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Quantum Clusters: Ranking the World's Deep-Tech Epicentres

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EXECUTIVE SUMMARY

The ECIPE Quantum Project has so far laid the groundwork for understanding the global quantum landscape. It introduced the fundamentals of quantum technologies, assessed national activity in investment, scientific output, and patents, and charted international collaboration patterns to show that progress relies as much on shared expertise as on scientific breakthroughs. This work has now led to the next phase: identifying the innovation hubs within each country where meaningful quantum advances occur – what we call **quantum clusters.**

Quantum R&D requires ultra-specialised, capital-intensive infrastructure that cannot easily be duplicated. The talent pool is also extremely scarce and concentrated in a small number of physics and engineering groups, creating inherent geographic bottlenecks. Combined with long pre-commercial timelines and immature supply chains, these constraints mean that genuine quantum innovation emerges only where specific capabilities and institutions co-locate. At the same time, the overwhelming complexity of the technology demands extensive inter-regional networking for knowledge integration. Therefore, the successful quantum cluster is not a self-contained hub, but the most effective node in a global and distributed network. **This makes quantum clusters especially important for policies aimed at strengthening coordination across industry, research, and government, both locally and globally.**

This paper presents the **first structured ranking of quantum clusters** – not to reinforce narratives of supremacy, but to showcase high-performing regions, revealing where real capabilities lie and where gaps persist. This analysis offers a clearer basis for designing targeted policy interventions in investment attraction, talent development, and infrastructure planning. **Viewing quantum through a cluster lens can help policymakers understand the external, institutional, and firm-level factors that shape quantum competitiveness**, enabling more integrated strategies and stronger collaboration among stakeholders.

In this report, we distinguish between **quantum clusters and quantum quasi-clusters.** A **quantum cluster** is a geographically concentrated ecosystem of startups, corporations, universities, research institutes, and government agencies that meets minimum thresholds of:

- **Startup funding:** a cluster qualifies as such if it hosts either at least two startups with USD 10 million or more in disclosed funding combined, or at least one startup with USD 25 million or more.
- **Institutional presence:** in addition, a cluster needs to be home to at least five institutions – research, industry, or government – that are actively engaged in quantum activities.

A **quantum quasi-cluster** is a geographic area where quantum activity is beginning to take shape but has not yet reached the critical mass required to function as a mature, self-sustaining innovation hub. It typically lacks a sufficient concentration of institutions and/or the presence, or substantial funding, of a quantum startup. As a result, it shows early potential but does not yet display the density and breadth characteristic of a fully developed quantum cluster.

This study identifies and ranks **45 quantum clusters** worldwide (see Table A below). These regions are the most likely to shape future outcomes in the global quantum landscape, as they offer the most favourable conditions for sustained innovation and high productivity in quantum.

The final ranking reflects the average of the scores across **three dimensions**; each built from three underlying indicators:

1. **Dimension 1: Market Orientation** – assesses how much a cluster's quantum activity is geared towards commercialisation. It reflects the scale and intensity of investment in quantum firms and the degree of industry participation in quantum collaborations.
2. **Dimension 2: Collaboration Intensity** – measures how actively and strategically a cluster engages in partnerships. This dimension captures the volume of collaborations, the openness to international partnerships, and the cluster's role as a connector within the global quantum network.
3. **Dimension 3: Ecosystem Maturity** – evaluates the institutional foundation and productivity of the local innovation environment. It measures how well quantum-active institutions are integrated and capable of sustaining long-term quantum growth.

Based on these three dimensions, **Cambridge (UK)** leads the global ranking, followed closely by **Greater Helsinki (Finland), Oxford (UK), the San Francisco Bay Area (US), and Greater Glasgow (UK)**. The top 5 reflects the continued dominance of established academic and technology ecosystems in the UK and the US. More broadly, the English-speaking world accounts for 10 of the top 15 clusters, including hubs in Australia (Canberra) and Canada (Toronto–Waterloo). The EU places two clusters in the top third – Helsinki and Karlsruhe – while Israel (Tel Aviv), China (Hefei), and Switzerland (Greater Geneva–Bern Area) each contribute one.

The middle third of the ranking is more geographically diverse. Strong European ecosystems such as Copenhagen, Paris, the Randstad Region, and Munich appear here, along with China's Beijing and Shanghai clusters. These ecosystems demonstrate rapid scientific activity but generally lag behind Anglophone peers in commercialisation outcomes.

The lower third consists of less developed clusters still building institutional capacity, market pipelines, and international linkages. Chinese clusters such as Shenzhen–Hong Kong–Guangzhou, Hangzhou, and Suzhou remain comparatively less mature in institutional engagement. Similarly, clusters in Spain and Berlin show promising research capabilities but face constraints in scale and industry participation. Emerging ecosystems in Bangalore, Dubai, and Seoul represent important entry points for quantum research and entrepreneurship but currently operate at a smaller scale than more established leaders.

We assess cluster performance across three dimensions because different features demand different policy responses. A cluster excelling in research but weak in industry engagement requires a different strategy from one with strong funding but limited collaboration. Analysing each dimension highlights what drives performance and where interventions are most needed.

This report also identifies **86 quantum quasi-clusters** globally. We do not rank them in the same detail, as they still lack the necessary components, but we assess their potential and group them into two tiers based on their proximity to becoming full clusters.

TABLE A: QUANTUM CLUSTERS RANKING

Rank	Quantum Cluster	Country	Region	Dimension Rankings		
				Market Orientation	Collaboration Intensity	Ecosystem Maturity
1	Cambridge	UK	UK, Canada, and Australia	2=	11=	2
2	Greater Helsinki	Finland	EU	2=	15	4
3	Oxford	UK	UK, Canada, and Australia	8	5	3
4	San Francisco Bay Area	US	US	1	11=	8=
5	Greater Glasgow	UK	UK, Canada, and Australia	16=	4	5
6	Tel Aviv Metropolitan Area	Israel	Rest of the World	6	19	7
7	Karlsruhe	Germany	EU	20=	2=	6
8	Hefei	China	China	4=	6=	24=
9	Denver–Boulder Region	US	US	4=	28=	15=
10	Greater Geneva Bern Area	Switzerland	Rest of the World	12	6=	15=
11	Bristol–Bath Region	UK	UK, Canada, and Australia	20=	23=	1
12=	Canberra	Australia	UK, Canada, and Australia	9	25=	11
12=	Toronto–Waterloo Corridor	Canada	UK, Canada, and Australia	10	31	8=
14=	Greater Boston	US	US	11	32	14
14=	London Commuter Belt	UK	UK, Canada, and Australia	16=	10	23
16	Greater Copenhagen	Denmark	EU	26	6=	13
17	Greater Sydney	Australia	UK, Canada, and Australia	15	21	19
18	Greater Washington	US	US	7	17	31
19	Metro Vancouver	Canada	UK, Canada, and Australia	14	35	20
20	Greater Paris	France	EU	13	33	24=
21	Greater Austin	US	US	20=	27	27
22	Munich Metropolitan Area	Germany	EU	18	40	22

Rank	Quantum Cluster	Country	Region	Dimension Rankings		
				Market Orientation	Collaboration Intensity	Ecosystem Maturity
23	Randstad Region	Netherlands	EU	31	28=	15=
24	Grenoble	France	EU	23	42	18
25	Singapore	Singapore	Rest of the World	39	28=	10
26	Shanghai	China	China	30	1	42
27	Greater New York	US	US	24	18	40=
28	Stuttgart Metropolitan Area	Germany	EU	25	22	33
29=	Beijing	China	China	27	23=	32
29=	Greater Montreal	Canada	UK, Canada, and Australia	36	20	24=
29=	Greater Tokyo	Japan	Rest of the World	28	16	34
32=	Bangalore	India	Rest of the World	34	6=	35=
32=	Shenzhen–Hong Kong–Guangzhou Region	China	China	19	11=	45
34	Hangzhou	China	China	35	11=	39
35	Greater Adelaide	Australia	UK, Canada, and Australia	32	44	12
36=	Barcelona Metropolitan Area	Spain	EU	41=	34	28=
36=	Greater Los Angeles	US	US	44	2=	40=
38	Valencia Metropolitan Area	Spain	EU	37=	38	28=
39	Berlin Metropolitan Area	Germany	EU	41=	37	28=
40	Chicagoland	US	US	45	39	21
41	Indianapolis Metropolitan Area	US	US	29	43	35=
42	Dallas–Fort Worth Metroplex	US	US	33	41	35=
43	Seoul Metropolitan Area	South Korea	Rest of the World	40	25=	43
44	Suzhou	China	China	43	36	44
45	Dubai	UAE	Rest of the World	37=	45	38

Source: ECIPE Quantum Database.

1. INTRODUCTION

Each decade brings a familiar pattern in the evolution of technology: breakthrough innovations do not diffuse evenly across the globe. They emerge in geographic hubs that possess distinct capacities for success. We have seen this pattern in software clusters, biotech corridors, pharmaceutical powerhouses[1], and more recently in autonomous vehicle ecosystems and AI hubs. These high-tech concentrations have become engines of local economic growth, job creation, and strategic advantage. In innovation-intensive sectors especially, clustering produces outsized productivity gains by enabling rapid, localised knowledge exchange among highly specialised actors.

Quantum follows this same historical pattern of clustering, but it also diverges from it in an important way. While key capabilities, such as specialised laboratories, fabrication facilities, or domain-specific expertise tend to concentrate in particular regions, quantum innovation depends on the integration of knowledge across physics, engineering, material science, and computational disciplines. Because no single location possesses all of these capabilities, substantive progress requires coordinated collaboration across institutions, regions, and countries. Thus, quantum advances emerge from both concentrated hubs and distributed networks.

Multidisciplinary integration is reflected in the development of quantum innovation, which is marked by a shift towards technological heterogeneity in its hardware stack. This stack relies on a heterogeneous mix of processors (like specialised FPGAs and high-performance GPUs), a technical reality that reinforces the notion that no single region has all the necessary expertise.[2] This supports a global collaboration pattern: while regional clusters remain critical, they must operate within broader inter-regional networks to pool diverse knowledge. The result is a hybrid innovation model, more interconnected and multidisciplinary than in previous tech waves.

Building on our earlier analyses, this paper continues ECIPE's effort to understand how innovation in quantum technologies takes shape. While our previous study mapped who participates in the global quantum ecosystem and how national systems connect[3], this paper goes deeper – identifying the main regional clusters that define today's quantum landscape. By tracing where concentrations of activity, collaboration, and investment intersect, we uncover how quantum innovation systems organise spatially and institutionally, and which forms of clustering are proving most conducive to technological and commercial success.

Section 2 explains why clusters are the engines of quantum innovation. It defines quantum clusters, describes the methodology for identifying them, and shows that nearly all commercial quantum activity occurs within these dense ecosystems. It introduces a focused analysis on larger clusters and comparative maps for Europe, North America, and East Asia.

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1 Porter, M. E. (1998). Clusters and the new economics of competition (Vol. 76, No. 6, pp. 77-90). Boston: Harvard Business Review.

2 Grandsen, J. (2025, August 28). GPUs, ASICs or FPGAs? Here's how they measure up for Quantum Error Correction. Riverlane Blog. Available at: https://www.riverlane.com/blog/gpus-asics-or-fpgas-here-s-how-they-measure-up-for-quantum-error-correction in Riverlane. (2025). Quantum Error Correction Report 2025. Riverlane Ltd.

3 Erixon, F., Dugo, A., Pandya, D. and Sisto, E. (2025, September). Mapping the quantum ecosystems: How are economies positioning themselves for innovation success. ECIPE Occasional Paper. https://ecipe.org/publications/mapping-the-quantum-ecosystems/

Sections 3–5 explore the three dimensions that underpin the Quantum Clusters Ranking. The first dimension, Market Orientation (Section 3), assesses commercial strength through funding levels, funding intensity, and industry collaborations, showing Anglosphere leadership. The second dimension, Collaboration Intensity (Section 4), evaluates partnership volume, openness, and network brokerage, highlighting the cooperative role of multiple hubs globally. The third dimension, Ecosystem Maturity (Section 5), measures institutional density, spinout efficiency, and startup formation, with UK clusters dominating due to strong institutional foundations and effective research–industry translation.

Section 6 identifies and classifies 86 quasi-clusters. It distinguishes between early-stage regions with emerging startups (Tier 1) and research-driven ecosystems without funded startups (Tier 2). The section analyses their development pathways and the conditions to transition into full clusters.

Prior to moving to the next sections, Table 1 below presents again the Quantum Clusters Ranking. It illustrates how the English-speaking world generally dominates the top third of the ranking, accounting for 10 of the top 15 quantum clusters. All five UK hubs – Cambridge, Oxford, Greater Glasgow, Bristol–Bath, and London – rank within this group. They are joined by three US clusters (San Francisco Bay Area, Denver–Boulder, and Greater Boston), as well as one cluster each from Australia (Canberra) and Canada (Toronto–Waterloo). The EU contributes two entries – Greater Helsinki (Finland) and Karlsruhe (Germany) – while Israel (Tel Aviv Metropolitan Area), China (Hefei), and Switzerland (Greater Geneva–Bern Area) each secure a single position.

Beyond the top 15, the middle third of the ranking reflects a more diverse geographical distribution. Several EU clusters, including Copenhagen (Denmark), Paris (France), the Randstad Region (Netherlands), and Munich (Germany) feature prominently, pointing to Europe's strengths, even if market orientation and ecosystem maturity often lag behind Anglophone peers. In China, clusters such as Beijing and Shanghai appear in this group, with rapid ecosystem growth but still comparatively immature market-facing capabilities.

The bottom third of the ranking is composed largely of less developed ecosystems. Many of these clusters are in the early stages of building institutional capacity, with limited commercialisation pipelines and weaker international linkages. Three Chinese clusters – the Shenzhen–Hong Kong–Guangzhou Region, Hangzhou, and Suzhou – fall into this group: while they benefit from strong investment, their ecosystems are still maturing and often lack the breadth of private-sector engagement relative to economic size seen in leading Western hubs. Similarly, less relevant European clusters – such as those in Spain and Berlin in Germany – show promising scientific activity but remain constrained by scale, resources, and industry participation. Across other regions, emerging ecosystems like Bangalore (India) and Dubai (UAE), but also Seoul (South Korea), represent important entry points for quantum research and entrepreneurship, though they currently operate at a more modest scale compared to more established leaders.

