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Future Forum 2025

Global Health

Using WebAI to monitor health landscapes.
A comparative study of Massachusetts and Baden-Württemberg.

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Imprint

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This study was commissioned by the German Center for Research and Innovation (DWIH) New York as part of the Future Forum 2025: Health. Tech. Diplomacy. held at the Broad Institute in Cambridge, MA in early October 2025. Reproduction and other distribution (including excerpts) is only permitted with reference to the source and upon submission of a specimen copy.

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Executive summary

This study presents a comparative analysis of the health sector ecosystems in Massachusetts (MA) and Baden-Württemberg (BW) using WebAI, an AI-driven large-scale web intelligence. The conducted comparison is illustrative, not exhaustive, and is designed to showcase the method rather than produce a definitive ranking in a transatlantic setting. Its central aim is to illustrate how WebAI can surface near-real-time insights into regional health innovation landscapes.

Health sector in numbers (2024):

- **Health-related firms**: 4.952 in MA, 4.498 in BW
- **Research-active firms**: 1,284 (25.9%) in MA, 522 (11.6%) in BW.
- **AI-using firms**: 420 (8.5%) in MA, 137 (3.0%) in BW.
- **Strongest geographic centres**: Boston, Cambridge (MA); Stuttgart, Heidelberg, Mannheim, Karlsruhe, Freiburg, Ulm (BW).

Corporate website texts were systematically collected and analysed with unsupervised machine learning methods, Large Language Models (LLMs) and retrieval-augmented generation (RAG) to provide actionable insights into ecosystem dynamics. The two regions were chosen as both Massachusetts and Baden-Württemberg are leading centres of health and innovation, with dense networks of hospitals, research institutions, and technology firms, while also offering contrasting socio-economic and regulatory contexts that enable a meaningful comparative analysis. Massachusetts can be characterized as a global hub for biopharmaceutical discovery, with high-risk, venture-backed firms developing e.g. RNAi therapeutics and scalable AI-driven health platforms. Baden-Württemberg excels in medical technology and precision engineering, with a dense network of specialised, privately owned providers, producing e.g. implantable neurotechnology and AI-enabled clinical tools. The analysis highlights opportunities for transatlantic collaboration, where Massachusetts companies can leverage Baden-Württemberg's manufacturing and clinical infrastructure, while German firms can benefit from the US biotechnology and digital health innovation. The study demonstrates that combining web intelligence, machine learning, and LLM-based synthesis enables real-time, large-scale insight into complex health ecosystems. The insights of this study can be used by state officials, cluster managers, university tech-transfer bureaus, investors, and hospital innovation leads.

Zusammenfassung

Diese Studie präsentiert eine vergleichende Analyse der Ökosysteme im Gesundheitswesen in Massachusetts (MA) und Baden-Württemberg (BW) unter Verwendung von WebAI, einer KI-gestützten groß angelegten Web-Intelligence. Der durchgeführte Vergleich ist illustrativ und dient eher der Veranschaulichung der Methode als der Erstellung einer endgültigen Rangliste im transatlantischen Kontext. Sein zentrales Ziel ist es, zu veranschaulichen, wie WebAI in Echtzeit Einblicke in regionale Gesundheitsinnovationslandschaften liefern kann.

Gesundheitssektoren in Zahlen (2024):

- **Unternehmen im Gesundheitssektor**: 4.952 in MA, 4.498 in BW
- **Forschungsaktive Unternehmen**: 1,284 (25.9%) in MA, 522 (11.6%) in BW.
- **KI-nutzende Unternehmen**: 420 (8.5%) in MA, 137 (3.0%) in BW.
- **Stärkste geographische Zentren**: Boston, Cambridge (MA); Stuttgart, Heidelberg, Mannheim, Karlsruhe, Freiburg, Ulm (BW).

Texte von Unternehmenswebsites wurden systematisch gesammelt und mit Hilfe von unüberwachten maschinellen Lernverfahren, Large Language Models (LLMs) und Retrieval-Augmented Generation (RAG) analysiert, um Erkenntnisse über die Dynamik der Ökosysteme zu gewinnen. Die beiden Regionen wurden ausgewählt, da sowohl MA als auch BW führende Zentren für Gesundheit und Innovation sind, über ein dichtes Netzwerk von Krankenhäusern, Forschungseinrichtungen und Technologieunternehmen verfügen und gleichzeitig kontrastierende sozioökonomische und regulatorische Rahmenbedingungen bieten. Massachusetts kann als globaler Knotenpunkt für biopharmazeutische Forschung charakterisiert werden, mit risikoreichen, von Risikokapital finanzierten Unternehmen, die z.B. RNAi-Therapeutika und skalierbare KI-gesteuerte Gesundheitsplattformen entwickeln. Baden-Württemberg zeichnet sich durch Medizintechnik und Präzisionstechnik aus und verfügt über ein dichtes Netzwerk spezialisierter, privater Anbieter, die z.B. implantierbare Neurotechnologie und KI-gestützte klinische Instrumente herstellen. Die Analyse zeigt Möglichkeiten für eine transatlantische Zusammenarbeit auf, bei der Unternehmen aus MA die Fertigungs- und klinische Infrastruktur in BW nutzen können, während deutsche Unternehmen von der US-amerikanischen Biotechnologie und den Innovationen im Bereich der digitalen Gesundheit profitieren können. Die Studie zeigt, dass die Kombination von Web Intelligence, maschinellem Lernen und LLM-

basierter Synthese einen Echtzeit-Einblick in komplexe Gesundheitsökosysteme in großem Maßstab ermöglicht. Die Erkenntnisse dieser Studie können von staatlichen Stellen, Clustermanagern, Technologietransferstellen von Universitäten, Investoren und Innovationsleitern von Krankenhäusern genutzt werden.

1. Introduction

The health sector represents one of the most dynamic, multifaceted and socially significant areas of economic and societal activity, encompassing prevention, diagnosis, treatment, and care across an increasingly complex biomedical and healthcare landscape (Johnson, 2011). Understanding the current developments, key actors, and prevailing trends in this sector is critical for evidence-based policymaking, strategic planning, and the effective allocation of resources. Traditional data sources, such as official statistics, scientific publications, or funding databases, provide valuable insights but capture only a partial picture of the sector (Kinne & Axenbeck, 2020). They thus often overlook emerging activities, informal collaborations, and the broader organizational and socio-economic context that shapes the health sector's structure and performance.

To address these limitations, our approach builds on the WebAI paradigm, i.e. the large-scale, automated collection and analysis of web-based information through web scraping combined with artificial intelligence (AI) analysis methods (Dahlke et al., 2025). This methodological framework enables the extraction of real-time, high-resolution insights into organisational activities, research topics, and network dynamics across the health innovation ecosystem. The vast scale and wide scope of web data allow observations across diverse organisations, from small enterprises to multinational corporations, providing a more complete picture than traditional, sampled datasets (Kinne & Axenbeck, 2020). Websites serve as self-curated, multi-stakeholder representations of organisations, encompassing both explicit information – such as products, services, and partnerships – and implicit signals about strategies, technological capabilities, and market positioning (Oertel & Thommes, 2018; Powell et al., 2016). The continuous availability and updating of web data enable near real-time monitoring of organisational activities, as well as tracing the evolution of topics and networks over time (Oberg et al., 2022). Furthermore, web data captures relational dimensions through direct connections, such as hyperlinks between websites, offering a consistent and systematic approximation of organisational networks (Abbasiharofteh et al., 2023; Katz, 2006; Vaughan et al., 2007). Using these properties of web data to generate data-driven insights, we aim to provide a more comprehensive and timely understanding of health-related innovation and its societal impact.

Studies using the WebAI paradigm have already been conducted on topics of product innovation (Kinne & Lenz, 2021), AI diffusion (Dahlke et al., 2024), 3D printing (Dehghan et al., 2023; Schwierzy et al., 2022), corporate sustainability (Schmidt et al., 2022), and firm collaborations (Abbasiharofteh et al., 2023; Schmidt et al., 2025). This report represents the first large-scale study on health-related topics.

The states of Massachusetts, USA and Baden-Württemberg, Germany were selected as focus regions for this study due to their prominent positions in the health and innovation sectors within their respective countries (Faißt et al., 2022; Pilger & Jahn, 2013; Reynolds & Uygun, 2018). Both regions are characterised by a high density of health-related organisations, including hospitals, research institutions, and technology-driven firms. Moreover, Massachusetts and Baden-Württemberg represent distinct socio-economic and regulatory contexts, allowing for an exploration of how organisational practices, sector priorities, and innovation dynamics manifest across different institutional environments. By comparing these regions, the study aims to uncover both shared patterns and region-specific characteristics in the health sector.

The report is structured as follows: First, we provide an overview of the five focus topics of our analysis. Then, we describe in detail the results of our regional comparative analysis between Massachusetts and Baden-Württemberg. For this, we employed both a supervised and an unsupervised machine learning approach. In addition, we evaluate the results from a spatial perspective and inspect collaboration networks through hyperlink analysis. Finally, the main takeaways are summarised in our conclusion.

2. Focus topics

This study was conducted for five dedicated focus topics. These topics were selected to capture a broad spectrum of organisational activities, ranging from technological innovation and clinical research to public health initiatives and social impact. By examining these diverse areas, the study aims to provide a comprehensive understanding of sector priorities, emerging trends, and patterns of engagement across different types of health-related organisations.

Health-focused NGOs & Social Enterprises

Health-focused non-governmental organisations and social enterprises play a vital role in improving population health through community health programs, disease prevention campaigns, and enhanced access to healthcare, particularly for underserved populations. They promote health education and awareness, address health equity and inclusion, and contribute to global health initiatives (Delisle et al., 2005). Many focus on capacity building, maternal and child health, mental health programs, vaccination campaigns, and innovative health financing (George et al., 2018; Humphries et al., 2011; Walton, 2017). By engaging in health advocacy, coordinating emergency health responses, and applying social impact measurement, these organisations strengthen healthcare systems and support sustainable, inclusive health ecosystems.

Digital Health & HealthTech

Digital health and health technology companies are at the forefront of transforming medical care through innovative technologies that enhance diagnosis, treatment, and patient engagement. By leveraging artificial intelligence, these companies enable advanced clinical decision support, improve diagnostic accuracy, and facilitate personalised treatment strategies. Telemedicine and remote patient monitoring expand access to care, particularly for patients in rural or underserved areas, while wearable health devices and consumer health platforms empower individuals to actively manage their health and wellness (Haleem et al., 2021; Iqbal et al., 2021). Digital therapeutics are increasingly used to deliver evidence-based interventions for chronic conditions such as diabetes and mental health disorders, complementing traditional care pathways (Carl et al., 2022; Ramakrishnan et al., 2021). There has been a steep increase in such digital health solutions since the COVID-10 pandemic (Shah et al., 2022).

