRNA OR ncRNAs OR dsRNAs OR dsRNAs OR aptamer* OR transgene* OR "interfering RNA" OR "interfering RNAs" OR "pre-mRNA" OR (gene ADJ silencing) OR (gene ADJ knockout) OR (gene ADJ knock-out) OR DNA* OR oligonucleotid* OR *nucleotide* OR ribonucleic acid* OR oligomer* OR oncolytic OR "proteolysis target* chimer*" OR antigen-binding* OR antigen binding* OR immunoglobulin* OR recombinant* OR (gene NEAR1 edit*) OR (genetic NEAR1 edit*) OR (genome NEAR1 edit*) OR (genomic NEAR1 edit*) OR (gene NEAR1 transfer*) OR (genetic NEAR1 transfer*) OR (gene NEAR1 deliver*) OR (genetic NEAR1 deliver*) OR (genome NEAR1 engineer*) OR (genetic NEAR1 engineer*) OR (genomic NEAR1 engineer*) OR CRISPR OR (Clustered ADJ Regularly ADJ Interspaced ADJ Short ADJ palindromic ADJ Repeat*) OR cas9 OR gRNA OR gRNAs OR (guide ADJ RNA) OR (guide ADJ RNAs) OR TALEN OR TALENs OR (zinc ADJ finger ADJ nuclease*) OR ZFN OR ZFNs OR (transcription ADJ activator ADJ like ADJ effector ADJ based ADJ nuclease*) OR meganuclease* OR ((AAV OR (AAV ADJ based) OR rAAV OR adeno-associated virus* OR non-viral OR retrovir* OR adenovir* OR vaccinia OR (herpes ADJ simplex) OR lentivir* OR (viral NEAR2 vector*) OR (viral NEAR2 particle*) OR (virus NEAR2 vector*) OR (virus NEAR2 particle*)) NEAR5 (vector* OR delivery OR delivering)) OR PROTAC OR PROTACs OR "protein degrad*" OR "CAR-T" OR "CAR T" OR "chimeric antigen receptor T cell" OR "chimeric antigen receptor T cells" OR "CAR-NK" OR "CAR NK" OR "chimeric antigen receptor NK cell" OR "chimeric antigen receptor NK cells" OR "chimeric antigen receptor natural killer cell" OR "chimeric antigen receptor natural killer cells" OR "CAR-DC" OR "CAR DC" OR "chimeric antigen receptor DC cell" OR "chimeric antigen receptor DC cells" OR "chimeric antigen receptor dendritic cell" OR "chimeric antigen receptor dendritic cells" OR "CAR-NKT" OR "CAR NKT" OR "chimeric antigen receptor NKT cell" OR "chimeric antigen receptor NKT cells" OR "chimeric antigen receptor natural killer T cell" OR "chimeric antigen receptor natural killer T cells" OR "tumor infiltrating lymphocyte" OR "tumor infiltrating lymphocytes" OR "tumor-infiltrating lymphocyte" OR "tumour-infiltrating lymphocytes" OR "tumour infiltrating lymphocyte" OR "tumour infiltrating lymphocytes" OR "tumour-infiltrating lymphocyte" OR "tumour-infiltrating lymphocytes" OR "TIL cell" OR "TIL cells" OR ((engineered OR engineer* OR engineering OR allogeneic OR syngeneic OR off-the-shelf OR "off the shelf" OR autologous OR stem OR embryonic OR mesenchymal OR hematopoietic OR progenitor OR stem-cell OR stem-cells OR pluripotent OR multipotent OR neural ADJ stem OR stromal OR iPS OR iPSs OR iPSC OR iPSCs OR adoptive OR activated) NEAR3 (cell OR cells OR lymphocyte* OR "b cell" OR "b cells" OR "t cell" OR "t cells" OR "dendritic cell" OR "dendritic cells" OR "NK cell" OR "NK cells" OR "NKT cell" OR "NKT cells")) OR iPSC OR iPSCs OR stem-cell OR stem-cells OR "stem cell" OR "stem