TABLE 1: QUANTUM CLUSTERS RANKING

Rank	Quantum Cluster	Country	Region	Dimension Rankings		
				Market Orientation	Collaboration Intensity	Ecosystem Maturity
1	Cambridge	UK	UK, Canada, and Australia	2=	11=	2
2	Greater Helsinki	Finland	EU	2=	15	4
3	Oxford	UK	UK, Canada, and Australia	8	5	3
4	San Francisco Bay Area	US	US	1	11=	8=
5	Greater Glasgow	UK	UK, Canada, and Australia	16=	4	5
6	Tel Aviv Metropolitan Area	Israel	Rest of the World	6	19	7
7	Karlsruhe	Germany	EU	20=	2=	6
8	Hefei	China	China	4=	6=	24=
9	Denver–Boulder Region	US	US	4=	28=	15=
10	Greater Geneva Bern Area	Switzerland	Rest of the World	12	6=	15=
11	Bristol–Bath Region	UK	UK, Canada, and Australia	20=	23=	1
12=	Canberra	Australia	UK, Canada, and Australia	9	25=	11
12=	Toronto–Waterloo Corridor	Canada	UK, Canada, and Australia	10	31	8=
14=	Greater Boston	US	US	11	32	14
14=	London Commuter Belt	UK	UK, Canada, and Australia	16=	10	23
16	Greater Copenhagen	Denmark	EU	26	6=	13
17	Greater Sydney	Australia	UK, Canada, and Australia	15	21	19
18	Greater Washington	US	US	7	17	31
19	Metro Vancouver	Canada	UK, Canada, and Australia	14	35	20
20	Greater Paris	France	EU	13	33	24=
21	Greater Austin	US	US	20=	27	27
22	Munich Metropolitan Area	Germany	EU	18	40	22
23	Randstad Region	Netherlands	EU	31	28=	15=
24	Grenoble	France	EU	23	42	18

Rank	Quantum Cluster	Country	Region	Dimension Rankings		
				Market Orientation	Collaboration Intensity	Ecosystem Maturity
25	Singapore	Singapore	Rest of the World	39	28=	10
26	Shanghai	China	China	30	1	42
27	Greater New York	US	US	24	18	40=
28	Stuttgart Metropolitan Area	Germany	EU	25	22	33
29=	Beijing	China	China	27	23=	32
29=	Greater Montreal	Canada	UK, Canada, and Australia	36	20	24=
29=	Greater Tokyo	Japan	Rest of the World	28	16	34
32=	Bangalore	India	Rest of the World	34	6=	35=
32=	Shenzhen–Hong Kong–Guangzhou Region	China	China	19	11=	45
34	Hangzhou	China	China	35	11=	39
35	Greater Adelaide	Australia	UK, Canada, and Australia	32	44	12
36=	Barcelona Metropolitan Area	Spain	EU	41=	34	28=
36=	Greater Los Angeles	US	US	44	2=	40=
38	Valencia Metropolitan Area	Spain	EU	37=	38	28=
39	Berlin Metropolitan Area	Germany	EU	41=	37	28=
40	Chicagoland	US	US	45	39	21
41	Indianapolis Metropolitan Area	US	US	29	43	35=
42	Dallas–Fort Worth Metroplex	US	US	33	41	35=
43	Seoul Metropolitan Area	South Korea	Rest of the World	40	25=	43
44	Suzhou	China	China	43	36	44
45	Dubai	UAE	Rest of the World	37=	45	38

Source: ECIPE Quantum Database.

2. THE GEOGRAPHY OF QUANTUM INNOVATION: DEFINING QUANTUM CLUSTERS

2.1 What Quantum Clusters Are and Why They Matter

Quantum technologies do not develop in isolation. They grow around geographically concentrated ecosystems of startups, corporates, research institutions and government agencies – what we refer to as quantum clusters. These ecosystems play a central role in organising scientific, engineering and commercial activity across the quantum stack.

Quantum clusters were detected using a density-based spatial clustering approach (DBSCAN) to identify contiguous areas with high concentrations of quantum-active institutions, independent of administrative boundaries. We then applied a maturity threshold, based on startup funding and institutional presence, to distinguish fully developed clusters from both emerging quasi-clusters and non-cluster regions.[4] A region qualifies as a cluster if:

1. it hosts either two or more startups with at least USD 10 million in combined disclosed funding, or a single startup with USD 25 million or more, and
2. it is home to at least five institutions – research, industry, or government – actively engaged in quantum.[5]

Regions that meet the spatial criterion but fall just below the maturity threshold are classified as quasi-clusters.

As Figure 1 below shows, by 2025, our ECIPE estimates suggest that 96 per cent of all global quantum company funding happens within clusters, up from 95 per cent in 2024 and 92 per cent up to 2023.[6] The consolidation of activity in clusters reflects their ability to generate powerful advantages that dispersed actors cannot replicate. This does not imply that all innovation is produced inside clusters – much still happens in universities or institutes outside our cluster boundaries – but it does show that commercial scaling, capital mobilisation and technology translation are overwhelmingly organised within a limited number of regional ecosystems.

Clusters matter because they combine three reinforcing advantages:

1. **Economies of scale,** as pooled infrastructure, shared talent pools, and localised supply chains reduce costs and increase efficiency.
2. **Knowledge spillovers,** which accelerate learning in a field where tacit know-how, system tuning and iterative experimentation are essential.
3. **Structured collaboration,** as clusters foster partnerships across disciplines and between public and private actors.[7]

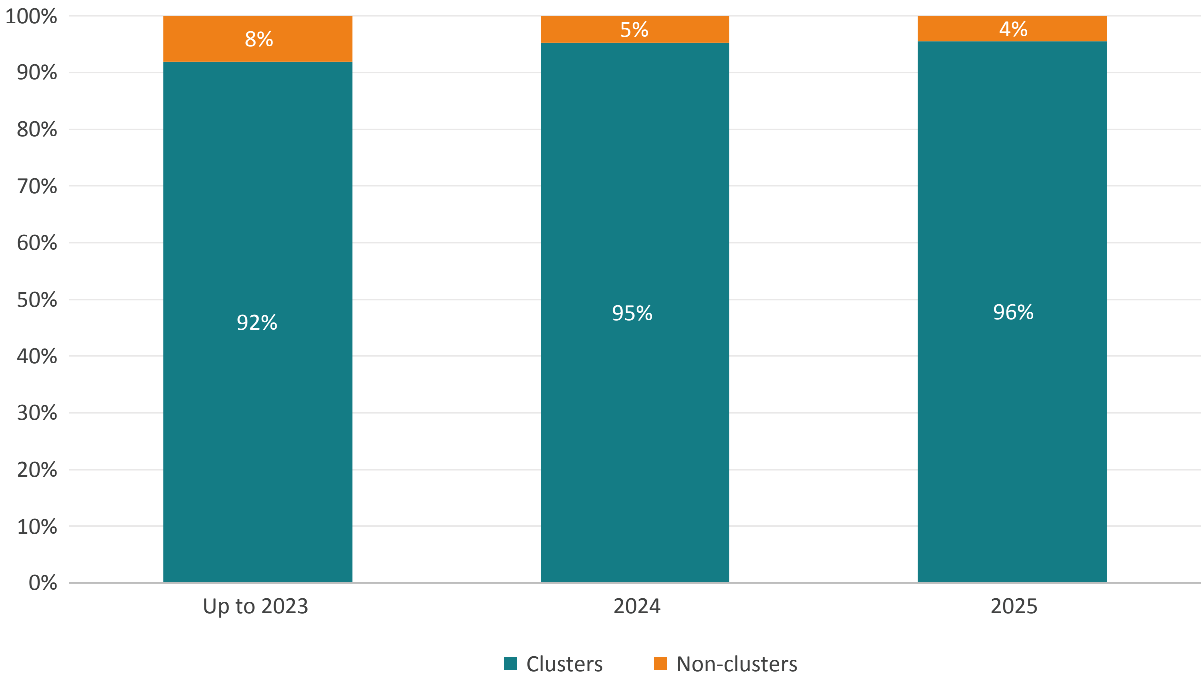
[4] Additional methodological details, including detection thresholds and robustness checks, are provided in Annex 1.

[5] Institutions are classified by headquarters location. For companies in particular, this may overstate activity in the HQ cluster and understate activity in subsidiaries elsewhere, but systematically tracking all subsidiary locations globally is not feasible; HQ location remains the most practical and consistent method for classification.

[6] Annex 2 provides supplementary info on funding distributions and institutional composition in clusters across regions.

[7] A fuller breakdown of collaboration patterns is available in Annex 2.

FIGURE 1: GLOBAL QUANTUM COMPANY FUNDING BY YEAR – CLUSTERS VS. NON-CLUSTERS



Source: ECIPE Quantum Database. Note: 2025 figures reflect funding recorded up to July 31, 2025. The "Up to 2023" category covers all funding through December 31, 2023.

2.2 Where Quantum Clusters Are

In the Introduction, we presented the complete ranking of 45 quantum clusters worldwide. Table 2 below narrows the lens to a strategically important subset: regions with a GDP of at least USD 750 billion. We highlight these clusters because their economic scale, fiscal resources, market depth, and institutional density give them a disproportionate ability to influence the development, commercialisation, and governance of quantum technologies. In other words, after identifying all regions with significant quantum activity, we focus here on those with the economic weight to more meaningfully shape the trajectory of the global quantum economy.

Silicon Valley stands out as the highest-ranked larger cluster, representing the most commercially advanced quantum hub among major regional economies. Its strength comes from deep integration between Big Tech and quantum startups (Google, Rigetti, D-Wave) and elite research institutions (Berkeley, Stanford), producing a uniquely tech-driven innovation model capable of rapid translation from lab to market.

London ranks immediately after, with telecom operator BT Group and cybersecurity quantum startup Arqit actively developing quantum-secure communication and encryption offerings, supported by a strong pipeline of talent and research from Imperial College London, UCL, and King's College London. London's quantum trajectory is anchored in commercial rollout, secure communications, and international partnerships, making it Europe's leading major cluster for quantum integration.

Washington, Paris, and Beijing form a recognisable capital-city archetype in quantum development: all three are state-steered ecosystems with strong aerospace, defence, and national security orientations. In Washington, established defence contractors such as RTX Corporation and Northrop Grumman intersect with emerging quantum startup IonQ, forming a hybrid defence–startup–federal research nexus, reinforced by the University of Maryland and its integrated research institutes jointly operated with federal agencies. In Paris and Beijing, a similar pattern emerges: state-backed aerospace and defence conglomerates like Thales and CASC coexist with scaling quantum startups such as PASQAL and Lonxun Quantum, embedded within dense research infrastructures.

Interestingly, four of the bottom five larger quantum clusters are Asian, signalling that Asia's largest economic regions are still behind in the process of converting sheer economic mass into actual quantum development with respect to Western counterparts. Los Angeles stands out as the only Western late-ranking major cluster.

TABLE 2: MAJOR QUANTUM CLUSTERS AND THEIR KEY INDUSTRY AND RESEARCH COLLABORATORS (METROPOLITAN AREAS WITH GDP OVER USD 750 BILLION)

Rank	Quantum cluster	Top industry collaborators	Top research collaborators
4	**San Francisco Bay Area**	Google • Rigetti Computing • D-Wave	UC Berkeley • Stanford University • RIACS
14=	**London Commuter Belt**	Arqit Quantum Inc. • BT Group • Crypto Quantique	Imperial College London • UCL • King's College London
18	**Greater Washington**	IonQ • RTX Corporation • Northrop Grumman	University of Maryland • Joint Quantum Institute • QuICS
20	**Greater Paris**	PASQAL • Quandela • Thales	Sorbonne University • University of Paris-Saclay • Paris Cité University
26	**Shanghai**	TuringQ • Guoke Quantum • CSSC	SJTU • ECNU • Fudan University
27	**Greater New York**	IBM • SEEQC • JPMorgan Chase	Columbia University • CUNY • NYU
29=	**Beijing**	Lonxun Quantum • CASC • Baidu	BAQIS • Tsinghua University • BUPT
29=	**Greater Tokyo**	NTT • Toshiba • Fujitsu	University of Tokyo • Waseda University • Keio University
32=	**Shenzhen–Hong Kong–Guangzhou Region**	SpinQ • Huawei • Tencent	Sun Yat-Sen University • SUSTech • HKU
36=	**Greater Los Angeles**	RadiaBeam Technologies • BlueQubit • Beyond Limits	Caltech • UCLA • USC
43	**Seoul Metropolitan Area**	SDT • Samsung • Hyundai	Seoul National University • SKKU • Kyung Hee University

Source: ECIPE Quantum Database.

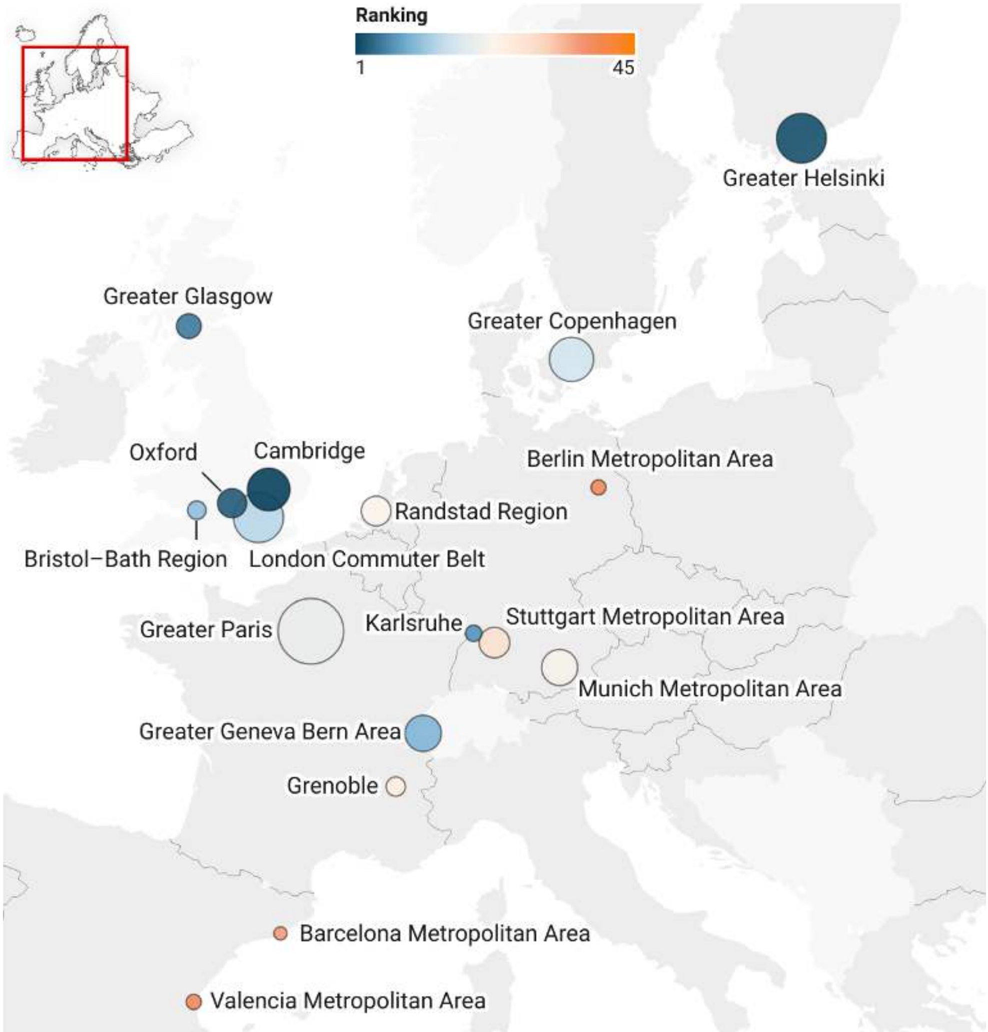
To complement the analysis, we present three regional maps that offer a visual overview of quantum clusters in the world's most significant regions: Europe, North America, and East Asia. The colour scale – from dark blue for the highest-ranking clusters to orange for the lowest –

represents their relative performance in the overall ranking. The size of each bubble indicates the level of total quantum company funding within that ecosystem.