Dermatology & Dermatopathology

Dermatology and dermatopathology centres specialise in diagnosing, treating, and researching skin diseases, including chronic, infectious, and aesthetic conditions. They combine clinical expertise with advanced imaging, histopathology, and molecular diagnostics to enhance early detection and personalised treatment strategies (Bolognia, 2024). These institutions are increasingly adopting AI and digital tools to improve diagnostic accuracy and streamline workflows. Teledermatology services have emerged as a critical tool for expanding access to specialised care, particularly for underserved populations or patients in remote area (Nami et al., 2012). The field is also advancing in

personalised skincare, integrating patient-specific data with clinical assessment to tailor treatments for conditions such as eczema, psoriasis, and acne. Environmental factors affecting skin health, including ultraviolet radiation and air pollution, are increasingly considered in both clinical practice and research, recognising their role in disease prevention (Krutmann et al., 2014). Dermatopathology specifically focuses on diagnosing complex conditions, such as skin tumours, leveraging high-resolution imaging and AI-assisted interpretation to improve diagnostic precision and workflow efficiency (Wells et al., 2021).

Genomics & Cancer Research

Genomics and cancer research institutions are at the forefront of understanding the genetic and molecular mechanisms that drive cancer development and progression. By investigating tumour biology through approaches such as single-cell genomics, spatial transcriptomics, and proteomics, these centres identify novel biomarkers and therapeutic targets, enabling the development of personalised treatment approaches tailored to individual patient profiles (Califf, 2018; Dias-Santagata et al., 2010; Garraway & Lander, 2013). Cutting-edge technologies, including CRISPR gene editing and epigenomic profiling, facilitate functional studies of cancer genes, while concepts such as synthetic lethality are leveraged to design targeted therapies with increased specificity and reduced toxicity (Kaminski et al., 2021; Zhan et al., 2019). Institutions increasingly employ AI-driven personalised screening tools and AI in drug discovery to enhance early detection, optimise treatment selection, and accelerate the identification of novel drug candidates (Esteva et al., 2019).

Cardiovascular Research

Cardiovascular research organisations are dedicated to the prevention, diagnosis, and treatment of heart and vascular diseases, which remain leading causes of mortality worldwide (Mathers et al., 2009). These institutions develop innovative therapeutics, medical devices, and monitoring technologies to improve patient outcomes and reduce cardiovascular risk. By investigating genetic risk factors and exploring targeted approaches, they contribute to precision strategies for preventing and managing cardiovascular disease. Advanced computational methods, including AI-based risk assessment, enable researchers to predict disease progression and tailor interventions to individual patient profiles (Khera et al., 2024). Organisations are also advancing structural heart interventions, such as minimally invasive therapies like transcatheter aortic valve

replacement (Srinivasan et al., 2024), which reduce patient recovery times while maintaining clinical efficacy. Moreover, regenerative medicine and stem cell therapies offer promising avenues for repairing damaged cardiac tissue (Golpanian et al., 2016).

3. Regional comparison

The present study aimed to compare the health sectors in Massachusetts and Baden-Württemberg through a systematic analysis of firm websites. By examining publicly available online content, the analysis sought to identify differences and similarities in focus areas, service offerings, and organizational priorities across these two regions.

To achieve this, two complementary analytical approaches were employed. The first approach utilized unsupervised machine learning to cluster website texts based on their intrinsic similarities. This method allowed patterns and thematic groupings to emerge without prior categorisation, providing an overview of the structural organisation of the health sector without relying on predefined categories. The second approach was a supervised analysis using a retrieval-augmented generation (RAG) framework in combination with a large language model (LLM). This method enabled the extraction of targeted information and classification of firms according to five specific focus topics, facilitating a detailed comparison of sector priorities and services between Massachusetts and Baden-Württemberg.

3.1 Cluster analysis

In the first step, an unsupervised cluster analysis was conducted to identify patterns in the text data without having to rely on predefined categories. This can be understood as a preliminary analysis step that helps to uncover interesting trends or topics.

To conduct a semantic cluster analysis, website texts have to be converted into numerical representations, so-called embeddings, which capture the semantic meaning of the content in a high-dimensional vector space (Wang et al., 2024). These embeddings can then be grouped by diverse algorithms into similar clusters, allowing naturally occurring themes and patterns to emerge across the corpus. For this, we used a k-Means approach, the most frequently employed clustering method. It partitions data into clusters

by minimising the distance between points and their assigned cluster centres (Sinaga & Yang, 2020). We chose a cluster size of 20, so that the output of our analysis was 20 distinct clusters.

For this cluster analysis, we created two datasets: We extracted the website texts of all relevant firms in Massachusetts and Baden-Württemberg in 2024 with our proprietary web scraping tool. In addition, we also accessed the website data from 2015 from CommonCrawl, a popular Internet archive (Kriesch & Losacker, 2025). Clustering was then performed on the entire text corpus to ensure consistency in topic detection over time, allowing for comparisons between 2015 and 2024.

The output of textual cluster analysis generally consists of the most representative words for each cluster. Since this is rather difficult for interpretation purposes, we subsequently used a Large Language Model (LLM) to generate a concise summary of the underlying topic of each cluster.

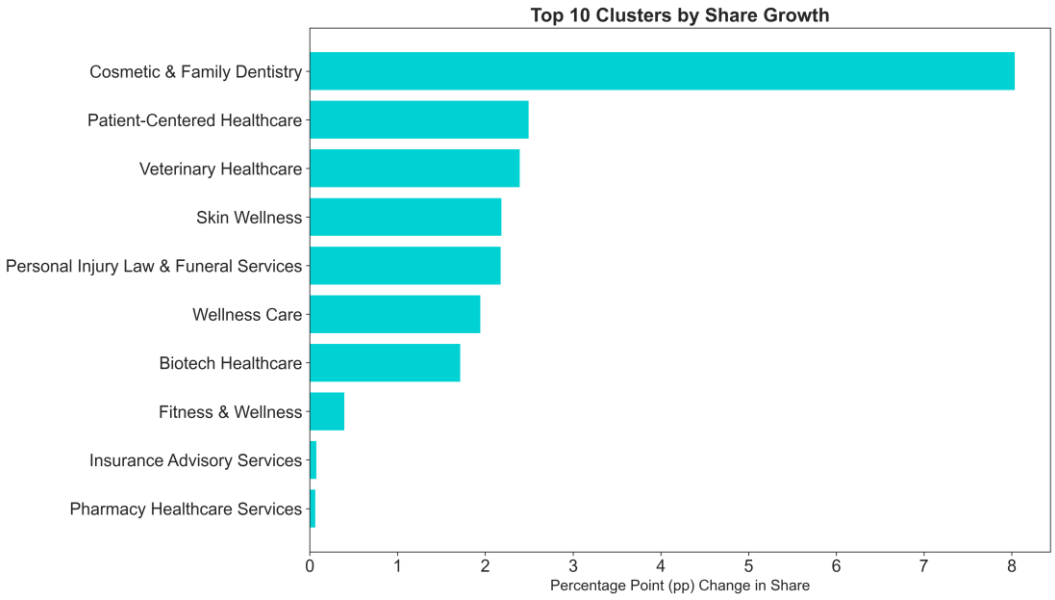

Figure 1 *Analysis of cluster share gains (2015-2024) in Massachusetts*

Figure 1 illustrates the distribution of percentage point (pp) change in topic share between 2015 and 2024 for the ten clusters with highest gains for the Massachusetts use case. The "Cosmetic & Family Dentistry" cluster demonstrated the most substantial growth, realising a gain of approximately 8.0 pp. This gain is significantly higher than that of all other semantic clusters. The next highest performers, "Patient-Centered

Healthcare" and "Veterinary Healthcare", form a secondary tier with more moderate but still robust gains, registering share increases between 2.0 pp and 2.5 pp. The majority of the remaining clusters, including "Skin Wellness", "Personal Injury Law & Funeral Services", and "Biotech Healthcare", cluster between 1.5 pp and 2.0 pp. Consequently, the remaining clusters did not have any significant gains from 2015 or 2024 or even showed a relative decrease.

Figure 2 shows the most significant percentage point losses in clustering share, indicating topics that have lost relevance between 2015 and 2024 in the health sector in Massachusetts. The three clusters with the most substantial losses were "Technology Community Services", "Community Health Education", and "Community Engagement Services". Each of these saw decreases exceeding -5.0 pp, with "Technology Community Services" leading the decline at over -8.0 pp. In contrast, the remaining four clusters experienced much more marginal contractions, indicating a relatively stable performance of these health subdisciplines. Consequently, more clusters experienced a relative increase than decrease in their share between 2015 and 2024.

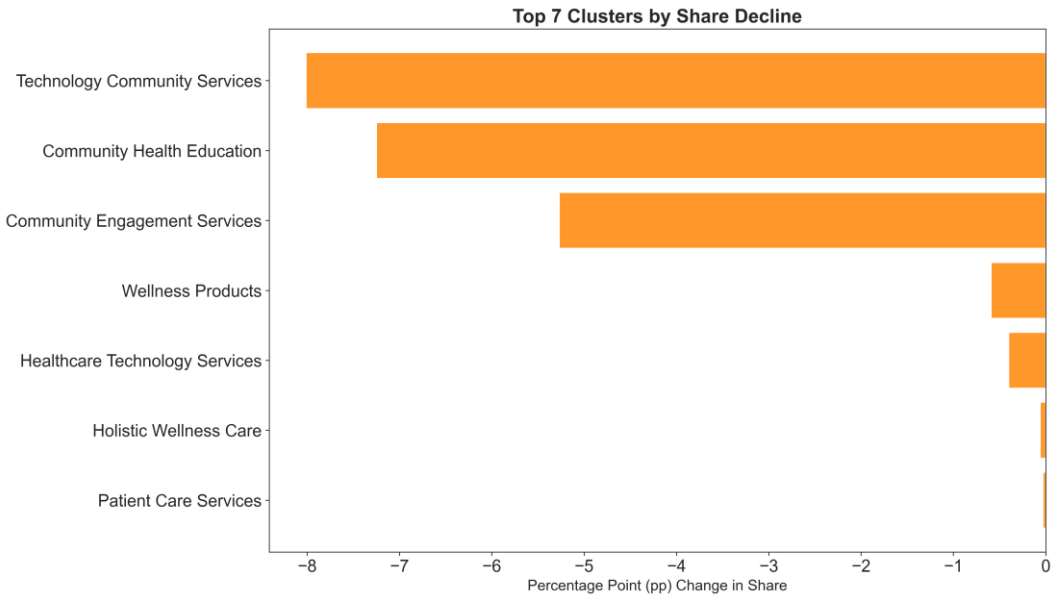

Figure 2 *Analysis of cluster share decline (2015-2024) in Massachusetts*

Figure 3 illustrates the distribution of percentage point (pp) change in topic share between 2015 and 2024 for the ten clusters with highest gains for Baden-Württemberg. The data shows that "Holistic Wellness Care" achieved the largest increase, with a gain of approximately 10 percentage points, followed closely by the cluster "Pharmacy

Healthcare Services". "Patient Care Services" and "Insurance Advisory Services" also experienced notable growth, both gaining around 3–4 percentage points in the reference period. Meanwhile, the clusters „Fitness & Wellness" and "Skin Wellness" still demonstrated moderate improvements, indicating a rising importance of preventive and lifestyle-related health services.