cells" OR (target* NEAR3 (protein* OR polypeptide*) NEAR3 (degrad* OR ubiquitin* OR proteasome* OR proteolysis)) OR vaccine* OR "Treg*" OR "T reg*" OR ((regulatory NEAR1 ("T cell*" OR "T-cell*")))))) AND NOT (IPCSmart=(A01B, A01C, A01D, A01F, A01G, A01H, A01J, A01L, A01M, A01N, A01P) OR CPCSmart=(A01B, A01Bmiss, A01C, A01Cmiss, A01D, A01Dmiss, A01F, A01Fmiss, A01G, A01Gmiss, A01H, A01Hmiss, A01J, A01Jmiss, A01Kmiss, A01L, A01Lmiss, A01M, A01Mmiss, A01N, A01Nmiss, A01P, A01Pmiss)) AND FilingDate=(>=2017-01-01)
Scientific Literature	((TS=(((cell OR cells OR cellular OR "cell-based" OR "cell based" OR immunocellular) NEAR/3 (therapy OR therapies OR therapeutic OR therapeutics OR therap* OR immunotherapy OR immunotherapies OR immunotherapeutic OR immunotherapeutics OR immunotherap* OR immuno-therapy OR immuno-therapies OR immuno-therapeutic OR immuno-therapeutics OR immuno-therap*)) OR ("chimeric antigen receptor" OR "CAR-T" OR "CAR T" OR "chimeric antigen receptor T cell" OR "chimeric antigen receptor T cells" OR "CAR-NK" OR "CAR NK" OR "chimeric antigen receptor NK cell" OR "chimeric antigen receptor NK cells" OR "chimeric antigen receptor natural killer cell" OR "chimeric antigen receptor natural killer cells" OR "CAR-DC" OR "CAR DC" OR "chimeric antigen receptor DC cell" OR "chimeric antigen receptor DC cells" OR "chimeric antigen receptor dendritic cell" OR "chimeric antigen receptor dendritic cells" OR "CAR-NKT" OR "CAR NKT" OR "chimeric antigen receptor NKT cell" OR "chimeric antigen 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cells")) OR iPSC OR iPSCs OR stem-cell OR stem-cells OR "stem cell" OR "stem cells") AND (*therapy OR *therapies OR *therapeutic* OR *therapeutics OR clinical OR pre-clinical OR preclinical OR treatment OR treating OR patient OR patients OR immunotherapy OR immunotherapeutic* OR immunotherap* OR "immuno-therapy" OR "immuno-therapeutic" OR "immuno-therapeutics" OR "immuno-therap*" OR "immuno therapy" OR "immuno therapeutic" OR "immuno therapeutics")) OR (cytotherapy OR cytotherap* OR "cell transplantation" OR "cellular transplantation" OR "cell transplant*" OR "therapeutic cell" OR "therapeutic cells" OR "cell therapy" OR "cellular therapy"))) OR (TS=((("gene therapy" OR "gene therapies" OR "gene therapeutic" OR "gene therapeutics" OR "gene therap*" OR "genetic therapy" OR "genetic therapies" OR "genetic therapeutic" OR "genetic therapeutics" OR "genetic therap*" OR "RNA therapy" OR "RNA therapies" OR "RNA therapeutic" OR "RNA therapeutics" OR "RNA therapeutic*" OR "DNA therapy" OR "DNA therapies" OR "DNA therapeutic" OR "DNA therapeutics" OR "DNA therapeutic*") OR ((antisense OR RNAi OR RNAis OR mRNA OR mRNAs OR lncRNA OR lncRNAs OR siRNA OR SiRNAs OR miRNA OR miRNAs OR microRNA OR microRNAs OR tRNA OR tRNAs OR rRNA OR rRNAs OR piRNA OR piRNAs OR aRNA OR aRNAs OR asRNA OR asRNAs OR shRNA OR shRNAs OR ncRNA OR ncRNAs OR dsRNAs OR dsRNAs OR aptamer* OR transgene* OR oligomer* OR "interfering RNA" OR "interfering RNAs" OR "pre-mRNA" OR "pre-mRNAs") NEAR/3 (*therapy OR *therapies OR *therapeutic* OR *therapeutics OR clinical OR pre-clinical OR preclinical OR treatment OR treating OR patient OR patients OR drug*)) OR ((antisense OR RNA OR RNAi OR RNAis OR mRNA OR mRNAs OR lncRNA OR lncRNAs OR siRNA OR SiRNAs OR miRNA OR miRNAs OR microRNA OR microRNAs OR tRNA OR tRNAs OR rRNA OR rRNAs OR piRNA OR piRNAs OR aRNA OR aRNAs OR asRNA OR asRNAs OR shRNA OR shRNAs OR ncRNA OR ncRNAs OR dsRNAs OR dsRNAs OR oligonucleotide* OR polynucleotide* OR *nucleotide OR *nucleotides OR aptamer* OR transgene* OR "ribonucleic acid*" OR oligomer* OR "pre-mRNA" OR "pre-mRNAs" OR (homology NEAR/3 (recombin* OR integrat*)) OR (homologous NEAR/3 (recombin* OR integrat*))) AND ((gene OR genes OR genetic OR expression OR splicing) NEAR/3 (modulat* OR inhibit* OR regulat* OR suppres* OR "gene expression" OR mutation)) AND (*therapy OR *therapies OR *therapeutic* OR *therapeutics OR clinical OR pre-clinical OR preclinical OR treatment OR treating OR patient OR patients OR drug* OR disease*)) OR ((("gene edit*" OR "genetic edit*" OR "genome edit*" OR "gene transfer*" OR "genetic transfer*" OR "gene deliver*" OR "genetic deliver*" OR "genome engineer*" OR "genetic engineer*" OR CRISPR OR "Clustered Regularly Interspaced Short palindromic Repeat*" OR cas9 OR gRNA OR gRNAs OR "guide RNA" OR "guide RNAs" OR TALEN OR TALENs OR "zinc finger nuclease*" OR ZFN OR ZFNs OR "transcription activator like effector based nuclease*" OR meganuclease* OR ((AAV OR "AAV based" OR "AAV-based" OR rAAV OR "adeno-associated virus*" OR "non-viral" OR retrovir* OR adenovir* OR vaccinia OR "herpes simplex" OR lentivir* OR viral NEAR/2 vector* OR viral NEAR/2 particle* OR virus NEAR/2 vector* OR virus NEAR/2 particle*) AND (vector* OR particle* OR delivery OR delivering))) AND (*therapy OR *therapies OR *therapeutic* OR *therapeutics OR treatment OR treating OR clinical OR pre-clinical OR preclinical OR patient OR patients OR drug* OR disease*)))) OR (TS=((antibod* OR "antibody-drug conjugate*" OR "ADC" OR *protein* OR *peptide* OR "mAb" OR "monoclonal antibod*" OR "immunoglobulin*" OR "antigen-binding*" OR "antigen binding*") NEAR/3 (*therapy OR *therapies OR *therapeutic* OR *therapeutics OR treatment* OR drug*)) OR TS=(("biologics" OR oncolytic* OR microbiom* OR "PROTAC" OR "PROTACS" OR (proteolysis NEAR/1 targeting NEAR/1 chimera*) OR (proteoly* NEAR/1 target* NEAR/1 (chimera* OR molecule* OR moiety OR moieties)) OR (target* NEAR/3 (protein* OR polypeptide*) NEAR/3 (degrad* OR ubiquitin* OR proteasome* OR proteolysis))) NEAR/3 (*therapy OR *therapies OR *therapeutic* OR *therapeutics OR treatment* OR drug*)) OR TS=("biologic drug*" OR "biologic therap*" OR "biologic immunotherapy*" OR "biologic immuno-therap*" OR "biologic monotherap*" OR "biologic combination therap*" OR "virotherap*")))

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