Figure 2 shows European quantum clusters. The UK's dominance is immediately visible, with a dense concentration of high-performing hubs – both in ranking and in funding – particularly in the southeast of the country. Within the EU, the picture is more heterogeneous. Northern clusters such as Helsinki and Copenhagen stand out as clear leaders, combining strong positions in the ranking with comparatively high levels of funding. By contrast, continental European clusters are more numerous but often mid-ranked, with funding levels varying widely. Southern hubs, including Barcelona and Valencia, are fewer in number, occupy the lower end of the ranking and attract only modest private quantum investment.

Paris stands out as the EU's most heavily funded cluster, with more than USD 750 million in total quantum investment. Helsinki follows as the second most well-funded EU hub, attracting over USD 418 million – nearly matching London's USD 422 million despite the latter being a much larger metropolitan area.

FIGURE 2: EUROPEAN QUANTUM CLUSTERS



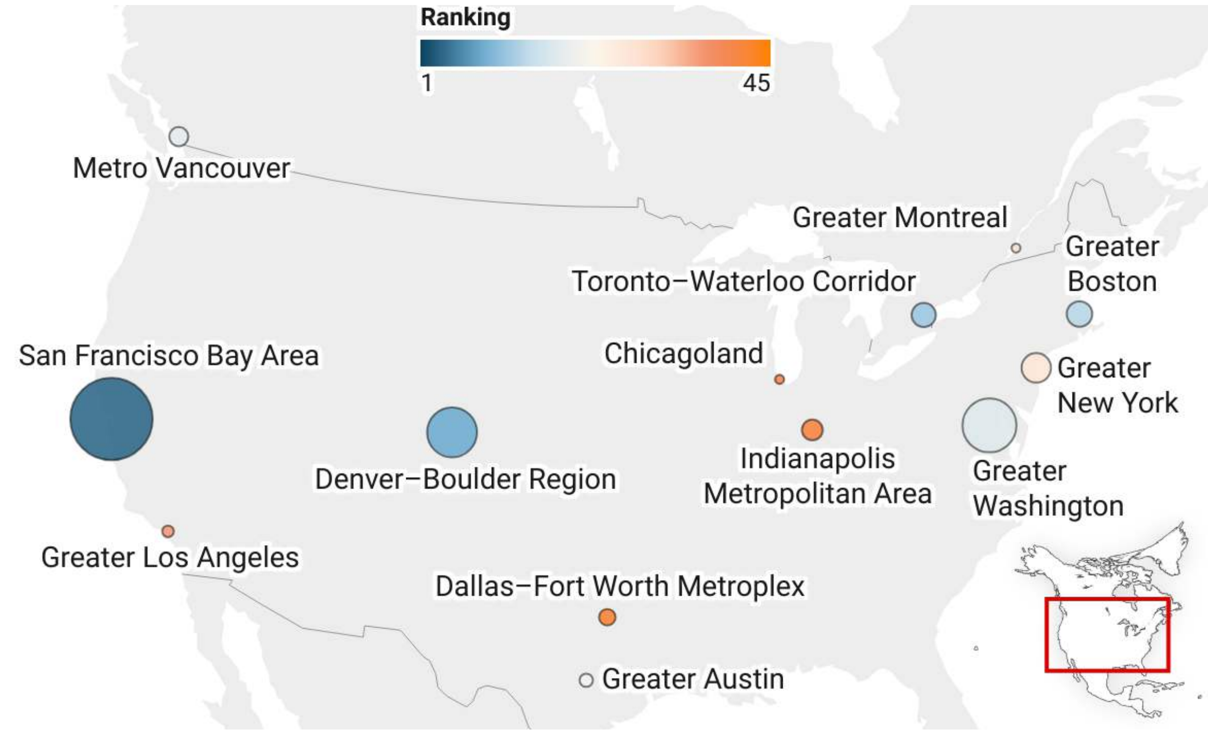
Source: ECIPE Quantum Database.

Figure 3 presents North American quantum clusters. The region is dominated by the US, with the San Francisco Bay Area standing out as both the highest-ranked cluster in North America and the most heavily funded cluster worldwide. Quantum companies in Silicon Valley have attracted over USD 6.2 billion in investment – nearly twice the combined total of all European clusters. This leadership reflects the unique concentration of venture capital, world-class startups and established tech corporations, and strong university–industry linkages.

Other leading US hubs include Denver–Boulder, Greater Washington, and Greater Boston, which secure high positions in the ranking and benefit from substantial investment flows. By contrast, clusters in large metropolitan areas such as Los Angeles, Chicago, and Dallas attract more modest levels of funding and are positioned towards the lower end of the ranking.

Canada plays an important role through the Toronto–Waterloo cluster, which ranks among the global top 15 and attracts funding levels comparable to those of Boston. However, other Canadian ecosystems – Montreal in particular – rank lower, reflecting smaller scale and more constrained funding.

FIGURE 3: NORTH AMERICAN QUANTUM CLUSTERS



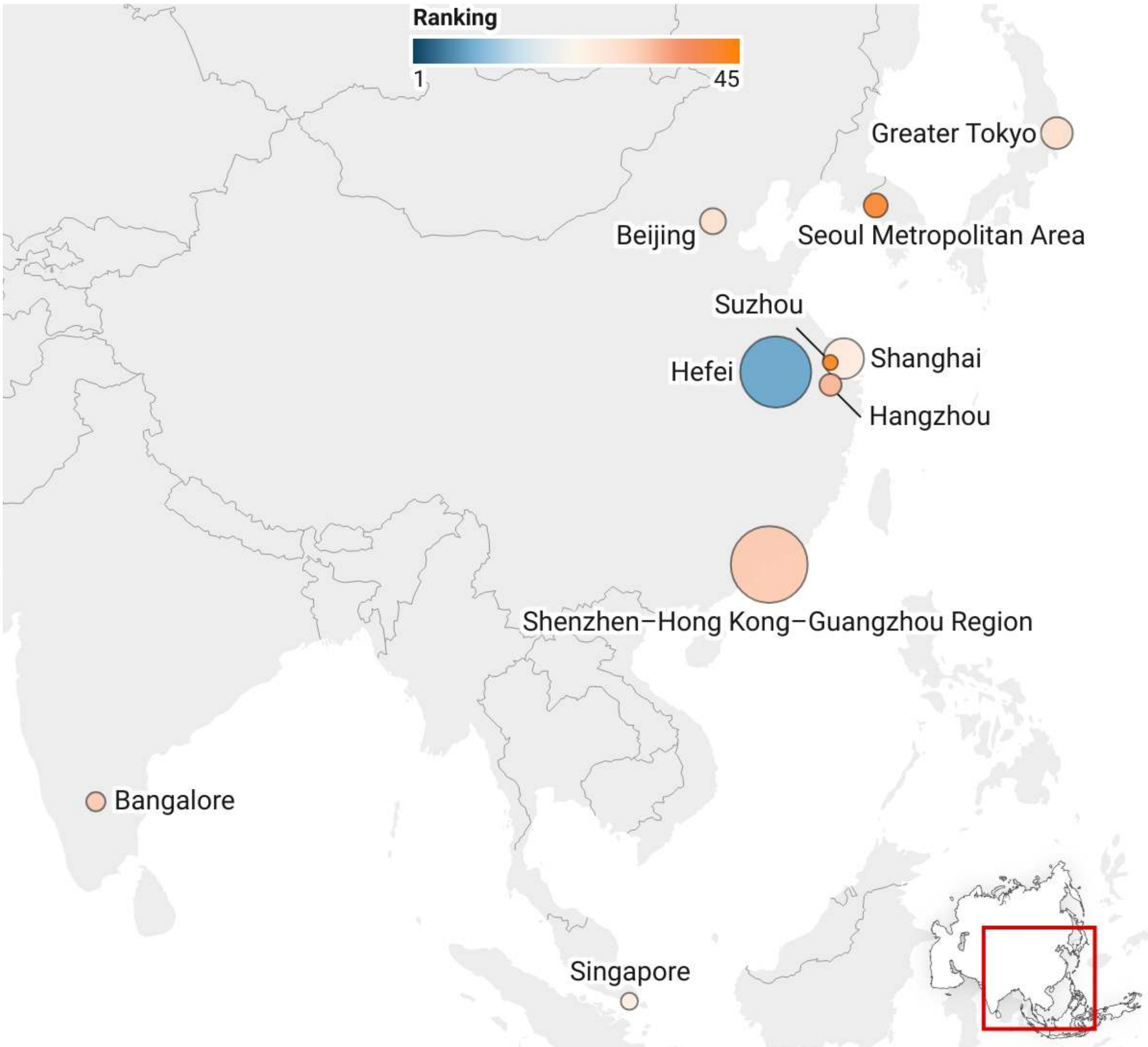
Source: ECIPE Quantum Database.

Figure 4 illustrates East Asian quantum clusters. The region is led by China, which accounts for six of the ten hubs in East Asia, each at different stages of development. Hefei stands out as both the highest-ranked cluster in China and the wider region, and the only one to appear in the global top 15. Its funding is also remarkable at over USD 1.1 billion – more than two and a half times the combined funding of the four non-Chinese clusters in East Asia. The Shenzhen–

Guangzhou–Hong Kong region also attracts substantial investment of more than USD 1.3 billion, though its relatively low ranking suggests this is largely a by-product of the area's vast GDP rather than ecosystem sophistication. Shanghai and Beijing also record relatively high funding volumes but are positioned only in the middle tier of the ranking.

Outside China, results are more modest. Tokyo and Singapore occupy mid-ranking positions and both face limited private investment – particularly Singapore, with just USD 43 million in funding. Seoul ranks even lower and attracts only slightly more than USD 100 million, signalling an emerging but as yet underdeveloped ecosystem.

FIGURE 4: EAST ASIAN QUANTUM CLUSTERS



Source: ECIPE Quantum Database.

3. DIMENSION 1: MARKET ORIENTATION

The **“Market Orientation”** dimension is the first pillar of the Quantum Clusters Ranking. It captures the extent to which quantum activity within a cluster is geared towards commercialisation, industry engagement, and economic impact. This dimension is assessed through three indicators:

1. **Total funding** – reflecting the absolute scale of investment in quantum companies within a cluster;
2. **VC, equity, and debt funding relative to GDP** – measuring the intensity of quantum startup financing as a share of the local economy;
3. **Industry-involving collaborations relative to GDP** – indicating the degree to which local industry participates in quantum collaborations.

TABLE 3: TOP 10 QUANTUM CLUSTERS RANKED ON “MARKET ORIENTATION”

Rank	Quantum cluster	Country	Region
1	San Francisco Bay Area	US	US
2=	Cambridge	UK	UK, Canada, and Australia
2=	Greater Helsinki	Finland	EU
4=	Denver–Boulder Region	US	US
4=	Hefei	China	China
6	Tel Aviv Metropolitan Area	Israel	Rest of the World
7	Greater Washington	US	US
8	Oxford	UK	UK, Canada, and Australia
9	Canberra	Australia	UK, Canada, and Australia
10	Toronto–Waterloo Corridor	Canada	UK, Canada, and Australia

Source: ECIPE Quantum Database.

Table 3 presents the top 10 global quantum clusters according to this dimension, pointing to those ecosystems where quantum innovation is most strongly anchored in market-oriented activity. The San Francisco Bay Area takes the top position, driven by its unparalleled scale of venture funding, density of both startups and tech corporates, and strong industry-academic ties. In joint second place, Cambridge and Greater Helsinki combine world-class research capacity with a growing ability to translate breakthroughs into commercial opportunities.

Hefei in China and the Denver–Boulder region in the US follow in fourth place, both demonstrating significant strengths in quantum commercialisation. Meanwhile, Tel Aviv emerges as the leading cluster outside the three main regions of North America, Europe, and China, confirming Israel’s position as a global innovation hotspot.

The US dominates the list with three entries (San Francisco Bay Area, Denver–Boulder, and Washington DC). The UK, Canada, and Australia collectively contribute four clusters (Cambridge, Oxford, Toronto–Waterloo, Canberra), with the UK alone represented twice. Continental Europe appears only once, with Helsinki, while China is represented solely by Hefei.

Overall, the ranking shows that the US and other English-speaking countries hold a clear advantage in commercialisation, claiming 7 of the top 10 spots. By contrast, the EU and China, despite their strong research foundation and extensive collaboration networks, continue to lag behind the Anglosphere in mobilising funding and securing deep industry engagement.

3.1 Total Funding

A closer look at the indicators underlying the "Market Orientation" dimension is needed to understand why some clusters secured the top positions. Figure 5 below delves into the first of these indicators, that is the total funding raised by quantum startups or committed by major corporations across clusters, revealing the dominance of a handful of metropolitan areas globally. The top 10 clusters account for more than three-quarters of all quantum company funding, leaving just 23 per cent for the remaining 35 clusters combined.