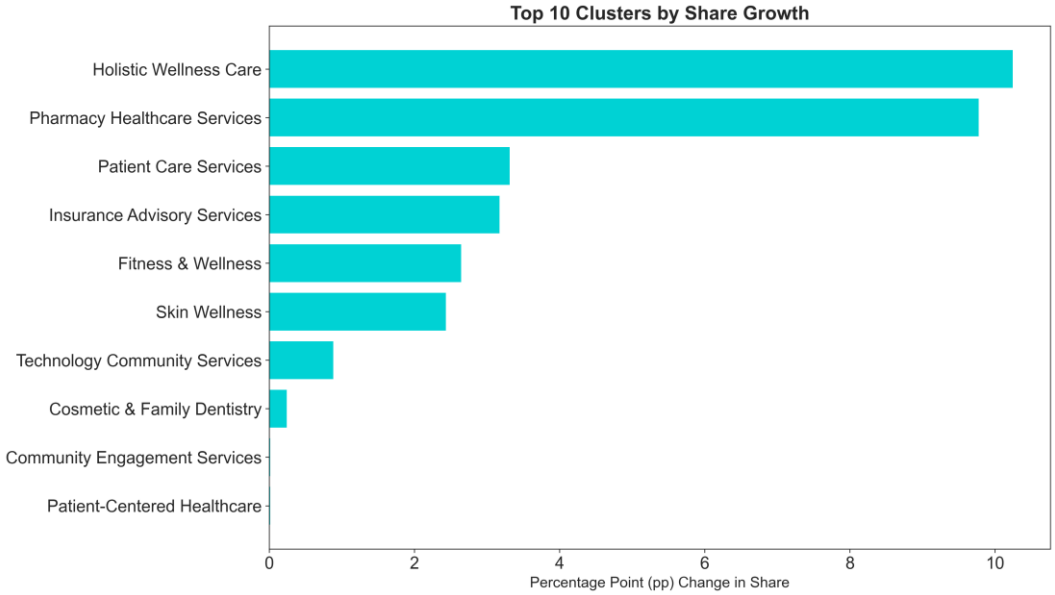

Figure 3 *Analysis of cluster share gains (2015-2024) in Baden-Württemberg*

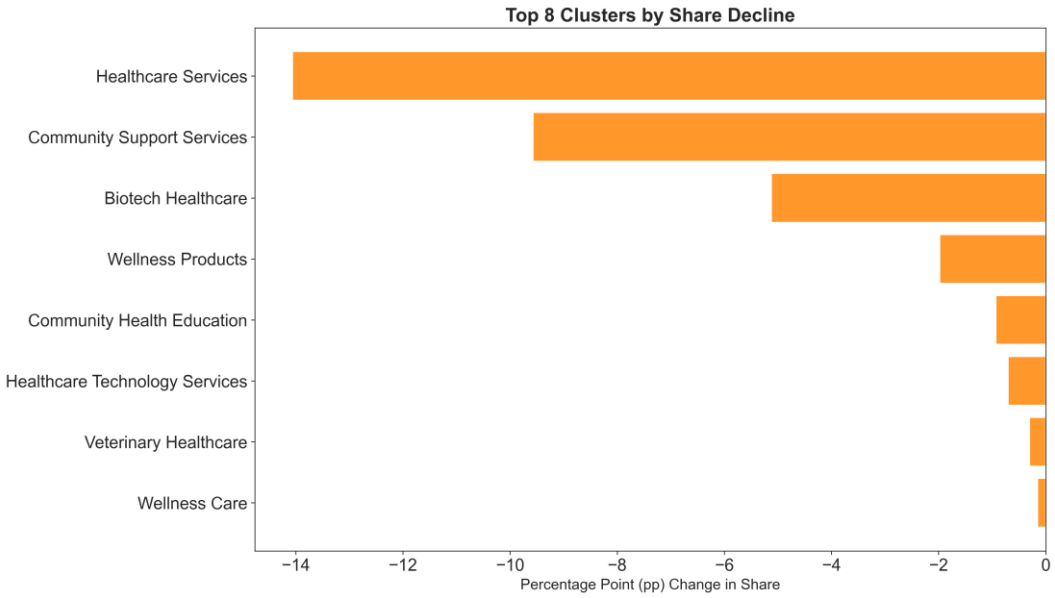

Figure 4 *Analysis of cluster share decline (2015-2024) in Baden-Württemberg*

Conversely, Figure 4 shows the clusters that have lost relative importance over the ten-year period. This applies most strongly to “Healthcare Services”, which has declined by 14 percentage points. “Community Support Services” and ”Biotech Healthcare” have also decreased in their share of the total population of health-related firms in Baden-Württemberg. These also include two wellness-related clusters, the content of which is difficult to differentiate from similar clusters, that mostly experienced significant growth, using this unsupervised methodology.

3.2 AI detail analysis

To derive more in-depth insights, we therefore implemented a semi-supervised machine learning approach in our analysis. This approach leverages advanced AI techniques, combining Large Language Models (LLMs) and Retrieval-Augmented Generation (RAG). LLMs are AI models trained to understand and generate human-like text, while RAG enhances their performance by retrieving and incorporating relevant information from external data sources before generating responses (Arslan et al., 2024). Together, this method enables a more precise and context-aware analysis of complex datasets.

3.2.1 Focus topics

One of the main goals of the analysis was the identification of firms pertaining to the five focus topics described in Section 2. Consequently, we analysed each company website in our corpus with the aim to generate a robust classification. If a company did not belong to any of the dedicatedly described topics, it was sorted into a separate category called “Other health-related firms”.

Figure 5 shows the distribution of all companies analysed according to these six categories for both regions. It becomes apparent that the majority of all companies under consideration do not fall under the five focus topics of this study. Overall, the distribution of categories was relatively similar between the two regions. While ‘Digital Health & HealthTech’ was the largest category in Baden-Württemberg (7.2%), ‘Health-focused NGOs & Social Enterprises’ was the most frequently represented focus topic in Massachusetts (10.0%). The topic ‘Genomics & Cancer Research’ was also relatively more important in Massachusetts. The fact that companies related to our focus topics accounted

for an 8 percentage point higher share of the company population can also be taken as an indication that the health industry in Massachusetts tends to be more oriented towards current trends.

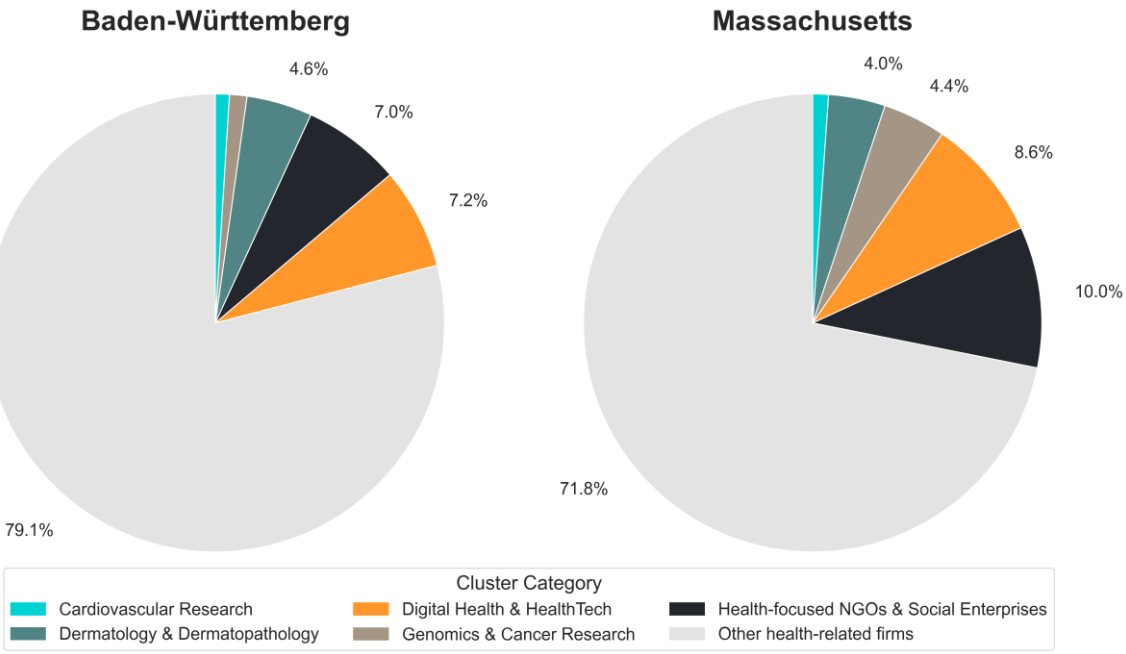

Figure 5 *Relative distribution of health sector firms per focus topic*

If companies that do not fit the focus topics are excluded from the descriptive analyses, the distribution in Figure 7 can be plotted as a direct comparison. Here, too, it is clear that the topic 'Genomics & Cancer Research' was significantly more strongly represented in Massachusetts, with an almost threefold share. Conversely, it should be noted that considerably more companies in Baden-Württemberg could be assigned to the focus topic 'Dermatology & Dermatopathology' than in Massachusetts. However, this can possibly be explained by a higher proportion of medical practices included in our German data set. For the other focus topics, the differences between the two regions were rather marginal, below 5 percentage points.