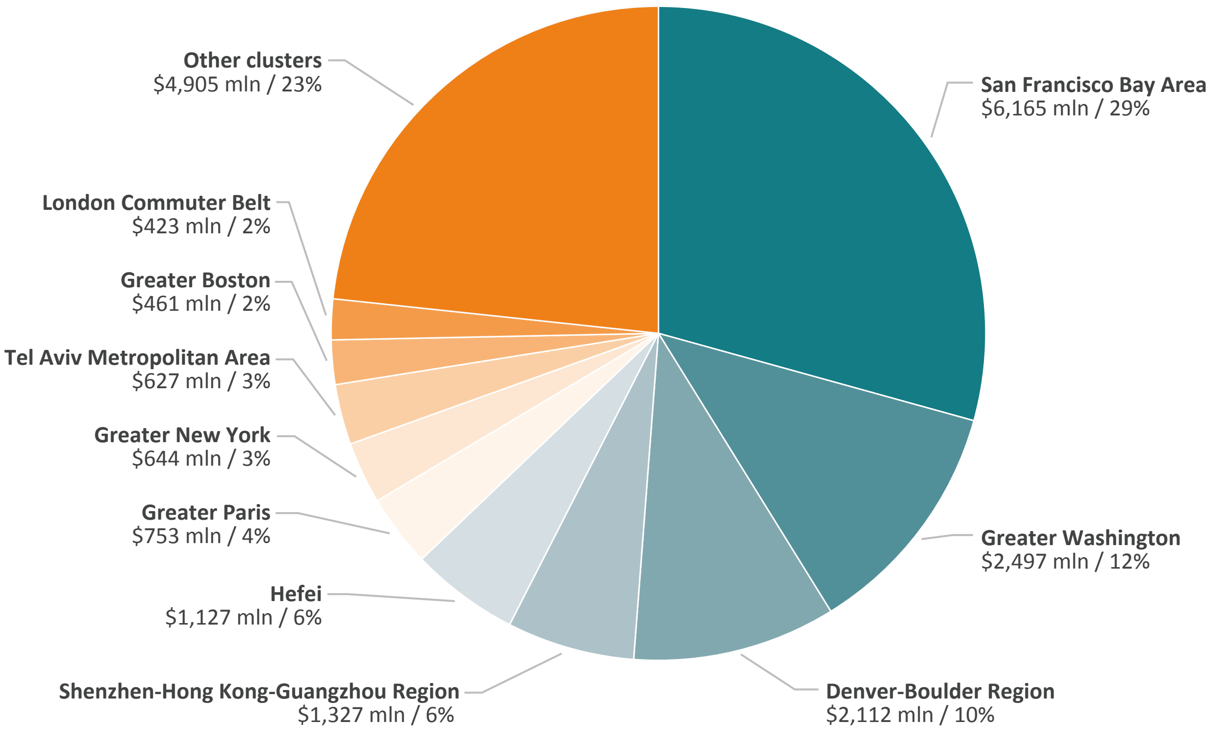
The San Francisco Bay Area leads by a wide margin, attracting USD 6.2 billion (29 per cent). This reflects its unmatched venture capital ecosystem, dense network of high-growth startups, and the presence of leading technology corporations. The Silicon Valley's prominence in quantum investment thus reinforces its global leadership not only in microchips and AI, but increasingly in next-generation computing.

The Greater Washington and Denver–Boulder regions follow with more than USD 2 billion each (12 and 10 per cent respectively), showing the depth of US quantum activity beyond San Francisco. While Silicon Valley is notorious for its innovation and startup culture, it is particularly interesting that Greater Washington and Denver–Boulder – areas less typically recognised as innovation hubs – emerge as highly relevant in the quantum sector. Together, these three clusters capture over half of all global quantum funding, pointing to the US's position as the world's leading hub for commercialisation and startup investment. Two further US clusters – New York and Boston – make the top ten, though each accounts for only 2–3 per cent of global funding.

Outside the US, funding is more dispersed but still significant. China's Shenzhen–Hong Kong–Guangzhou and Hefei regions each raise over USD 1 billion (both around 6 per cent). In Europe, only Paris (4 per cent) and London (2 per cent) feature among global leaders by total funding, pointing to the EU and UK's relatively modest role in absolute terms. Remarkably, Tel Aviv is the sole cluster outside the US, Europe, and China to break into the top ten.

The global landscape is highly asymmetric: while the US clusters dominate quantum company funding, other regions remain at a clear disadvantage in mobilising large-scale private investment.

FIGURE 5: TOP 10 QUANTUM CLUSTERS BY TOTAL QUANTUM COMPANY FUNDING AND GLOBAL SHARE



Source: ECIPE Quantum Database. Note: Quantum funding data is cumulative to July 31, 2025.

BOX 1: WHY QUANTUM STARTUPS END UP GRAVITATING TO SILICON VALLEY

The origins of Silicon Valley date back to the late 1940s, when pioneering work in semiconductors and electronics began to take root in the region. By the 1960s and 1970s, the growing concentration of semiconductor firms had transformed the area into a global hub of innovation, fuelling the rise of the personal computer industry. Much of this success is rooted in the role of **Stanford University**, whose research and industry partnerships became central to the region's innovation ecosystem. Stanford became **a bridge between innovation and entrepreneurship**, fostering collaboration between academia and industry. Equally crucial was the region's culture, one of **entrepreneurialism, risk-taking, and a strong "do-it-yourself" ethos.**

This legacy continues to shape where deep-tech startups, including those in quantum technology, choose to locate. Firms such as **PsiQuantum** (founded in Bristol, UK) and **D-Wave** (founded in Burnaby, Canada) – the first and fourth best-funded quantum startups globally – illustrate this dynamic. In 2016, PsiQuantum's founders realised that to build a scalable quantum computer, substantial funding was essential. After exploring options across the UK, Europe, and the US, they found the **strongest investor response** in the US, specifically, Silicon Valley, raising USD 13 million in seed funding. Over the years, the company raised USD 1.3 billion from venture capital investors such as Blackrock, and signed two public-private partnerships with governments, neither from Europe in 2024. *"It's very hard to make things* *like that happen in Europe,"* says Mark Thompson, co-founder PsiQuantum. *"For these big capital and infrastructure heavy projects, you need that public-private partnership to make them work."* [8]

Similarly, D-Wave Quantum announced in 2023 plans to relocate its principal executive office from Metro Vancouver to the US.[9] The company cited accounting and regulatory alignment as key reasons for the move, noting that as a US domiciled corporation, it would now engage a US-based auditor. More broadly, the shift reflected both the financial pressures of a capital-intensive sector and the continued pull of the US innovation ecosystem. **Quantum technology development demands substantial investment,** and proximity to Silicon Valley's venture capital and talent networks offered strategic advantages. D-Wave's long-standing ties to the region, through Silicon Valley hires and a USD 30 million equity investment from US investors as early as 2013[10], further the importance of this connection.

3.2 VC, Equity, and Debt Funding Relative to GDP

Total funding is an important indicator, as it reflects the overall scale of quantum investment. However, it is equally important to consider the economic size of each cluster. Some clusters may receive lower absolute levels of funding simply because they are smaller, yet when funding is assessed relative to their GDP, they may prove highly competitive. Accordingly, the second indicator within the "Market Orientation" dimension measures venture capital (VC), equity, and debt funding as a share of each cluster's GDP. This indicator focuses exclusively on startup funding and does not include investment committed by established corporations.

Figure 6 below ranks the top 10 quantum clusters by this indicator. Unlike in absolute terms, smaller but innovation-focused economies rise to the top. Cambridge leads by a wide margin, with quantum startup funding exceeding 1.3 per cent of local GDP, highlighting the disproportionate scale of venture capital channelled into its startup ecosystem.[11] Oxford, in fifth place, mirrors this pattern on a smaller scale.

US clusters feature prominently in relative terms as well. The San Francisco Bay Area and the Denver–Boulder Region take second and fourth place respectively, while the Greater Washington metropolitan area also appears further down the list in seventh place. This shows the strength of these American quantum startup ecosystems even when accounting for the vast scale of their local economies.

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8 Nicol-Schwarz, K. (2025, January 31). 'Europe is falling behind': Cofounder of world's best-funded quantum startup on why the region risks losing out in the sector. Sifted. https://sifted.eu/articles/psiquantum-europe

9 Silcoff, S. (2023, June 14). D-Wave Quantum loses outside accounting firm, plans to move executive office to U.S.. TheGlobeandMail. Available at: https://www.theglobeandmail.com/business/article-d-wave-quantum-loses-outside-accounting-firm-plans-to-move-offices-to/#:~:text=Latest%20in,Story%20continues%20below%20advertisement

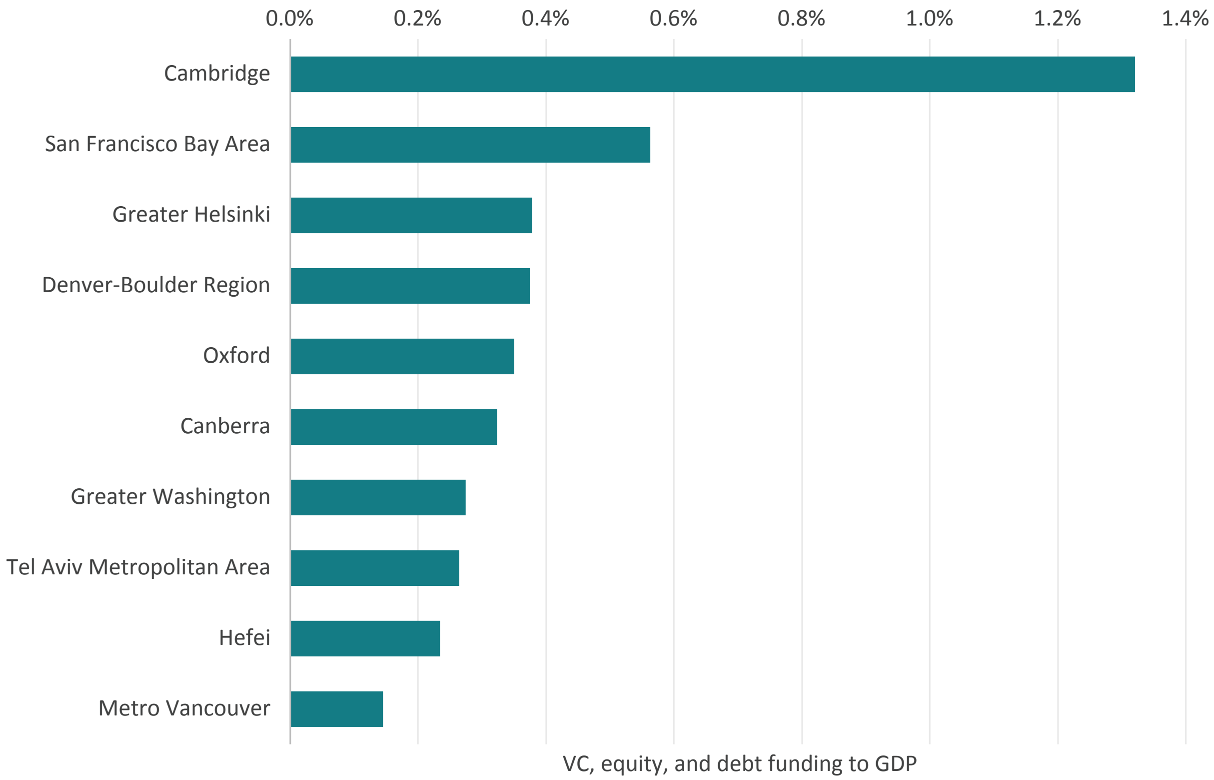
10 CNBC. (2012, October 4). D-Wave Systems, Inc., the World's First Commercial Quantum Computing Company, Secures $30 Million in a New Equity Round From Investors Including Bezos Expeditions and In-Q-Tel. Available at: https://www.cnbc.com/2012/10/04/dwave-systems-inc-the-worlds-first-commercial-quantum-computing-company-secures-30-million-in-a-new-equity-round-from-investors-including-bezos-expeditions-and-inqtel.html

11 The Cambridge cluster total includes funding raised by Cambridge Quantum Computing prior to its 2021 merger with Honeywell Quantum Solutions to form Quantinuum, while the company was still a standalone UK entity.

In the EU, only Greater Helsinki enters the top ten, matching Denver–Boulder's funding intensity. Canberra and Metro Vancouver also stand out, as they show that Australia and Canada both host some of the world's most concentrated quantum startup hubs. Beyond the transatlantic space, both Hefei and Tel Aviv make the top ten, as they did in absolute terms, demonstrating ecosystems that combine both scale and intensity in ways that rival Western hubs.

Taken together, these results point to how smaller, innovation-driven economies can punch well above their weight. While the US continues to dominate in both absolute and relative terms, clusters in the UK, Finland, Australia, Canada, China, and Israel emerge as highly competitive once investment intensity is factored in.

FIGURE 6: TOP 10 QUANTUM CLUSTERS BY QUANTUM STARTUP FUNDING INTENSITY (PERCENTAGE OF GDP)



Source: ECIPE Quantum Database. Note: Quantum funding data is cumulative to July 31, 2025.

When examining startup funding intensity, it is useful to position quantum activity within the broader startup landscape. To do this, Figure 7 plots quantum startup funding intensity – the indicator just described – against the overall value of the local startup ecosystem as a share of GDP. This metric, calculated by the economic consultancy Startup Genome, captures the total value of exits and startup valuations within a given period for each cluster. It therefore serves as a proxy for the overall value of the startup ecosystem in that cluster, across all sectors rather than quantum alone.

This comparison helps to illustrate whether strong performance in quantum within a particular cluster merely reflects its general dynamism in frontier technologies, or whether it signifies a distinctive area of specialisation. In Figure 6, clusters positioned close to the orange line exhibit balanced strength in both quantum and the wider startup economy. Those above the line show a stronger-than-expected focus on quantum, while those below the line display relatively less emphasis on quantum and greater strength in general startup activity.

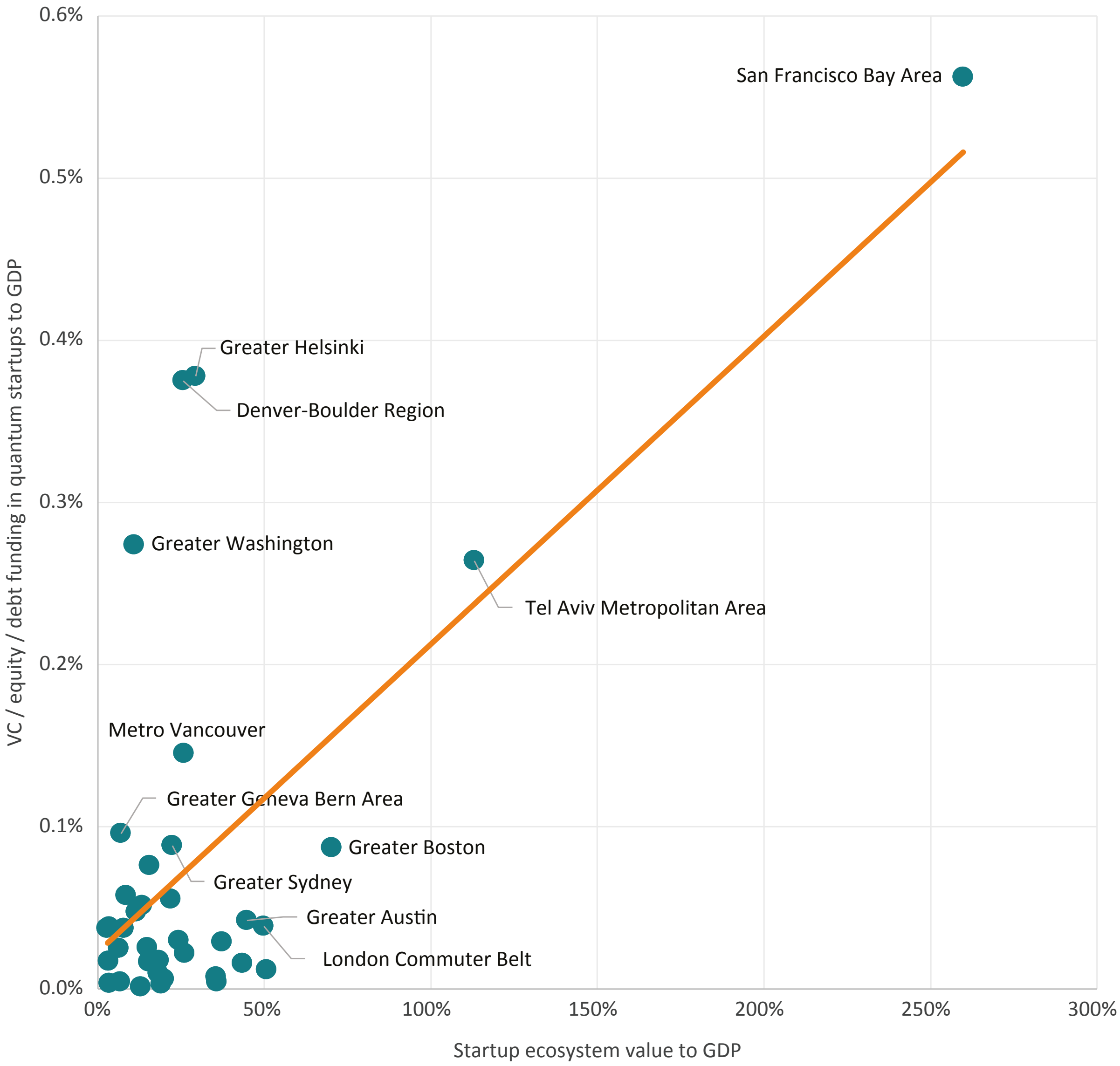
The San Francisco Bay Area stands out clearly, combining the world's most valuable startup ecosystem with an exceptionally high concentration of quantum funding. This reinforces Silicon Valley's role as the undisputed leader in translating frontier technologies into commercial opportunities across multiple domains. Tel Aviv also performs strongly on both measures, reflecting Israel's established edge in deep-tech commercialisation.

Other clusters show a different profile. Denver–Boulder and Greater Helsinki both achieve relatively high levels of quantum startup funding despite operating within more modest overall startup ecosystems. On a smaller scale, Greater Washington and Metro Vancouver display a similar pattern. This signals a sharper specialisation of these clusters in quantum than their local startup context might suggest.

By contrast, several prominent startup hubs – such as Boston, Austin, and London – fall closer to the baseline, indicating that while they host vibrant technology ecosystems, quantum does not yet represent a disproportionately strong component within them.

This cross-comparison is analytically important because it highlights two distinct models of success: clusters where quantum activity rides on the coattails of broader tech startup dynamism (as in the Bay Area and Tel Aviv) and those where it has emerged as a clear specialisation in its own right (as in Helsinki and Denver–Boulder). This suggests that smaller economies with targeted investments can gain visibility in quantum that far exceeds their overall innovation footprint.

FIGURE 7: QUANTUM STARTUP FUNDING INTENSITY VS. BROADER STARTUP ECOSYSTEM VALUE



Source: Startup Genome12 and ECIPE Quantum Database. Note: Ecosystem value figures cover H2 2021–2023; quantum funding data is cumulative to July 31, 2025. Cambridge, Canberra, Greater Glasgow, Grenoble, Hefei, Karlsruhe, Oxford, and Suzhou were excluded due to unavailable ecosystem data. For visual clarity, only a selection of cluster labels is shown.

3.3 Industry-involving Collaborations Relative to GDP

A final aspect captured by the third indicator in the "Market Orientation" dimension is industry-involving collaborations. As shown in our previous study, the extent of industry collaboration is a strong proxy for commercialisation in quantum: it correlates closely with funding, yet also reflects knowledge exchange and industrial development in ways that financial data alone cannot

[12] Startup Genome. Discover Global Tech Ecosystems. https://startupgenome.com/ecosystems

capture.[13] Incorporating this measure is therefore essential for assessing the true commercial orientation of quantum clusters.

Table 4 below highlights the top 10 quantum clusters when measured by industry-involving collaborations relative to GDP, offering a complementary view to funding-based measures. The results point to the prominence of smaller but research-intensive ecosystems. Cambridge tops the ranking by a wide margin, with industry collaborations almost twice as high as Oxford, which takes second place. Both are anchored by world-class universities and spinout companies such as Riverlane and PQShield, which exemplify how academic excellence can be successfully translated into commercial partnerships.

Canberra and Greater Helsinki follow closely, showing that Australia and Finland host highly collaborative quantum ecosystems relative to their economic size. Their top partners, QuintessenceLabs and IQM Quantum Computers, illustrate the importance of specialised startups that bridge university research (ANU and Aalto University) with industry needs.

China's Hefei also appears in the top five, emphasising the central role of Origin Quantum and the University of Science and Technology of China (USTC) in driving industry–research integration. Further down the list, the Bristol–Bath Region and Karlsruhe show how targeted European hubs can punch above their economic weight through specialised startups and strong institutional anchors.

Interestingly, the San Francisco Bay Area makes the ranking but only in eighth place despite its global leadership in funding. This contrast suggests that while Silicon Valley dominates in funding, smaller ecosystems may achieve higher relative intensity of industry collaboration. Toronto–Waterloo and Greater Austin round out the top ten, driven by local startups such as Xanadu and Strangeworks.

Overall, the table illustrates that clusters like Cambridge, Oxford, and Helsinki excel not only in attracting capital but also in fostering tight linkages that involve industry, which are essential for translating quantum innovation into commercial applications.

[13] Erixon, F., Dugo, A., Pandya, D. and Sisto, E. (2025, September). Mapping the quantum ecosystems: How are economies positioning themselves for innovation success. ECIPE Occasional Paper. https://ecipe.org/publications/mapping-the-quantum-ecosystems/

TABLE 4: TOP 10 QUANTUM CLUSTERS BY INDUSTRY COLLABORATIONS TO GDP AND THEIR KEY INDUSTRY AND RESEARCH COLLABORATORS

Quantum cluster	Industry collaborations to GDP	Top industry collaborator	Top research collaborator
Cambridge	1,821	Riverlane	University of Cambridge
Oxford	1,334	PQShield	University of Oxford
Canberra	938	QuintessenceLabs	Australian National University (ANU)
Greater Helsinki	697	IQM Quantum Computers	Aalto University
Hefei	370	Origin Quantum (本源量子)	University of Science and Technology of China (USTC)
Bristol–Bath Region	334	Phasecraft	University of Bristol
Karlsruhe	323	Kipu Quantum	Karlsruhe Institute of Technology
San Francisco Bay Area	272	Google	University of California, Berkeley
Toronto–Waterloo Corridor	244	Xanadu	University of Waterloo
Greater Austin	237	Strangeworks	University of Texas at Austin

Source: ECIPE Quantum Database. Note: Industry-involving collaborations are measured per trillion USD of GDP.

Key "Market Orientation" Dimension Takeaways

1. **US and Anglosphere dominance** – The US and other English-speaking countries (UK, Canada, Australia) account for 7 of the top 10 clusters, highlighting their strength in mobilising venture capital, startup dynamism, and industry partnerships. The EU and China lag despite strong research bases.

2. **Scale vs. intensity** – Silicon Valley, Denver–Boulder, and Greater Washington perform strongly in both absolute and relative terms, while smaller ecosystems such as Cambridge, Helsinki, and Oxford excel when measured relative to GDP, showing how niche, innovation-driven clusters can outperform in intensity.

3. **Industry collaboration as a commercialisation driver** – Cambridge, Oxford, Canberra, and Helsinki top the ranking for industry-involving collaborations to GDP, signalling that smaller ecosystems can achieve tighter industry integration than the big US hubs, where funding dominates.

4. **Two distinct success models** – Leading quantum clusters either ride on the strength of broad frontier-tech ecosystems (e.g. Bay Area, Tel Aviv) or develop

quantum as a distinct specialisation within otherwise relatively modest startup environments (e.g. Helsinki, Denver–Boulder), illustrating two alternative models for competitiveness.

4. DIMENSION 2: COLLABORATION INTENSITY

The **"Collaboration Intensity"** dimension is the second pillar of the Quantum Clusters Ranking. It measures the volume, openness, and connective role of each cluster. This dimension consists of three indicators:

1. **Total number of institutional collaborations** – capturing overall collaborative activity and internal network density;
2. **External collaborations as a share of total** – indicating openness and global integration;
3. **Brokerage role in collaboration network** – showing bridging role and cross cluster connectivity.

TABLE 5: TOP 10 QUANTUM CLUSTERS RANKED ON "COLLABORATION INTENSITY"

Rank	Quantum cluster	Country	Region
1	Shanghai	China	China
2	Greater Los Angeles	US	US
3	Karlsruhe	Germany	EU
4	Greater Glasgow	UK	UK, Canada, and Australia
5	Oxford	UK	UK, Canada, and Australia
6	Greater Copenhagen	Denmark	EU
7	Hefei	China	China
8=	Bangalore	India	Rest of the World
8=	Greater Geneva Bern Area	Switzerland	Rest of the World
10	London Commuter Belt	UK	UK, Canada, and Australia

Source: ECIPE Quantum Database.

The top 10 clusters for this dimension are presented in Table 5. Shanghai, Los Angeles, and Karlsruhe form the top 3. Unlike the two other dimensions, no single world region dominates this ranking. However, Chinese clusters – especially Shanghai and Hefei – are performing strongly in this dimension compared to others.

As such, this dimension highlights which clusters are most active in forging partnerships and how they position themselves within the wider quantum innovation network. As emphasised in our previous work, collaboration is not simply supportive of quantum progress, it is its core foundation.[14] Quantum technologies require the integration of highly specialised and diverse capabilities across physics, computer science, engineering, cryogenics, materials science and more, making it very hard for any single institution, or even any single cluster or country, to advance in isolation.

Our earlier study showed that 61 per cent of all global quantum partnerships take place between research institutions, reflecting the field's pre-commercial nature and the need to pool scientific expertise across borders. It also demonstrated that no country dominates all segment of the quantum stack, and that the most successful national ecosystems, such as the UK, US, and Finland, are those embedded in dense international collaboration networks.

Furthermore, our previous analysis pointed to how quantum development is unevenly distributed, with countries and institutions specialising in different sub-fields (e.g., hardware, photonics, cryptography), making cross-cluster and cross-border partnerships essential for combining these complementary strengths. We also showed that countries with higher international openness, such as Finland, Canada, Switzerland and Singapore, occupy structurally advantageous positions as "Global Innovation Hubs" within the quantum ecosystem, enabling them to access frontier developments and accelerate commercial maturity.

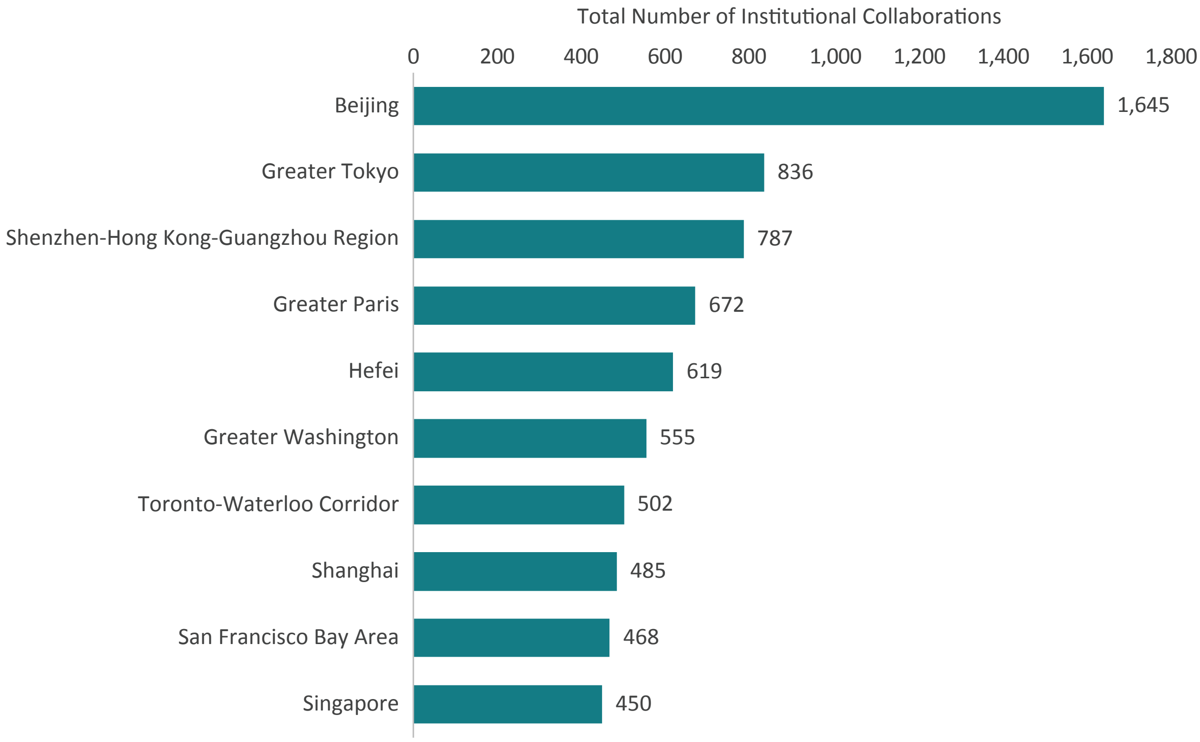
Building on these insights, Dimension 2 applies the same structural logic at the cluster level: clusters that combine high collaboration volume with diverse external partnerships and strong brokerage roles tend to unlock interdisciplinary combinations and serve as crucial connectors within the global innovation network. While the total number of collaborations partly reflects the size of each cluster, the two other indicators capture the more qualitative aspects of network behaviour: openness and connectivity. They show whether a cluster looks beyond its internal ecosystem and whether it acts as a bridge between otherwise disconnected actors. In other words, Dimension 2 not only identifies the busiest clusters, but also those with the most valuable collaboration patterns (see Box 2 below).