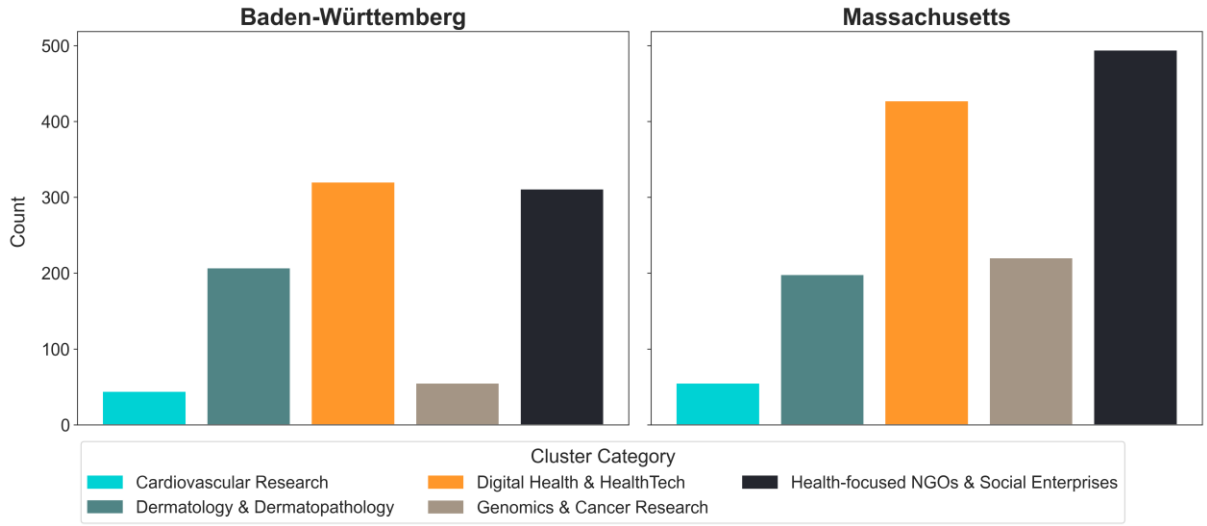

Figure 6 *Absolute distribution of health sector firms per focus topic*

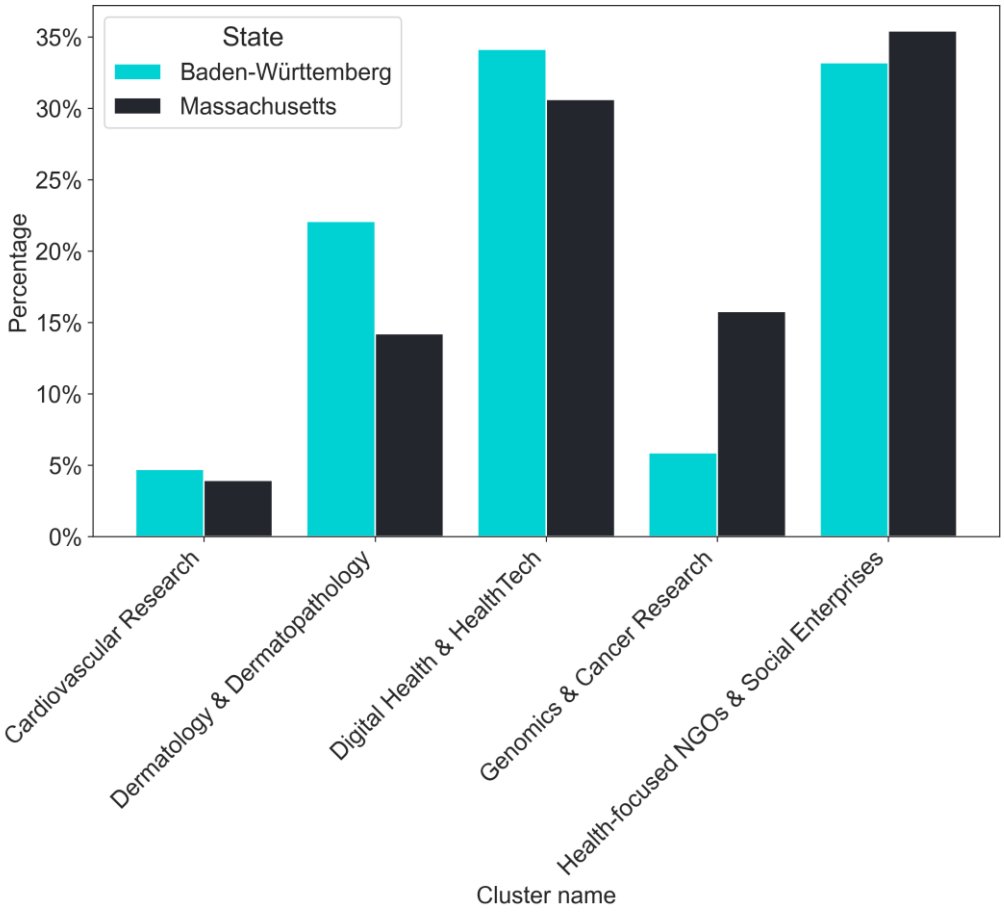

Figure 7 *Comparison of focus topics*

Figure 6 shows the distribution of focus topics with absolute numbers. This shows that the health-related company populations of the two regions are quite comparable in size.

None of the categories contained more than 500 companies. The smallest category was 'Cardiovascular Research' in Baden-Württemberg with 44 companies.

3.2.2 Research focus

In addition to categorisation, we were able to answer explicit questions based on the website content in our corpus. Since health represents an economic sector closely related to academia, often forming industrial-university-research cooperations (Xia & Jia, 2023), we wanted to inquire how many companies were actively involved in research. Figure 8 compares the absolute number of relevant companies for Massachusetts and Baden-Württemberg. It becomes apparent that the number of firms in Massachusetts with a clear research focus is considerably higher, at 1.284 firms in comparison to merely 522 firms in Baden-Württemberg. This also holds true when looking at relative number, where 25.9% of health-related firms in Massachusetts reported some direct collaboration with academia. In Baden-Württemberg, only 11.6% of all health-related firms under consideration displayed a certain closeness to research.

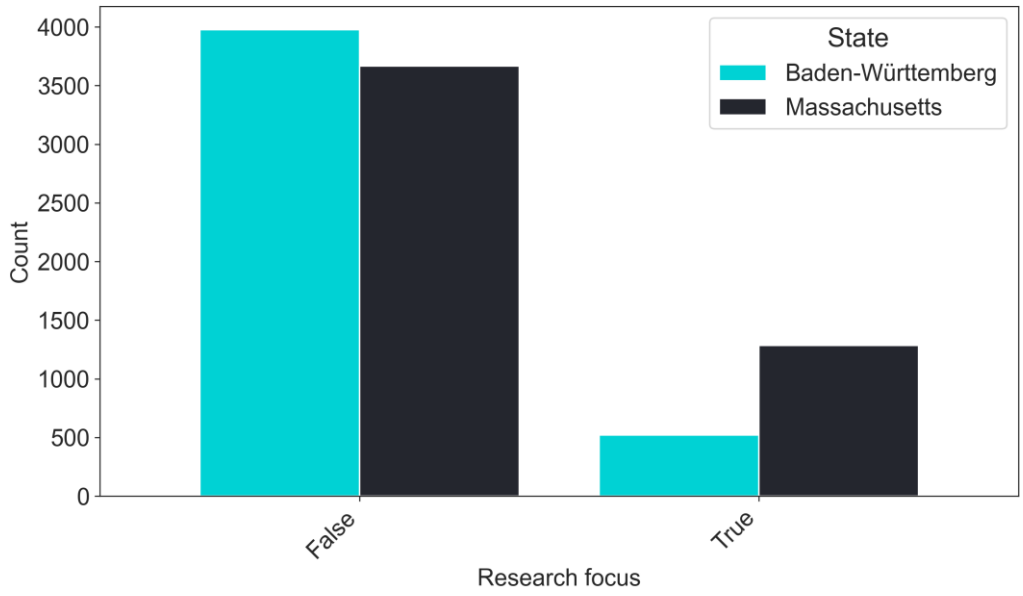

Figure 8 *Health sector firms with research focus*

3.2.3 AI engagement

As it was stated in chapter 2, AI is currently a "hot topic" across several health-related disciplines. For this reason, we investigated for each website in our data sample whether

the respective firm employed any AI tools in their daily business. Figure 9 summarises this for both states, showing that the number of health-related firms using AI was higher in Massachusetts, where we identified 420 health-related firms engaged in AI (8.5%). In Baden-Württemberg, we were only able to find 137 such firms (3.0%).

Using a LLM to summarise our firm-level findings, we could identify that both regions leverage AI, but in different ways. Massachusetts companies build scalable, AI-driven platforms that are often the product itself, targeting national or global adoption. In contrast, Baden-Württemberg companies develop AI-enabled tools to enhance existing clinical products or processes, emphasising precision and integration rather than scale.

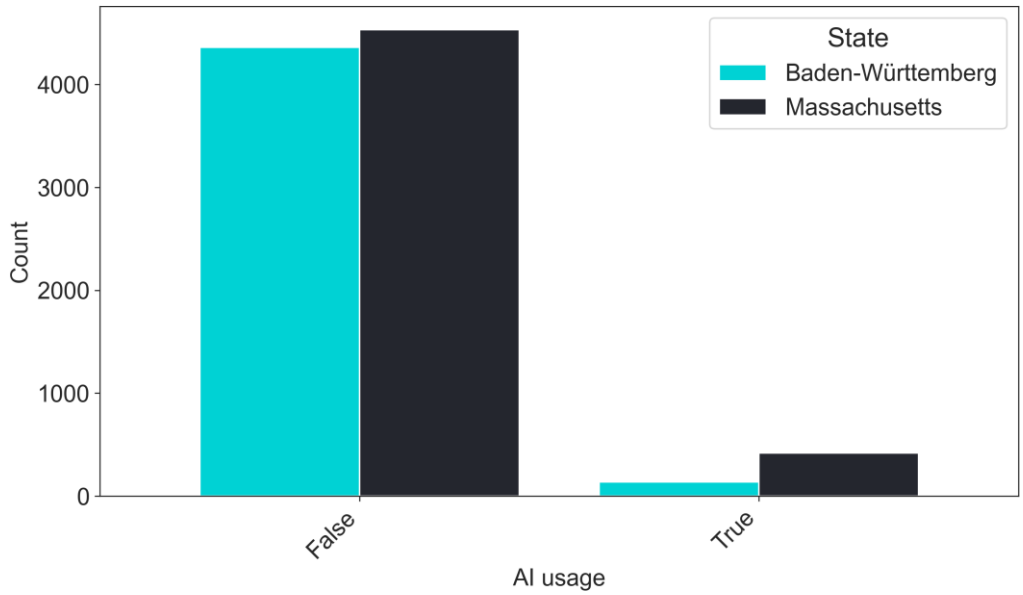

Figure 9 *Health sector firms with AI usage*

3.2.4 Core business activities

For each website, we also determined the most important keywords that describe the companies' core activities. In Baden-Württemberg, the health sector is dominated by companies focused on pharmaceuticals, patient care services, and integrative health offerings. Keywords like *pharmacy* (410), *e-prescription* (266), and *community pharmacy* (246) indicate a strong presence of businesses providing medication distribution, digital health solutions, and pharmacy-related services. Aligning with our previous unsupervised cluster analysis, there is also a notable emphasis on wellness, holistic care,

and alternative therapies, with high frequencies for *naturopathy* (227), *homeopathy* (194), *acupuncture* (157), and *holistic health* (142). Primary and patient-centred services are also reflected in keywords like *general practice* (210), *patient care* (201), and *preventive care* (165), showing that firms providing services to healthcare providers or directly to patients have a significant footprint. Overall, the Baden-Württemberg health sector appears diverse, spanning pharmaceuticals, digital health, patient support services, and wellness/alternative health companies.