4.1 Total Number of Institutional Collaborations

Let us now examine the three indicators underlying the "Collaboration Intensity" dimension in more detail. Figure 8 presents the first of these indicators, that is the top 10 clusters with the highest number of collaborations. Chinese clusters account for four out of the top ten clusters with Beijing, Shenzhen–Hong Kong–Guangzhou, Hefei and Shanghai. Other major global hubs such as Tokyo and Paris also feature in the top tier. Since this indicator counts all institutional collaborations, China's strong academic base pushes its clusters upwards in the ranking. The composition of these partnerships is overwhelmingly research-driven (96 per cent involve a university or another research actor). Dimension 2 captures a different aspect of Chinese clusters than Dimension 1, that is its role more as a research hub than a centre of industry-led quantum innovation.

[14] Erixon, F., Dugo, A., Pandya, D. and Sisto, E. (2025, September). Mapping the quantum ecosystems: How are economies positioning themselves for innovation success. ECIPE Occasional Paper. https://ecipe.org/publications/mapping-the-quantum-ecosystems/

FIGURE 8: TOP 10 CLUSTERS BY TOTAL INSTITUTIONAL COLLABORATIONS



Source: ECIPE Quantum Database.

BOX 2: WHY COLLABORATION NETWORKS MATTER FOR QUANTUM INNOVATION

A large body of research in innovation economics and network science shows that the structure of collaboration networks – how dense, diverse, and connected they are – strongly shapes the capacity of regions to generate breakthrough technologies. **Innovation emerges when previously separate, yet cognitively related capabilities are combined in new ways.**[15] These mechanisms are particularly relevant for quantum technologies, whose development requires the coordinated integration of physics, engineering, cryogenics, materials science, control systems, software and more.

Dense collaboration networks facilitate the rapid exchange of tacit knowledge, essential in quantum, where experimental setups are highly sensitive, error rates evolve incrementally, and engineering challenges require continuous calibration. Research emphasises that achieving error-corrected quantum computing requires continuous, iterative coordination between hardware teams, control-system engineers, and algorithm developers, because the performance of one layer of the stack is inseparable from the others. **Such tight interdependence reinforces why clusters with many institutional collaborations**, reflecting

[15] Fleming, L. (2001). Recombinant uncertainty in technological search. Management science, 47(1), 117-132; Boschma, R. (2005). Proximity and innovation: a critical assessment. Regional studies, 39(1), 61-74; Hidalgo, C. A., & Hausmann, R. (2009). The building blocks of economic complexity. Proceedings of the national academy of sciences, 106(26), 10570-10575; Balland, P. A., Boschma, R., & Frenken, K. (2022). Proximity, innovation and networks: A concise review and some next steps. Handbook of proximity relations, 70.

high network density, **tend to learn faster and advance more quickly** along the technological frontier.[16]

Breakthrough innovation typically arises from the recombination of diverse but related knowledge bases.[17] Research on quantum highlights that progress in quantum error correction (QEC) and system scalability requires co-design across multiple specialists, including qubit physicists, cryogenic engineers, microwave specialists, materials scientists, control-electronics designers, and software and algorithm teams. Because these capabilities are rarely co-located, **diverse external collaborations are essential for integrating knowledge across the quantum stack**. Clusters with a high share of external partnerships are therefore better positioned to combine heterogeneous expertise and generate novel solutions.

Quantum capabilities are globally dispersed, with countries specialising in different hardware platforms, communications technologies and QEC approaches. No single organisation or nation can advance quantum independently, and future systems will rely on modular, networked architectures that link multiple processors into larger distributed systems, allowing scale to be achieved through coordinated, interoperable modules rather than monolithic machines.[18] **Clusters with strong connecting roles are thus particularly valuable:** they connect otherwise separate communities, bring together complementary capabilities, and help drive the integration needed for scalable quantum technologies.

4.2 External Collaborations as a Share of Total

The second indicator captures how outward-looking each cluster is. A higher share of external collaborations indicates greater integration with other clusters and greater exposure to diverse knowledge inputs. As highlighted in Box 2, innovation in quantum technologies often emerges from the ability to integrate distinct layers of the stack (hardware, control systems, materials, QEC algorithms, etc). Clusters with strong external linkages are therefore better positioned to access complementary expertise and accelerate system-level advances.

Since our unit of analysis is the cluster, we do not distinguish collaborations with clusters in the same country or abroad; the indicator instead measures whether the cluster is more internally self-focused or externally connected. Because quantum is still largely pre-commercial and highly specialised, we would expect smaller clusters to rely more on external collaborations and larger clusters to be able to collaborate more internally. A clear size effect emerges when comparing cluster's collaboration volumes with their external collaboration shares. The correlation between the two indicators is -0.5: larger clusters such as Beijing, Greater Paris, Greater Tokyo, and Shenzhen-Hong Kong-Guangzhou, tend to have lower external collaboration shares (Figure 9).[19]

[16] Riverlane. (2025). Quantum Error Correction Report 2025. Riverlane Ltd.

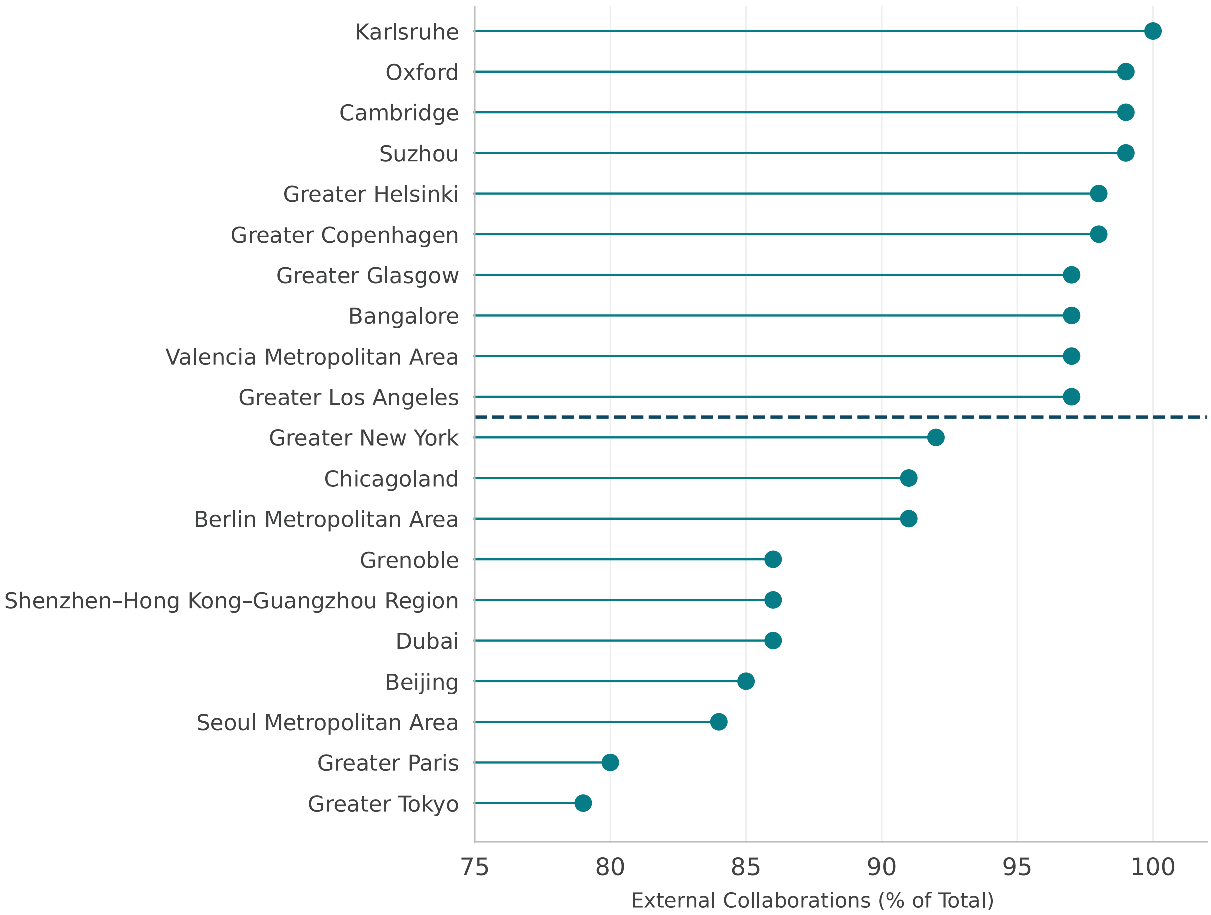
[17] Hidalgo, C. A., & Hausmann, R. (2009). The building blocks of economic complexity. Proceedings of the national academy of sciences, 106(26), 10570-10575; Balland, P. A., Jara-Figueroa, C., Petralia, S. G., Steijn, M. P., Rigby, D. L., & Hidalgo, C. A. (2020). Complex economic activities concentrate in large cities. Nature human behaviour, 4(3), 248-254.

[18] Riverlane. (2025). Quantum Error Correction Report 2025. Riverlane Ltd.

[19] The correlation is highly statistically significant ($p < 0.001$).

Smaller clusters display much higher external openness, suggesting they rely on external connections to access scientific and technological capabilities. Exceptions such as Shanghai, Hefei, Singapore and Greater Boston, which combine substantial size with an unusually high degree of external openness, suggest a more outward-oriented mode of knowledge production can also exist for larger clusters.

FIGURE 9: TOP 10 AND BOTTOM 10 CLUSTERS BY SHARE OF EXTERNAL COLLABORATIONS



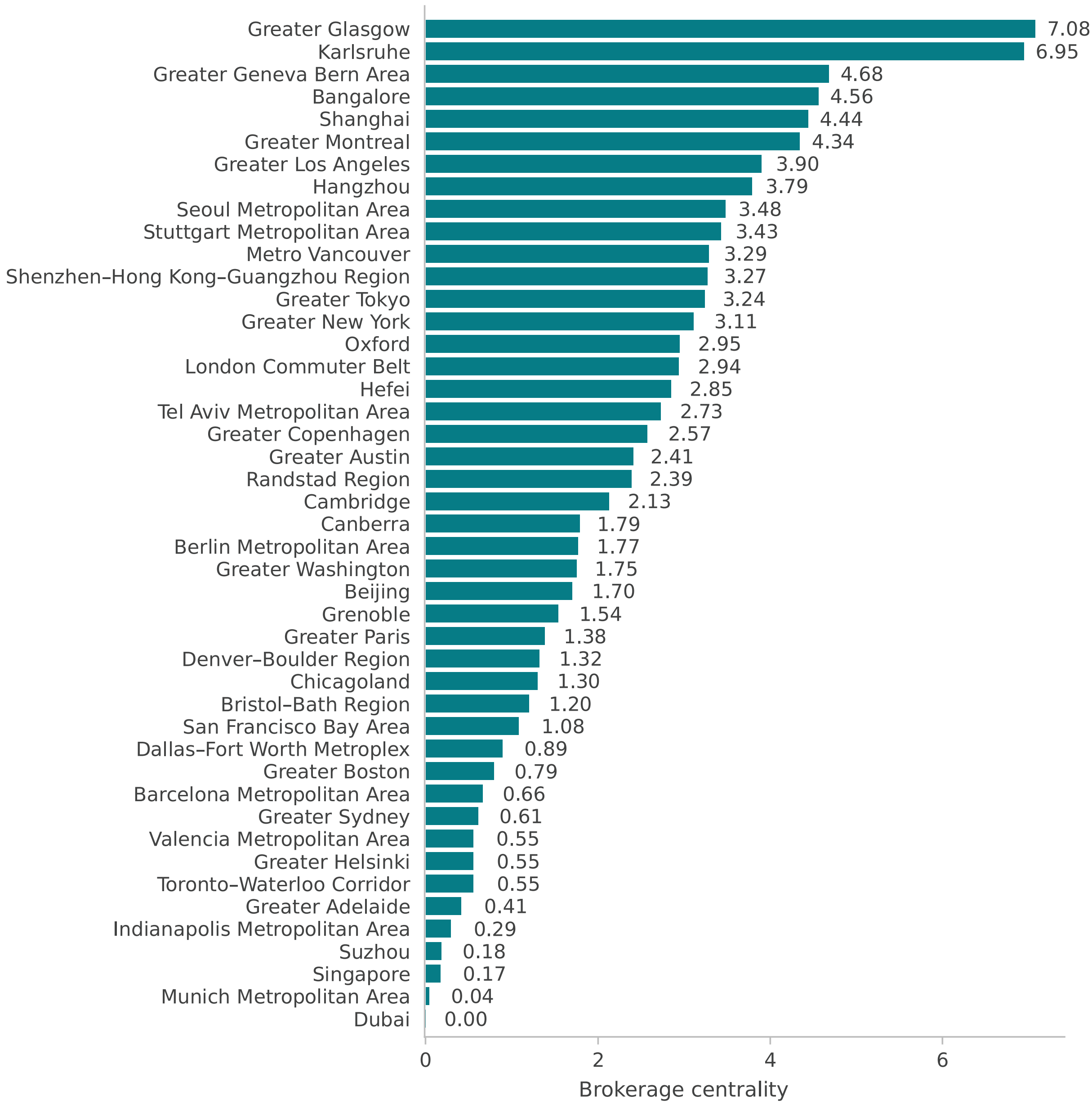
Source: ECIPE Quantum Database. Note: The dashed line indicates omitted middle-range clusters.

4.3 Brokerage Role in Collaboration Network

Finally, the third and last indicator of Dimension 2 is the brokerage role of each cluster in the collaboration network. As explained previously, brokerage captures a cluster's ability to connect clusters who would otherwise remain unconnected. As discussed in Box 2, this is especially valuable in quantum technologies, where global capabilities are fragmented across different hardware platforms, communication technologies and QEC approaches, and where scalable systems will rely on modular, networked architectures that link multiple processors into larger distributed systems. Clusters in brokerage positions help integrate these dispersed capabilities by facilitating information flows, enabling cross-platform collaboration, and supporting the co-design processes required for QEC and system-level performance.

Practically, clusters with high brokerage scores are not necessarily the largest or the most internally dense; rather, they occupy structurally strategic positions. They often play a key role in diffusing ideas internationally, enabling partnerships between firms and institutions that might not otherwise interact. Conversely, low-brokerage clusters tend to be more locally embedded, collaborating mainly within their own regional networks.[20]

FIGURE 10: BRIDGING POWER OF CLUSTERS



Source: ECIPE Quantum Database.

[20] Brokerage is computed on a projected cluster-cluster network, using only collaborations where both partners are assigned to a quantum cluster. Collaborations with institutions outside identified clusters are not included in the brokerage score, but they are reflected in the overall collaboration and external-share indicators.

The results from Figure 10 show that only a small number of clusters play a genuine bridging role. These hubs do more than simply collaborate widely; they connect communities that would otherwise remain more isolated. Greater Glasgow, Karlsruhe, Geneva, Bangalore, Montreal, and Shanghai stand out as the main conduits linking these otherwise more isolated parts of the network.

Because quantum expertise is globally fragmented across different hardware platforms, communication technologies and QEC approaches, such bridging hubs are also well positioned to facilitate exchanges across different strands of the quantum stack. In a field that will increasingly rely on modular, networked systems linking multiple processors, these connector clusters help hold the global ecosystem together and support the conditions needed for future system-level integration.

Key "Collaboration Intensity" Dimension Takeaways

1. **Collaboration leadership spans regions, not one geography** – Unlike Market Orientation and Ecosystem Maturity, no single region dominates Collaboration Intensity. China, Europe, India, Switzerland, the UK, and the US all feature in the top 10. Large research-driven clusters such as Shanghai, Hefei, Paris, Tokyo, and Beijing top the rankings on collaboration volume, reflecting the strong academic foundations of many non-Anglosphere ecosystems.

2. **Clear size-openness trade-off, with notable outliers** – Larger clusters (e.g., Beijing, Paris, Tokyo, and Shenzhen-Hong Kong-Guangzhou) show lower external collaboration shares, whereas smaller clusters depend more heavily on external partnerships to access specialised capabilities. Yet several major hubs – Shanghai, Hefei, Singapore, Boston – combine scale with unusually high external openness, demonstrating more outward-oriented knowledge production than expected for their size.

3. **A handful of clusters act as global connectors** – Only a small group of clusters, including Greater Glasgow, Karlsruhe, Geneva, Bangalore, Montreal, and Shanghai, play a genuine brokerage role. These clusters do more than collaborate widely: they bridge otherwise disconnected scientific and technological communities. In a field characterised by globally fragmented capabilities, these bridging hubs help integrate the quantum stack across hardware, communications, and QEC specialisations.

5. DIMENSION 3: ECOSYSTEM MATURITY

The **“Ecosystem Maturity”** dimension represents the third and final pillar of the Quantum Clusters Ranking. It focuses on the institutional foundation and the productivity of the innovation environment within each cluster. In other words, it measures how well the research, entrepreneurial, and industrial actors of a cluster are connected and capable of sustaining long-term quantum growth. This dimension is evaluated using three indicators:

1. **Institutions per million people** – a measure of institutional density, indicating the relative availability of quantum-active institutions in proportion to the population;
2. **Spinouts-to-research institutions ratio** – a proxy for knowledge translation, assessing how effectively research actors generate commercial ventures;
3. **Startup-to-institution ratio** – an indicator of ecosystem productivity, showing whether institutions successfully foster entrepreneurial activity and contribute to a vibrant quantum startup scene.

TABLE 6: TOP 10 QUANTUM CLUSTERS RANKED ON “ECOSYSTEM MATURITY”

Rank	Quantum cluster	Country	Region
1	Bristol–Bath Region	UK	UK, Canada, and Australia
2	Cambridge	UK	UK, Canada, and Australia
3	Oxford	UK	UK, Canada, and Australia
4	Greater Helsinki	Finland	EU
5	Greater Glasgow	UK	UK, Canada, and Australia
6	Karlsruhe	Germany	EU
7	Tel Aviv Metropolitan Area	Israel	Rest of the World
8=	Toronto–Waterloo Corridor	Canada	UK, Canada, and Australia
8=	San Francisco Bay Area	US	US
10	Singapore	Singapore	Rest of the World

Source: ECIPE Quantum Database.

Table 6 displays the top 10 global quantum clusters according to this dimension. The UK stands out most prominently, as four of the top five positions are occupied by UK clusters: Bristol–Bath, Cambridge, Oxford, and Glasgow. This concentration reflects the country’s strong institutional foundations as well as its ability to transform research into commercial ventures, a result of long-term investments in both academia and entrepreneurship in the quantum space. Outside the UK, Europe is further represented by two EU clusters – Greater Helsinki in Finland and Karlsruhe in Germany.

Beyond Europe, North America features twice: the Toronto–Waterloo Corridor in Canada shares eighth place with the San Francisco Bay Area, pointing to how both university-led ecosystems and Silicon Valley's entrepreneurial culture contribute to quantum maturity, though through different institutional models. Tel Aviv and Singapore also appear in the top 10, each demonstrating strong connections between research institutions, entrepreneurs, and investors, sustained by targeted government strategies and vibrant private-sector engagement.

Taken together, these results suggest the UK quantum clusters currently set the global benchmark (see Box 3), but other regions are also rapidly strengthening their institutional and entrepreneurial foundations to compete at the same level.

Box 3: What explains the maturity of the UK's quantum ecosystem

The UK's quantum journey began as early as 2014 with the National Quantum Technologies Programme (NQTP), which set a long-term framework for public–private investment. It created six national centres – including four Research Hubs, the National Quantum Computing Centre (NQCC), and the Quantum Metrology Institute (QMI) at NPL – forming the basis of an integrated national ecosystem.

The UK stands out for a clear strategy and coherent infrastructure. It hosts multiple industry testbeds and the Quantum Business Incubation Centre, supporting startups across hardware, software, and sensing. This infrastructure spans the Quantum Space Laboratory at STFC RAL Space, STFC Cryogenics, Element Six, the Diamond Light Source, and the Central Laser Facility, creating a connected pipeline from research to deployment.

A defining strength is the UK's ability to **pair long-term planning with effective commercialisation**. The country produces more tech unicorns than any other in Europe, supported by a mature venture capital landscape and a startup culture that rapidly translates science into markets. Institutions like the University of Cambridge reinforce this advantage. Its integrated model – combining VC networks, angel investors, and a central innovation hub – successfully scales deep-tech startups and strengthens the research-to-market loop.

The wider tech sector further boosts this environment: between 2020 and 2021 it grew by 42 per cent, with a new tech firm registered every 30 minutes. This momentum supports quantum commercialisation. The UK's innovation legacy, rooted in Alan Turing's computing work, continues today. Quantum Motion's recent achievement – the first full-stack quantum computer built with standard silicon CMOS and deployed at the NQCC – marks a major step toward scalable, manufacturable quantum hardware.[21]

[21] Quantum Motion. (2025, September 19). Quantum Motion Delivers the Industry's First Full-Stack Silicon CMOS Quantum Computer. Available at: https://quantummotion.com/quantum-motion-delivers-the-industrys-first-full-stack-silicon-cmos-quantum-computer/

5.1 Institutions per Million People

Let us now examine the indicators that make up the "Ecosystem Maturity" dimension. Figure 11 below presents the top 10 quantum clusters ranked by the first of these indicators: the number of institutions active in quantum per million people, further broken down by type of institution – research, government, or industry. While a large number of actors involved in quantum does not guarantee success on its own, strong institutional density is essential for building a robust quantum ecosystem. Institutions reflect the underlying capacity to generate and absorb quantum activity, drive scientific and commercial development, and enable collaborations with other institutions, thus forming the foundation of ecosystem performance, as shown in our previous report.[22]

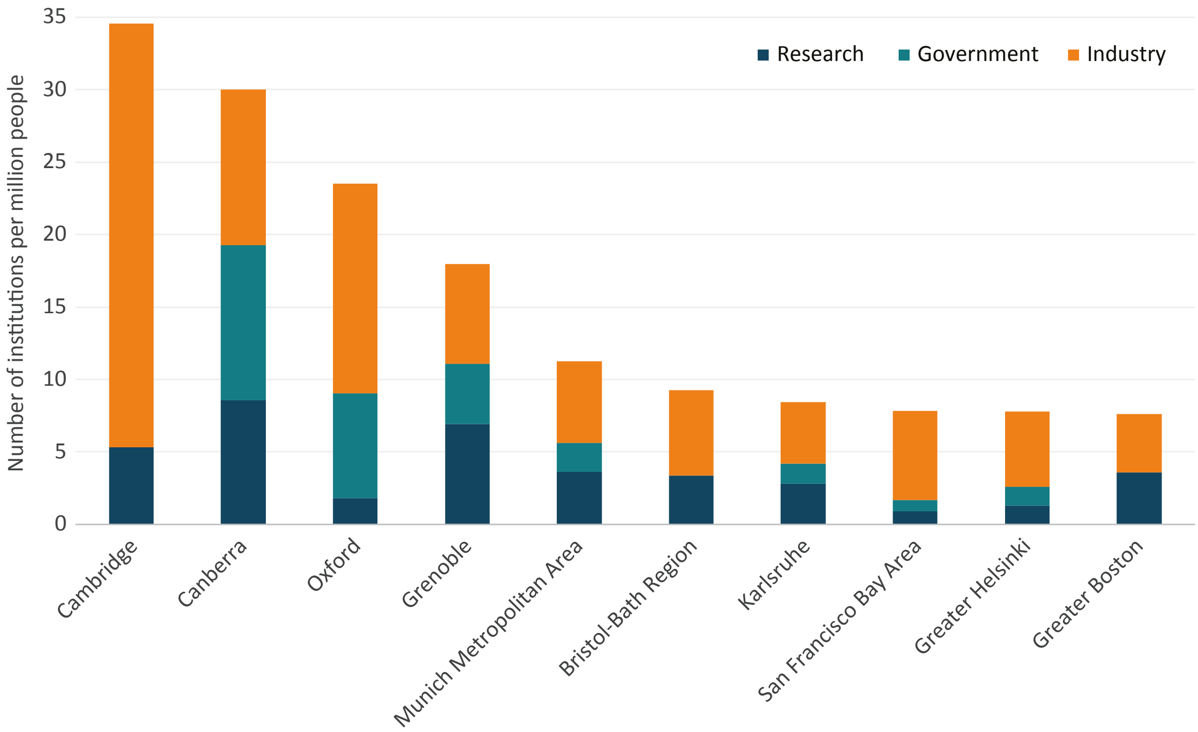
The chart is heavily dominated by Europe with four EU clusters (Grenoble, Munich, Karlsruhe, and Helsinki) and three from the UK (Cambridge, Oxford, and Bristol–Bath). This reflects Europe's concentration of quantum activity, especially relative to population size.

Smaller clusters appear somewhat advantaged in this measure, as the ratio of institutions to population is higher than in large metropolitan areas. Conversely, globally recognised hubs such as the San Francisco Bay Area or Greater Boston host a large number of institutions but serve much bigger populations, which lowers their ranking on a per-capita basis.

A final interesting feature is the predominance of industry institutions in most of these top clusters. This reflects the breadth of industry engagement, but it should not be equated with commercial orientation. Institutional density captures capacity – the availability of actors that could support translation and uptake – whereas actual commercialisation depends on separate drivers, such as private capital and market demand, as noted in Dimension 1.

[22] Erixon, F., Dugo, A., Pandya, D. and Sisto, E. (2025, September). Mapping the quantum ecosystems: How are economies positioning themselves for innovation success. ECIPE Occasional Paper. https://ecipe.org/publications/mapping-the-quantum-ecosystems/

FIGURE 11: TOP 10 QUANTUM CLUSTERS BY QUANTUM-ACTIVE INSTITUTIONS PER MILLION PEOPLE, BY TYPE



Source: ECIPE Quantum Database.

5.2 Spinouts-to-research institutions Ratio

We now turn to the second indicator of "Ecosystem Maturity" – the spinouts-to-research institutions ratio. This metric captures the number of quantum startups originating from universities or research institutes in relation to the total number of research institutions within a cluster. In doing so, it provides an indication of how effectively a quantum cluster translates academic and research-based knowledge into market-ready ventures.

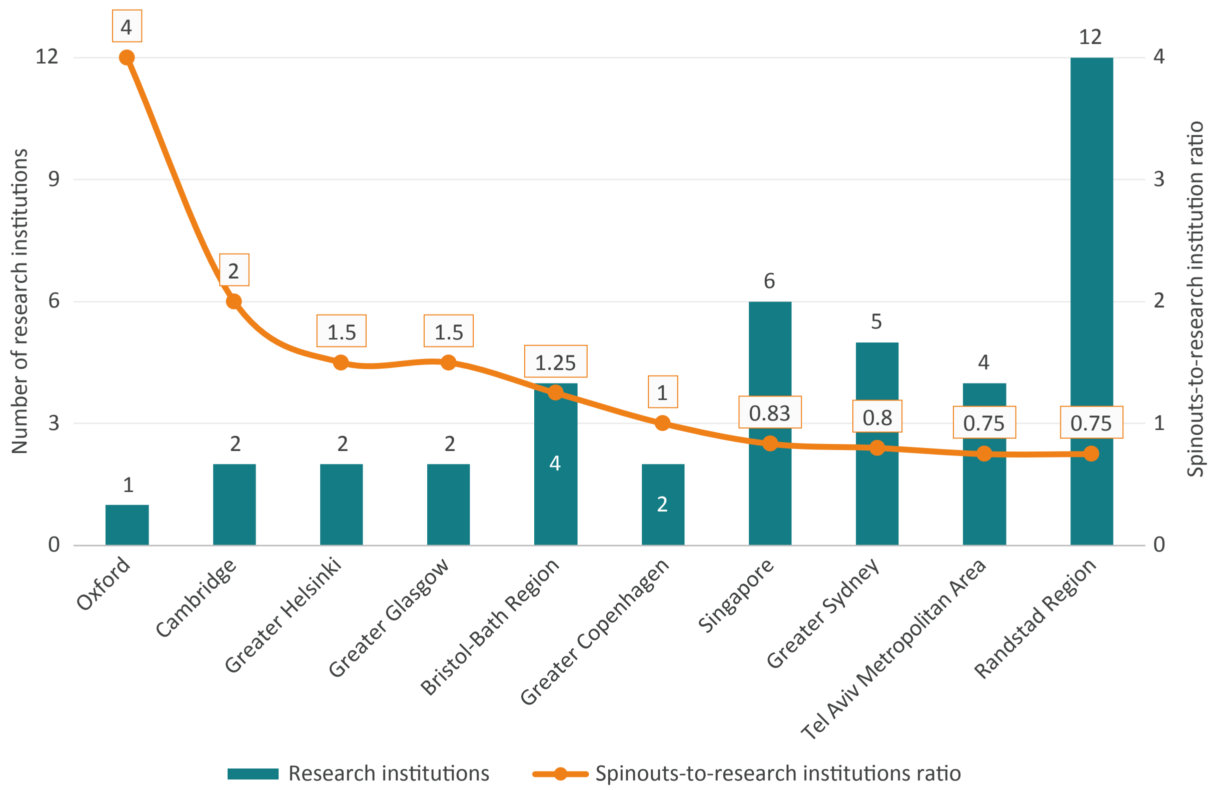
Figure 12 illustrates the top ten quantum clusters globally according to this measure. Clusters are ranked in descending order of the spinouts-to-research institutions ratio, represented by the orange line. The blue bars, by contrast, show the actual number of research institutions in each cluster.