In Massachusetts, the health sector has a stronger focus on dental, cosmetic, and specialised health services, reflecting a business environment centred on elective, high-value, and niche markets. Leading keywords include *cosmetic dentistry* (298), *dental implants* (262), *general dentistry* (193), and *teeth whitening* (191), showing the prevalence of companies providing dental products, clinical services, and aesthetic treatments. Recurring terms such as *botox* (145), *dermal fillers* (93), and *laser hair removal* (75) suggest a substantial market for cosmetic interventions. Preventive and patient-focused services appear, but less prominently (*preventive care*, *patient education*), showing a secondary market emphasis. Other health sector niches, including *telehealth* (85), *nonprofit* (268), and *nutrition* (69), indicate emerging or specialised segments within the market. In sum, the Massachusetts health sector seems highly specialised, with a strong focus on dental and cosmetic companies, alongside some emerging digital and patient-oriented services.

3.2.5 Comparative summary

Massachusetts is characterised by a high-risk, venture-fuelled R&D ecosystem, particularly in biopharma and scalable digital health solutions. The region contains many biotech and health tech startups, often backed by venture capital and associated with large academic medical centres. These companies focus on developing novel therapeutic platforms, such as RNAi, CAR-T, or gene therapies, or building scalable, AI-driven digital health platforms. Innovation in Massachusetts is generally platform-first and disruptive, with high-risk, high-reward funding profiles, and exit strategies often relying on acquisitions or IPOs. Digital health companies in the region aim to create national or global solutions for patient engagement, data analytics, and remote care. The talent pipeline is

strongly fuelled by university and hospital spinouts, ensuring a continuous influx of highly skilled researchers and scientists.

By contrast, Baden-Württemberg's health sector ecosystem is engineering- and application-driven, anchored in precision manufacturing, medical device engineering, and a dense network of family-owned companies. Its dominant company archetypes include specialised SMEs, physician-owned clinics, and community pharmacies. Innovation tends to be product-first and incremental, focused on improving tangible medical devices, diagnostics, and clinical workflow tools, with an emphasis on reliability, quality, and long-term customer relationships. Funding is typically private or grant-supported, favouring sustainable growth over high-risk ventures. Digital health solutions in Baden-Württemberg are designed to enhance existing clinical workflows rather than replace them, with AI-enabled tools augmenting imaging, diagnostics, and hospital data management. Talent development is supported by applied science universities, producing a highly technical workforce well-suited for MedTech manufacturing and engineering-intensive innovation.

Key differences between the two regions are evident in company focus and business models. Massachusetts companies concentrate heavily on biopharmaceutical discovery and scalable digital platforms, exemplified by startups developing RNAi therapeutics, CAR-T therapies, or AI-driven patient engagement solutions. Baden-Württemberg, on the other hand, demonstrates its strength in medical technology and precision engineering, with companies producing high-precision diagnostic tools, neurotechnology implants, and clinical workflow solutions. The Massachusetts ecosystem is largely venture capital-driven, while Baden-Württemberg relies on a network of privately owned or family-run companies, often with practitioner-led clinical services.

3.3 Spatial analysis

Since we are able to link every company website to a physical location based on its postal address through geocoding, we can also transfer the insights generated into geographical space. Spatial analysis helps to visualise and understand how health-related firms are distributed across regions. Mapping these patterns reveals industrial concentrations, regional strengths, and potential gaps in the innovation landscape. By

examining where firms are located, we gain insights into the geography of health-sector activity and its relationship to research and regional development.

In the following, we show the distribution of firms that were classified into our focus topics. Figure 10 and Figure 11 show the location of firms in cardiovascular research and the field of dermatology, respectively. Figure 12 reveals patterns for firms specialising in genomics and cancer research.

All maps show similar patterns: in Massachusetts, the health sector is clearly concentrated in Boston and Cambridge, which are also the state's most important urban areas. Inland, however, e.g. near Springfield, there are hardly any relevant companies. The only category that deviates somewhat from this are companies in the field of dermatology, which are also found in rural areas. However, it should be noted here that many of these hits are small businesses and medical practices. In Baden-Württemberg, there is a clear focus of the health industry on the large urban centres. The university cities of Stuttgart, Heidelberg, Karlsruhe, Mannheim, Freiburg im Breisgau and Ulm are particularly noteworthy in this regard. In contrast to Massachusetts, however, companies are also more frequently found in more rural regions here. The border region with Switzerland in the far south-west also stands out, which could be explained by its proximity to Basel, an important chemical industry location.

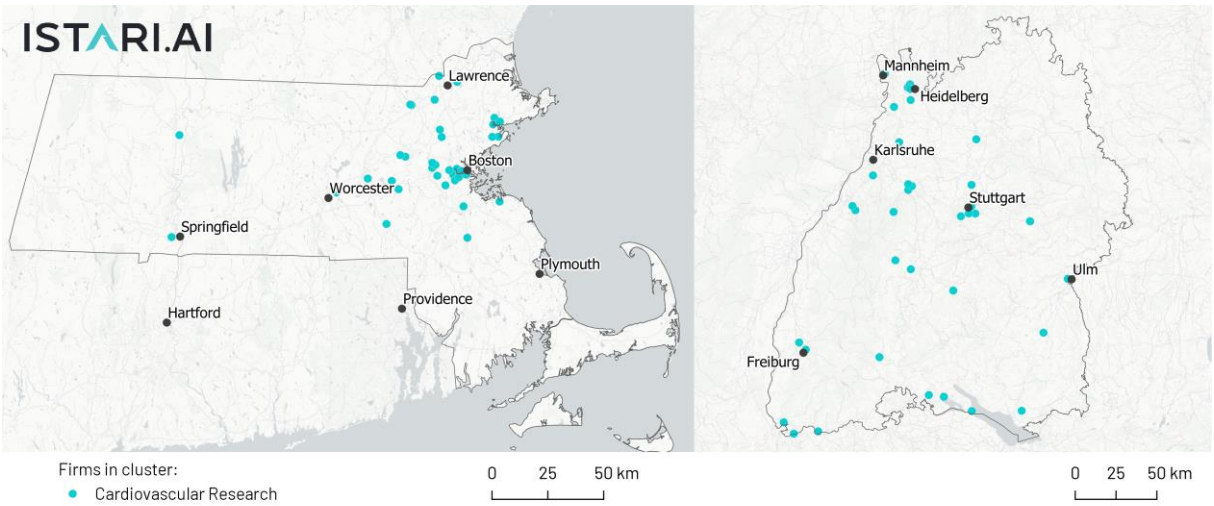

Figure 10 *Distribution of firms in Cardiovascular Research*

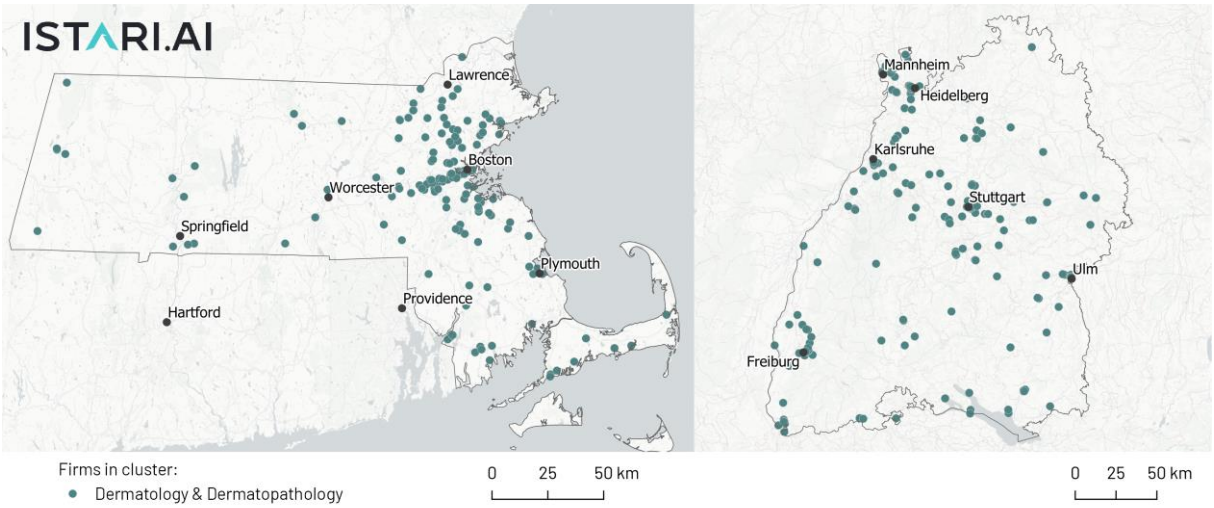

Figure 11 *Distribution of firms in Dermatology & Dermatophology*

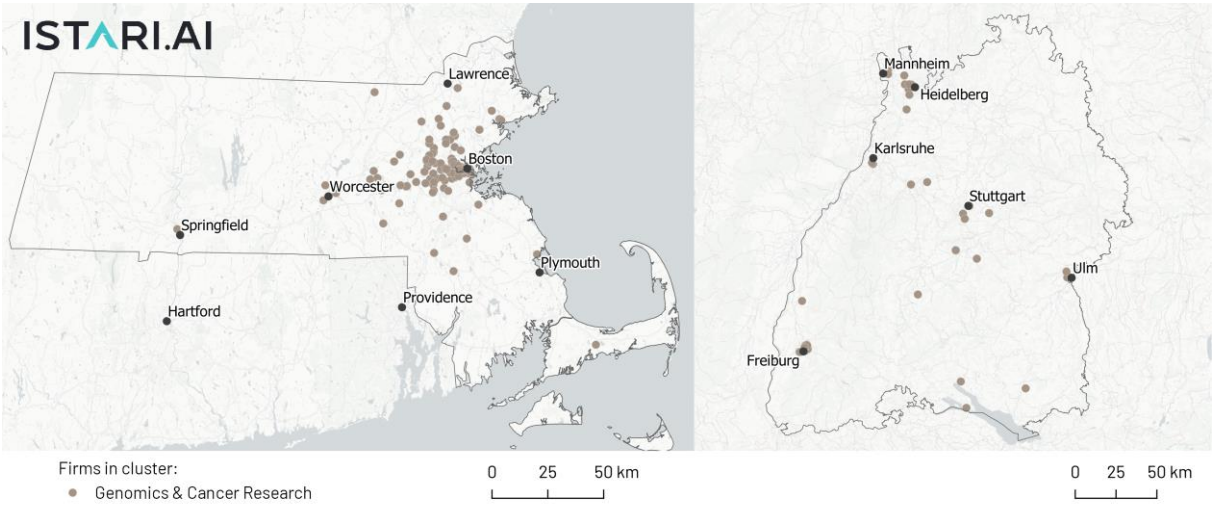

Figure 12 *Distribution of firms in Genomics & Cancer Research*

3.3.1 Boston

Since Boston and Cambridge were identified as particularly relevant communities in the state-level analyses, Figure 13 shows a zoom map with all health-related firms that we could find there. It suggests that there are clear clusters of the health industry in Boston. These are particularly evident in the downtown area (Financial District, Back Bay, Beacon Hill). Other districts, such as East Boston, South Boston or Roxbury, on the other hand, have only a few relevant businesses. In Cambridge, clear clusters can be seen in close proximity to the Massachusetts Institute of Technology (MIT) and Harvard University. Harvard's medical and public health schools drive advances in clinical medicine, population health, and translational research, generating new knowledge in disease

prevention, treatment, and health systems while training clinicians and researchers who bridge science and patient care. Relevant institutes include the Department of Population Medicine, which focuses on improving healthcare delivery and outcomes (HPHCI, 2025), and the Harvard T.H. Chan School of Public Health, which conducts research on global health, epidemiology, and disease prevention (HSPH, 2025).

MIT contributes transformative breakthroughs in biotechnology, biomedical engineering, and health data science. For instance, the Institute for Medical Engineering & Science (IMES) at MIT pioneers research at the nexus of science, engineering, computation, and medicine, with interdisciplinary scientists, engineers, and clinicians collaboratively engaged in developing new ways to prevent, diagnose, and treat human disease (IMES, 2025). At the intersection of these institutions stands the Broad Institute, a joint research centre founded in 2004 that accelerates discoveries in genomics, molecular biology, and precision medicine. The institute accelerates discoveries in genomics, molecular biology, and precision medicine by enabling cross-disciplinary collaboration, developing and sharing advanced technologies, and translating research into clinical applications. Broad's work spans major projects such as the Human Genome Project, the Cancer Genome Atlas, and the Human Cell Atlas, and supports clinical trials for diseases including cancer and heart disease, improving health outcomes globally (Broad Institute, 2025).

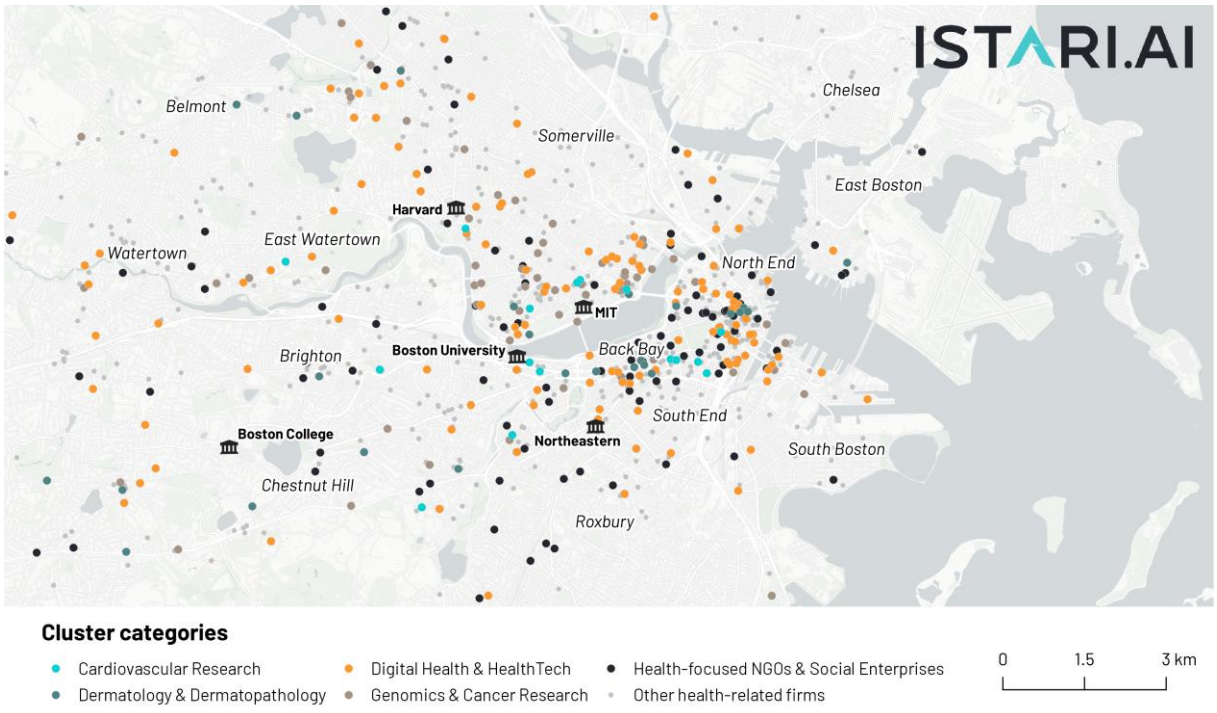

Figure 13 *Distribution of health sector in Boston, MA*

3.3.2 Stuttgart

Due to its pluricentric structure, we decided to take a closer look at several cities in Baden-Württemberg. We selected the state capital Stuttgart, the university cities of Heidelberg and Freiburg im Breisgau, and the industrial centre of Mannheim.
Driven by a strong background in mechanical engineering and R&D (Eickelpasch, 2008), Stuttgart is positioning itself as a leading center for health innovation in southern Germany. As shown in Figure 14, there is a clear cluster of companies in the health sector in the downtown area (Mitte) in Stuttgart. Other relevant centres are the districts of Ost, Bad Cannstatt and Feuerbach. In some districts, such as Fellbach or Degerloch, there are a few health-related companies, but hardly any companies that could be assigned to the focus topics of this study.

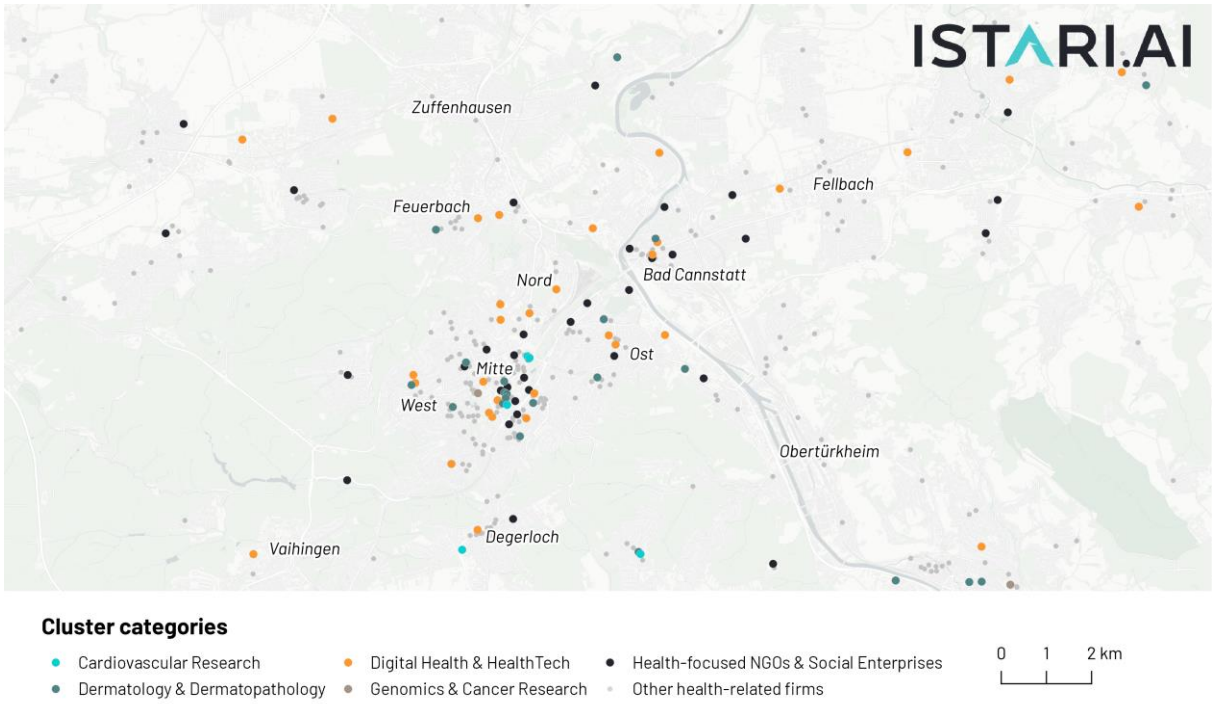

Figure 14 *Distribution of health sector in Stuttgart, Germany*

3.3.3 Freiburg im Breisgau

A very similar pattern can be observed in Figure 15 for Freiburg im Breisgau, a university city with around 230,000 inhabitants in the south of the federal state. The majority of the companies identified are located in the historic city centre (Altstadt). In addition, the neighbouring districts of Betzenhausen, Brühl and, in particular, Neuburg, where some of the university's institutes are located, and Wiehre are also relevant. The eastern part

of the city, which topographically blends into the foothills of the Black Forest, has hardly any relevant companies.

3.3.4 Heidelberg

Heidelberg is structurally quite similar to Freiburg, both in population size and urban planning, but has a remarkably different distribution of health companies, as can be seen in Figure 16. While Freiburg's focus was strongly on the old town, this is less relevant in Heidelberg, presumably because the district Altstadt is very touristy. Much more significant is the Neuenheim district, where a large part of the university is located, including the German Centre for Cancer Research (DKFZ). However, there are also some districts in Heidelberg, such as Pfaffengrund, Handschuhsheim and Ziegelhausen, which have hardly any relevant companies.

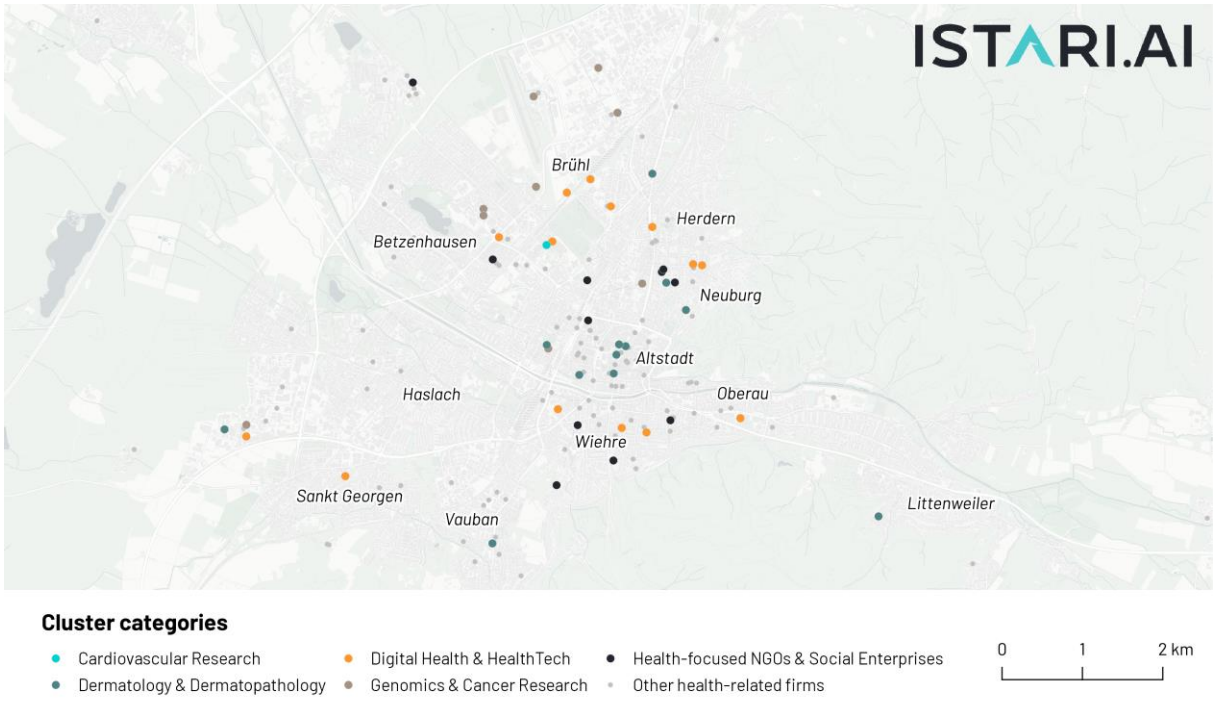

Figure 15 *Distribution of health sector in Freiburg im Breisgau, Germany*

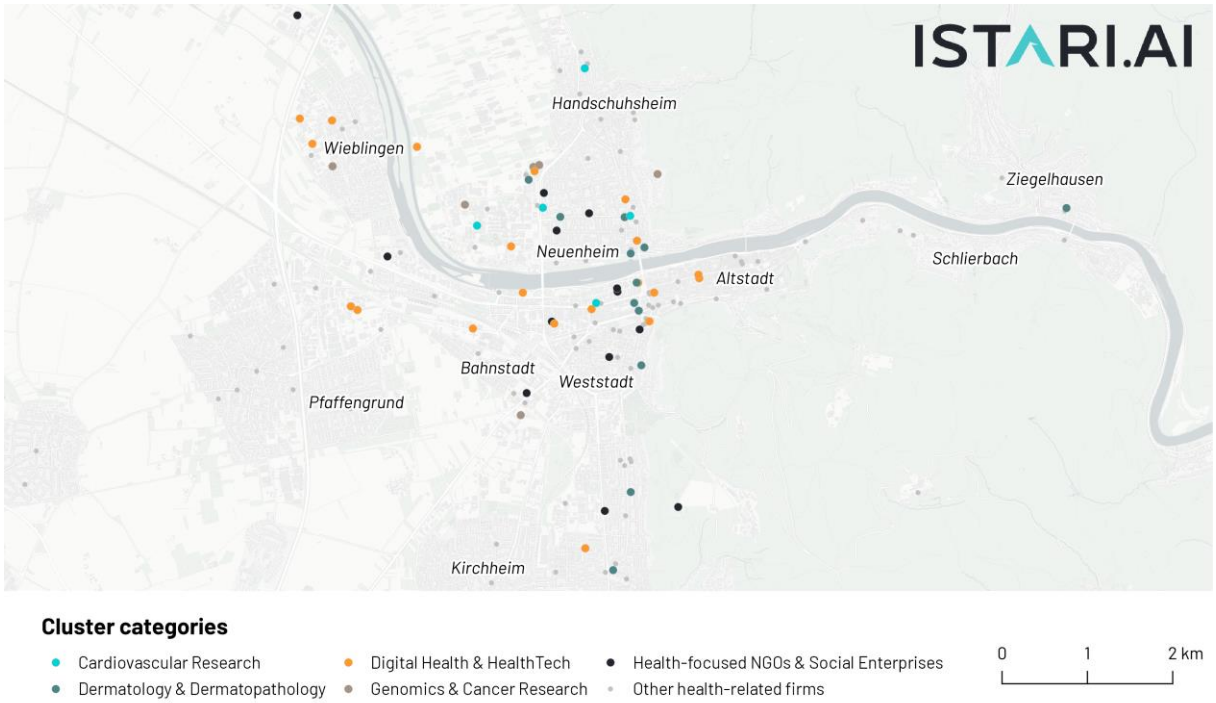

Figure 16 *Distribution of health sector in Heidelberg, Germany*

3.3.5 Mannheim

Figure 17 shows the distribution of health-related firms in Mannheim, which is a rather industrialised and large city in the northwest of Baden-Württemberg. Once again, the city centre (Innenstadt) is particularly relevant, where many health-related businesses are located, especially in the eastern part. However, most of these do not fall within the five defined focus areas. Only a few relevant companies are in districts further away from the city centre, such as Seckenheim or Käfertal. As Mannheim is located directly on the state border with Ludwigshafen am Rhein in the state of Rhineland-Palatinate, which was not examined in this study, it should be mentioned that the western part of the map omits a significant agglomeration of health-related companies.

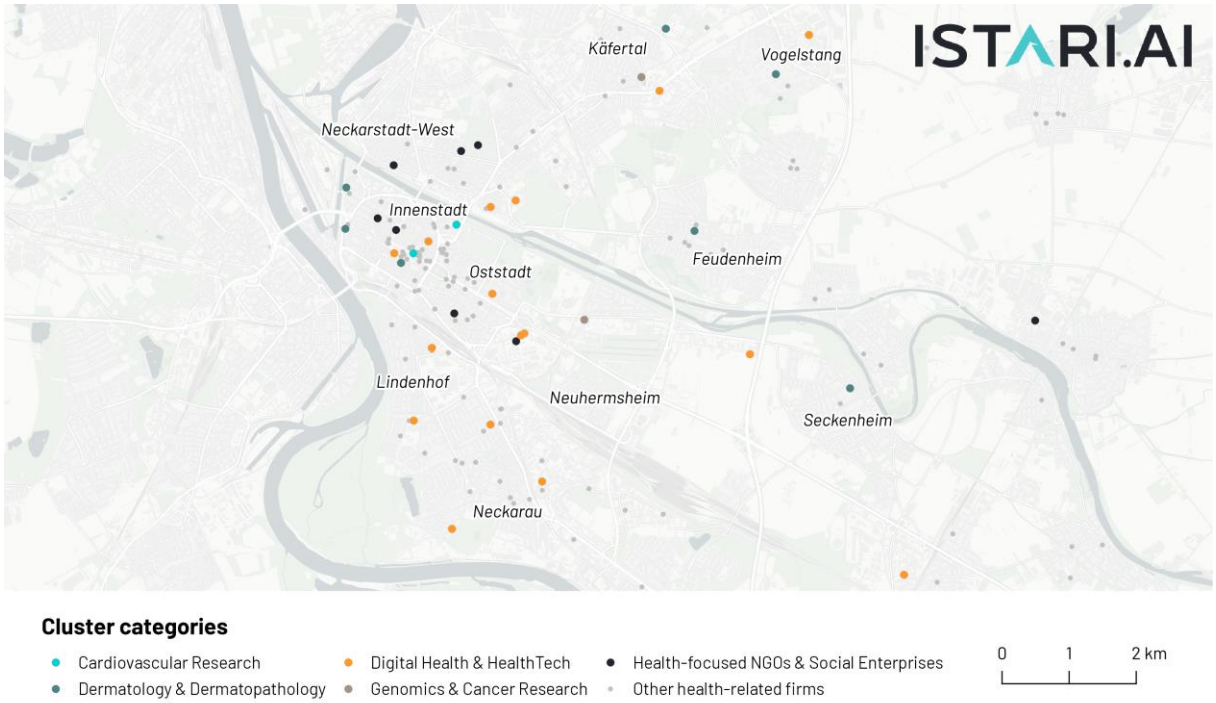

Figure 17 *Distribution of health sector in Mannheim, Germany*

3.4 Hyperlink network analysis

Collaborations play a central role in the creation and dissemination of innovations, especially in knowledge-intensive industries such as the healthcare sector (Stoumpos et al., 2024). They enable the exchange of expertise, resources and technologies between stakeholders and make a decisive contribution to transforming new ideas into marketable solutions. However, it is often difficult to compile a database of such cooperation networks, especially on a large scale, as the available information usually only provides a fragmentary picture of the actual network structures. Traditional indicators such as co-patents or joint publications provide valuable insights but only capture part of the real interactions (Dahlke et al., 2025).

More recently, hyperlinks have proven to be a promising approximation for large-scale corporate networks. Studies such as Abbasiharofteh et al. (2023) or Dahlke et al. (2024) have shown that hyperlink data is a suitable and innovative data source. This holds particularly true for analysing interregional linkages (Schmidt et al., 2025). Building on these findings, the following chapter examines how digital connections between companies can be used to identify and evaluate innovation networks in the health industry.

The basic assumption is that creating a hyperlink is a deliberate decision, indicating a real-world connection between two entities (Dahlke et al., 2025; Vaughan et al., 2007). Hyperlinks can be transformed into networks by representing companies as nodes and the links between corporate websites as directed edges. Using the postal address of each company, these networks can even be mapped into geographic space, allowing for visualisations on maps.

Firstly, we were interested in finding out which regions were home to relevant cooperation partners of the health sector. The majority of outgoing links from Massachusetts targeted other U.S. states, with California (4,543), Massachusetts itself (4,101), New York (1,429), Illinois (736), and Florida (649) leading. Internationally, the most linked countries were the United Kingdom (951), Ukraine (633), China (608), Canada (397), and France (376). Germany was only the eight most linked country, with 240 unique hyperlink connections.

Table 1 *Regions with most outgoing hyperlinks from health sector firms in Massachusetts*

	Country	State
1	United States (21,079)	California (4,543)
2	United Kingdom (951)	Massachusetts (4,101)
3	Ukraine (633)	New York (1,429)
4	China (608)	Illinois (736)
5	Canada (397)	Florida (649)
6	France (376)	Texas (601)
7	Australia (276)	Virginia (485)
8	Germany (240)	District of Columbia (481)
9	Belgium (238)	Washington (458)
10	United Arab Emirates (216)	Pennsylvania (437)

We were able to identify a similar pattern for Baden-Württemberg. Most hyperlink connections led to companies in the local context, i.e. either in the federal state itself (4,936) or in other German regions (7,803). Other European countries such as Spain (769), the UK (725), France (261) and German-speaking neighbouring countries were also

particularly relevant. What is striking here, however, is the greater importance of the USA (3,164), which was by far the most frequently linked foreign country. Overall, firms from the state of California (2,242) were even linked more frequently than firms from any German federal state other than Baden-Württemberg itself.

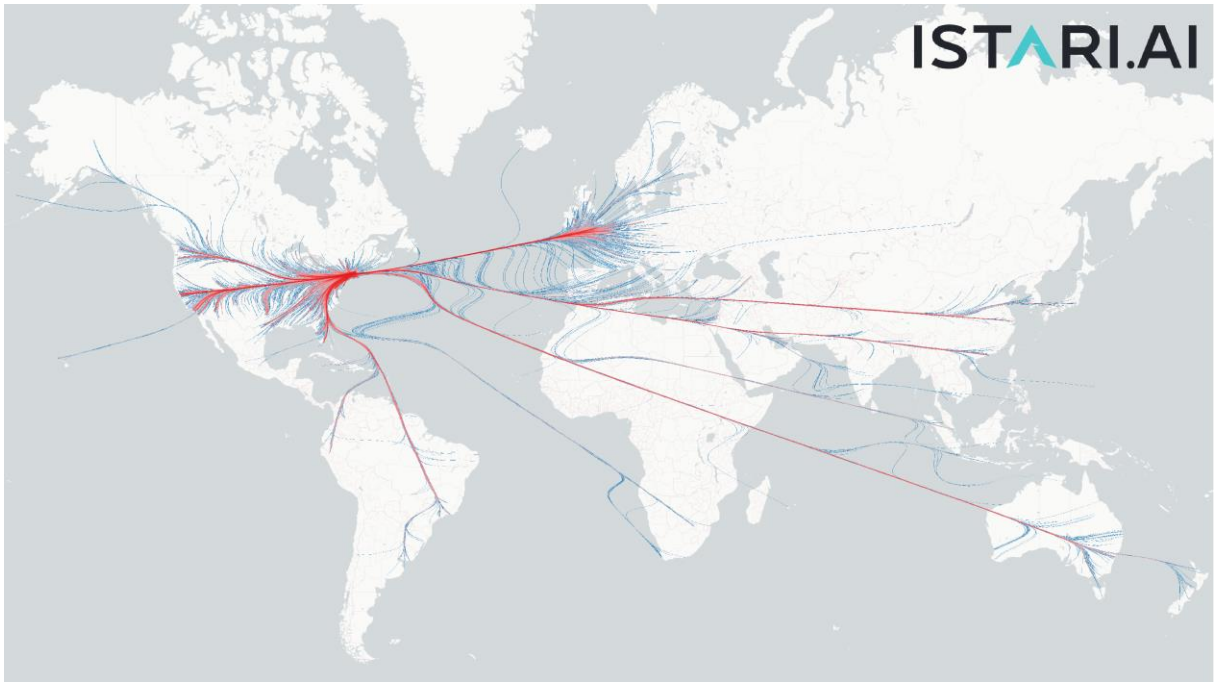

Figure 18 transfers the hyperlink connections into a map representation. The underlying principle is known as edge bundling, which combines frequently occurring connections and visualises them according to a predefined colour scheme. Particularly frequent connections are shown in red, while less frequent connections are shown in blue and are thinner. If we take the health-related companies in Massachusetts as the starting point of the network, i.e. only examine their connections, interesting patterns emerge. Basically, we were able to identify a global network, with the aforementioned national focus standing out. California (especially Los Angeles and the Bay Area) and the rest of the East Coast were particularly prominent. However, there were also strong connections to Europe, with the south of the UK and parts of Central Europe being particularly notable. Still, many regions of the world, such as large parts of Africa and Russia, were virtually unrepresented.

Figure 19 shows the same edge-bundled network map for health-related companies from Baden-Württemberg. The network in Central Europe, especially within the German-speaking region, was much more pronounced, with connections radiating in all directions. The connection to the USA was also strong, especially along the axis from New

York to San Francisco. In less represented regions of the world, the destinations were mostly the same as for US companies, e.g. the major Brazilian cities, the Australian east coast and Hong Kong. For both firm samples, the connections to Asia communicated on websites were relatively weak.

Table 2 *Regions with most outgoing hyperlinks from health sector firms in Baden-Württemberg*

	Country	State
1	Germany (12,739)	Baden-Württemberg (4,936)
2	United States (3,164)	California (2,242)
3	Spain (769)	Nordrhein-Westfalen (1,625)
4	United Kingdom (725)	Bayern (1,465)
5	Mexico (388)	Berlin (1,096)
6	Ukraine (263)	Hessen (966)
7	France (261)	Thüringen (622)
8	Austria (234)	Hamburg (594)
9	Switzerland (215)	Niedersachsen (331)
10	Kenya (134)	Rheinland-Pfalz (290)

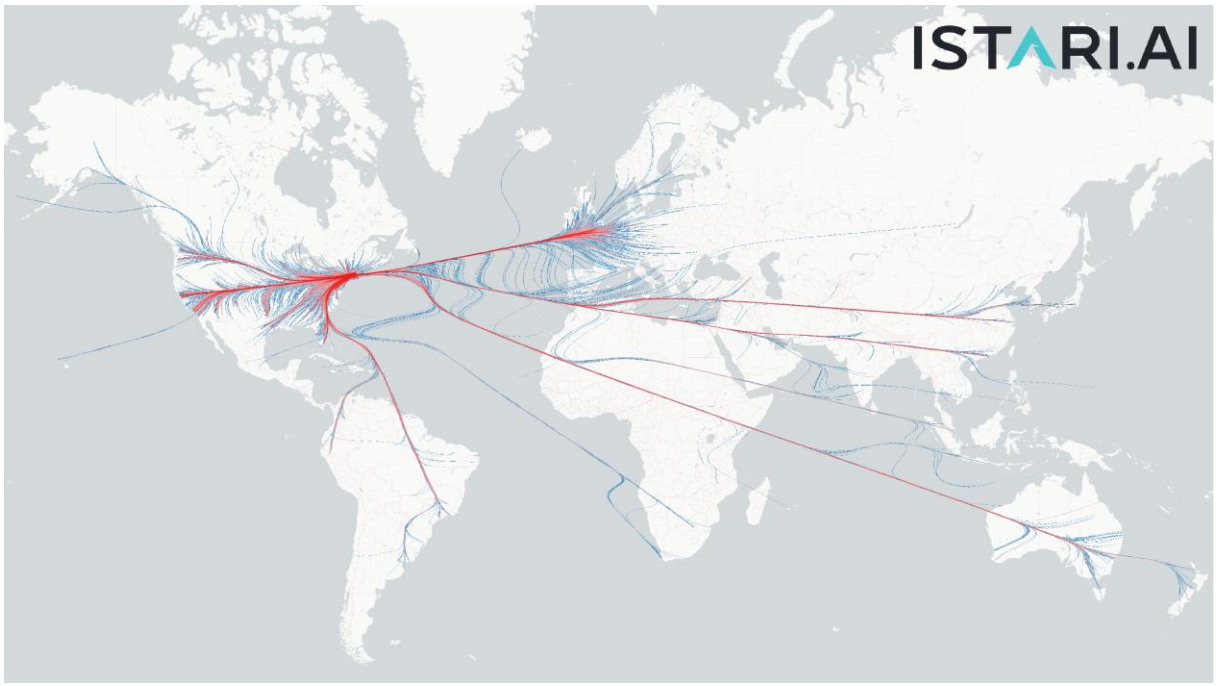

Figure 18 *Global hyperlink networks for Massachusetts firms*

Our web analysis also unveiled several notable collaborations between health-related entities in Baden-Württemberg and Massachusetts. These partnerships span corporate research, ecosystem development, and academic exchange, demonstrating a solid foundation for transatlantic innovation in health technology.

Figure 19 *Global hyperlink networks for Baden-Württemberg firms*

Several examples highlight these collaborations. In terms of corporate and research partnerships, Blueprint Medicines, a precision therapy company based in Cambridge, Massachusetts, has an active collaborative research programme with Roche, whose diagnostics division is headquartered in Mannheim, Baden-Württemberg. This partnership connects a leading Massachusetts biotechnology company with a global health technology enterprise in Baden-Württemberg. Actome, a life-science start-up based in Freiburg, Baden-Württemberg, collaborates with BioLabs, an organisation headquartered in Cambridge, Massachusetts, which operates an international network of shared laboratory facilities, including a site in Heidelberg, Baden-Württemberg. Similarly, Benefit GmbH, a funding consultancy based close to the Black Forest, has a project involving the Fraunhofer Society, Germany's leading applied research organisation. Fraunhofer has a significant presence in the United States, including a centre in Brookline, Massachusetts, creating a channel for connecting state-funded German research and development with the Massachusetts ecosystem.

These examples collectively demonstrate that the health sector ecosystems of Baden-Württemberg and Massachusetts are actively interconnected, with collaborations spanning research, infrastructure, and talent development. This transatlantic engagement creates strong opportunities for innovation, knowledge exchange, and joint growth in health technology. Baden-Württemberg companies entering Massachusetts can provide high-quality manufacturing, device development, and lab automation to support Massachusetts startups and biotech firms, while Massachusetts companies entering Baden-Württemberg can leverage the region's dense network of specialised clinics for clinical validation, pilot studies, and real-world evidence generation. Moreover, Baden-Württemberg's manufacturing excellence offers a reliable base for localised production and supply chain optimisation. Talent and research collaborations are also promising, linking Massachusetts' science-driven workforce with Baden-Württemberg's applied engineering expertise to jointly develop advanced health solutions.

4. Conclusion

Basing our insights on the AI-powered large-scale analysis of corporate websites, we find that the health industries of Massachusetts and Baden-Württemberg exhibit similar overarching structures, each combining strong research ecosystems with clusters of innovative firms. Massachusetts is a global epicentre for biopharmaceutical discovery, hosting a high concentration of companies developing novel methods and tools for RNAi therapeutics, CAR-T therapy, and AAV gene therapy. These are often high-risk, research-intensive ventures, supported by a venture capital ecosystem where investors actively fund biotech startups from the seed stage. Companies in Massachusetts also build scalable, AI-driven platforms that often constitute the product itself.

Baden-Württemberg, while also maintaining a strong pharmaceutical presence, shows its core strength in medical technology and precision engineering. Companies in the region focus on developing implantable neurotechnology, endovascular simulators, and other high-precision devices, reflecting the region's broader industrial identity in mechanical and automotive engineering. The ecosystem is characterised by a dense network of privately owned, specialised providers, including a vast number of independent, physician-owned specialty clinics and pharmacies. Baden-Württemberg firms increasingly develop AI-enabled tools that enhance existing clinical products or processes.

These complementary strengths create a solid foundation for transatlantic cooperation. Firms from Baden-Württemberg bring precision manufacturing and engineering excellence, making them ideal partners for Massachusetts' biotechnology and life-science enterprises that require complex instruments or customised automation. Conversely, Massachusetts companies can leverage Baden-Württemberg's dense network of specialised clinics and high-quality manufacturing base to conduct clinical validation, pilot studies, and real-world evidence generation.

In conclusion, the two ecosystems are highly complementary. Massachusetts thrives on high-risk, venture-backed innovation in biopharma and scalable digital platforms, whereas Baden-Württemberg excels in precision engineering, applied medical technology, and specialised SMEs. Strategic transatlantic collaboration can harness these strengths, combining Massachusetts's scientific innovation with Baden-Württemberg's operational and engineering excellence to create robust, scalable, and high-quality health solutions that address both current and emerging healthcare challenges.

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