Because quantum spinouts remain relatively rare globally, clusters with only one or two research institutions can reach high ratios even with a small number of spinouts. This explains the striking results in Oxford and Cambridge: each hosts a limited number of research institutions (one and two, respectively), yet both have generated multiple quantum spinouts. The high ratio therefore reflects intensive spinout activity per institution, rather than a large spinout ecosystem overall.

The UK features even more prominently, with two further clusters – Glasgow and Bristol–Bath – also achieving relatively high ratios, alongside Helsinki. These cases illustrate how institutional culture, dedicated technology-transfer structures, and strong entrepreneurial networks can amplify spinout formation within a small research footprint.

By contrast, larger clusters such as Copenhagen, Singapore, Sydney, Tel Aviv, and the Randstad region show lower ratios due to hosting far more research institutions. In these ecosystems, the number of research institutions is higher than the number of spinouts – a structural feature of the ratio for larger clusters rather than an indication of weak performance. Many of these clusters still demonstrate solid commercialisation capacity and outperform many of their equally large peers, maintaining ratios just under 1.

FIGURE 12: TOP 10 QUANTUM CLUSTERS BY SPINOUTS-TO-RESEARCH INSTITUTIONS RATIO



Source: ECIPE Quantum Database.

5.3 Startup-to-institution Ratio

The third indicator within the "Ecosystem Maturity" dimension is the startup-to-institution ratio. It measures the number of quantum startups in a cluster relative to all institutions active in quantum. Unlike the previous indicator – which focused on research-to-market translation – this metric captures entrepreneurial intensity within the broader institutional landscape. In other words, it indicates how prominently quantum startups feature among all actors shaping quantum activity in a cluster.

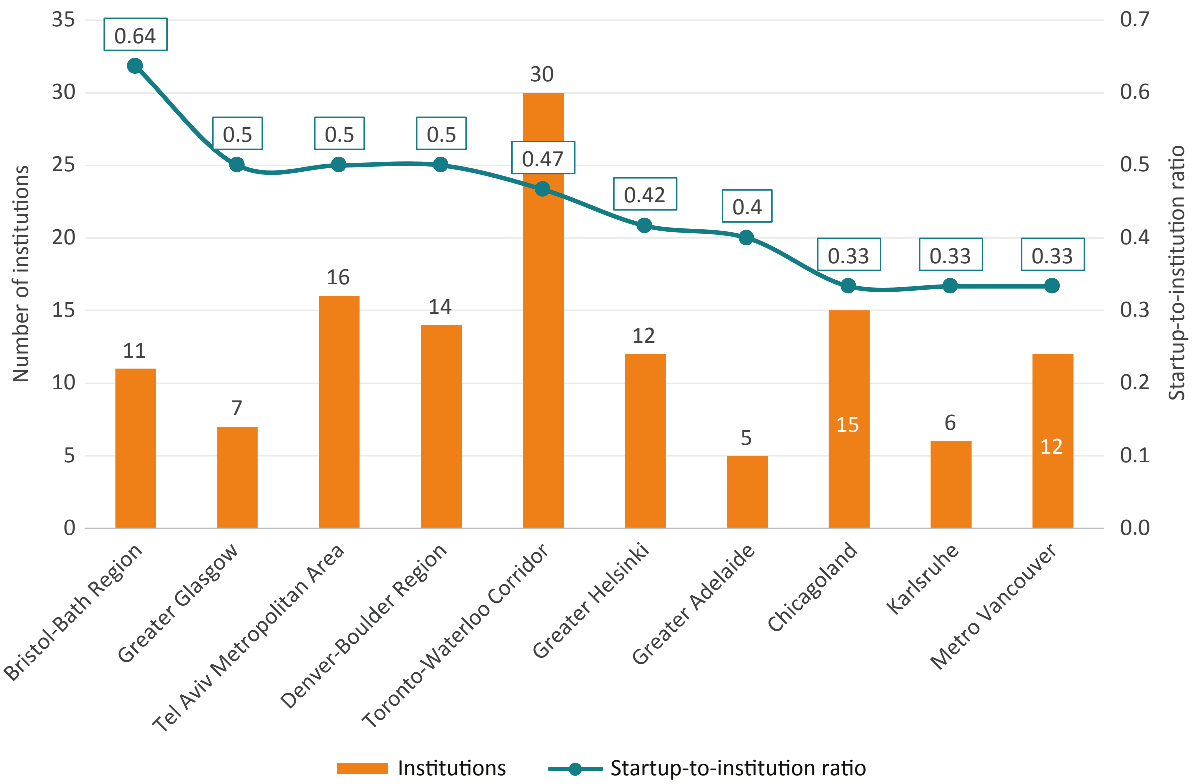
Because this metric includes all quantum-active institutions, it offers a broad view of how startups fit within the institutional composition of an ecosystem. This breadth also means that clusters with extensive public-sector or research footprints may score lower, even if they host a substantial number of startups in absolute terms. In this sense, the indicator highlights how startup-driven and commercially oriented a cluster is relative to its overall institutional architecture, rather than measuring startup performance in isolation.

Figure 13 presents the top 10 clusters according to this measure. Bristol–Bath leads the ranking with the highest ratio (0.64), followed by Greater Glasgow, the Tel Aviv Metropolitan Area, and the Denver–Boulder Region (all 0.50). These clusters are relatively small in institutional size, and even modest numbers of startups therefore represent a significant share of their ecosystems. Their strong ratios signal concentrated entrepreneurial activity rather than large absolute numbers of startups.

Among larger clusters, the Toronto–Waterloo Corridor stands out, with 14 of its 30 institutions being startups – a ratio of 0.47. This suggests not just an active startup community but an ecosystem capable of supporting such ventures at scale.

Some smaller clusters, such as Karlsruhe and Greater Adelaide, also rank highly. Their ratios are elevated largely because their institutional baselines are small: two or three startups constitute a large share of the total institutions present. This points again to how the indicator reflects startup concentration rather than overall entrepreneurial output.

FIGURE 13: TOP 10 QUANTUM CLUSTERS BY STARTUP-TO-INSTITUTION RATIO



Source: ECIPE Quantum Database.

Key "Ecosystem Maturity" Dimension Takeaways

1. **UK leadership in ecosystem maturity** – Four of the top five clusters (Bristol–Bath, Cambridge, Oxford, Glasgow) are in the UK, reflecting strong institutional foundations and effective research-to-market pipelines built over years of government strategy, coordinated investment in academia and entrepreneurship, and commercialisation.

2. **Spinout efficiency in some smaller clusters** – Oxford, Cambridge, Glasgow, Bristol–Bath, and Helsinki achieve exceptionally high spinout-to-research institution ratios, demonstrating that smaller clusters with robust institutional cultures and efficient technology-transfer structures can create strong knowledge-translation performance in compact ecosystems.

3. **Entrepreneurial intensity drives performance** – Clusters such as Bristol–Bath, Glasgow, and Tel Aviv show that startups can make up half or more of their institutional base, underlining how entrepreneurial orientation can allow small and mid-sized clusters to punch above their weight in global competitiveness.

6. QUANTUM QUASI-CLUSTERS

In the preceding sections, we identified where quantum clusters are located and outlined the dimensions that justify their classification as such. Yet, another notable feature of the quantum landscape is the rise of quasi-clusters, regions that are in a formative phase but with potential to evolve into full-fledged clusters if supported by conditions that extend beyond governance structures and institutional linkages. These enabling factors include sustained public and private investment, research–industry co-location, and access to risk capital, all of which are essential for translating scientific excellence into commercial capacity.

Because it is still premature to apply the same multidimensional metrics used for more mature clusters, we introduce two tiers of quasi-clusters:

- **Tier 1 quasi-cluster:** Must host at least one quantum startup with funding exceeding USD 5 million[23], alongside five or more institutions active in quantum, engaged in a minimum of 50 documented collaborations.
- **Tier 2 quasi-cluster:** Meets the same institutional and collaboration criteria as the first tier – five or more institutions and at least 50 documented collaborations – but does not yet host a startup with funding above USD 5 million.

[23] We set a USD 5 million funding threshold for startups within quasi-clusters because, in most quantum technology markets, this amount typically corresponds to a large seed or Series A round – the stage when firms transition from research prototypes to deployable products. At this level, a company has moved beyond laboratory experimentation to develop proprietary technology, attract external investors, and establish a stable operational base. As such, USD 5 million serves as a practical proxy for commercial anchoring within a quantum ecosystem: startups that reach this stage demonstrate sustained investor confidence and the capacity to scale, whereas those below it tend to remain pre-commercial or research-affiliated, still reliant on grants and academic infrastructure.

Unlike Tier 2 quasi-clusters, Tier 1 quasi-clusters present a configuration that already signals the presence of a concentrated and interactive quantum network. However, such ecosystems are still nascent, lacking the systemic maturity that characterises true clusters, where feedback loops between science, capital, and enterprise are deeply integrated and self-reinforcing. In quasi-clusters, these loops remain fragmented and externally dependent, meaning the innovation cycle has not yet become self-sustaining.

Findings from Tier 1 reveal a pronounced academic origin. Among the eight quasi-clusters identified and displayed in Table 7 below, six feature quantum startups that are either university or research spinouts, pointing to the catalytic role of academia in seeding commercial activity. The high number of collaborations observed reinforces this pattern: universities often act as early validators of market potential, connecting scientific discovery with entrepreneurial ambition. At this stage, technologies may not yet have a clear commercial pathway, but the institutional frameworks surrounding universities enable a steady translation of research insights into venture creation.

Even in the absence of a fully developed industrial base, innovation can emerge through academic and institutional channels. For quasi-clusters that do not follow this trajectory, development is instead driven by spillovers from adjacent industries, illustrating that regions meeting Tier 1 criteria can also arise through market-led dynamics. In Chengdu, China, for instance, Zhongwei Daxin Technology (中微达信) builds on the region's strong semiconductor and photonics capabilities within Sichuan's High-Tech Zone, while in Ottawa, Quantropi leverages Canada's established cybersecurity and communications sectors. Given the number of institutions and the volume of collaborations in both cases, these ecosystems retain close integration with the local research environment, pointing to a yet narrow innovation pipeline that positions them as quasi-clusters.

TABLE 7: TIER 1 QUASI-CLUSTERS

Tier I quasi-cluster	Region	Quantum startup	Institution of origin	Type of origin
Chengdu	China	Zhongwei Daxin Technology (中微达信)	–	–
Dublin	EU	Equal1	University College Dublin	University spinout
Jena	EU	Quantum Optics Jena	Fraunhofer Institute for Applied Optics and Precision Engineering (IOF)	Research spinout
Milan	EU	Ephos	Italian National Research Council (CNR)	Research spinout
Ottawa	UK, Canada, and Australia	Quantropi	–	–
Vienna	EU	Quantum Industries	Austrian Academy of Sciences	Research spinout
Wuhan	China	CAS Cold Atom (中科酷原)	Chinese Academy of Sciences	University spinout
Wuhu	China	Qasky (问天量子)	University of Science and Technology of China (USTC)	University spinout

Source: ECIPE Quantum Database.

Tier 1 identifies quasi-clusters that show strong potential to evolve into full clusters, provided the necessary institutional and environmental conditions eventually develop. Tier 2, in contrast, highlights the institutional and collaborative foundations that support and amplify this potential over time. Even in the absence of an emerging startup ecosystem, a dense concentration of research institutions engaged in quantum-related collaborations signals latent capacity for future startup formation and, ultimately, full cluster development.

Using this criteria, we identified 78 cities globally that fall under the Tier 2 quasi-clusters category. Among those with very limited startup activity but notable institutional depth and collaboration intensity are Daejeon, Frankfurt, Prague, Zurich, and Los Alamos. For regions where no quantum startups are present, Buenos Aires, Chennai, Hanoi, Rome, Nanjing, São Paulo, and Warsaw stand out for their strong research ecosystems and growing participation in global quantum networks.[24]

Figure 14 below illustrates the regional distribution of quasi-clusters recorded in our database. Combining both tiers, we identify a total of 86 quasi-clusters across five regions.

In the US, only two quasi-clusters are recorded, reflecting the fact that most American quantum ecosystems have already moved beyond the quasi stage into more mature, industrially anchored clusters. The UK, Canada, and Australia together host five quasi-clusters, suggesting that, similar to the US, most English-speaking ecosystems have largely transitioned beyond the formative phase.

We note here that the US is likely "beyond the quasi stage" because its cluster infrastructure is already fully developed, even though the commercial market for quantum technologies remains nascent. US clusters have dense concentrations of startups, large corporates, venture capital, specialised talent, and translational institutions. These components form a complete ecosystem capable of absorbing new scientific advances and scaling commercial activity once the technologies themselves become market-ready. In contrast, quasi-clusters in other regions lack some of these structural elements, particularly private investment, industrial anchors, or commercialisation pathways. This means that even as the underlying technology progresses globally, these regions risk being unable to capture value without further capability building.[25]

China hosts 15 quasi-clusters, as its regional ecosystems continue to evolve from institutional concentration towards commercial integration. The EU accounts for 34 quasi-clusters, pointing to the continent's strong research and collaborative networks but also its slower conversion of academic excellence into scalable commercial activity.

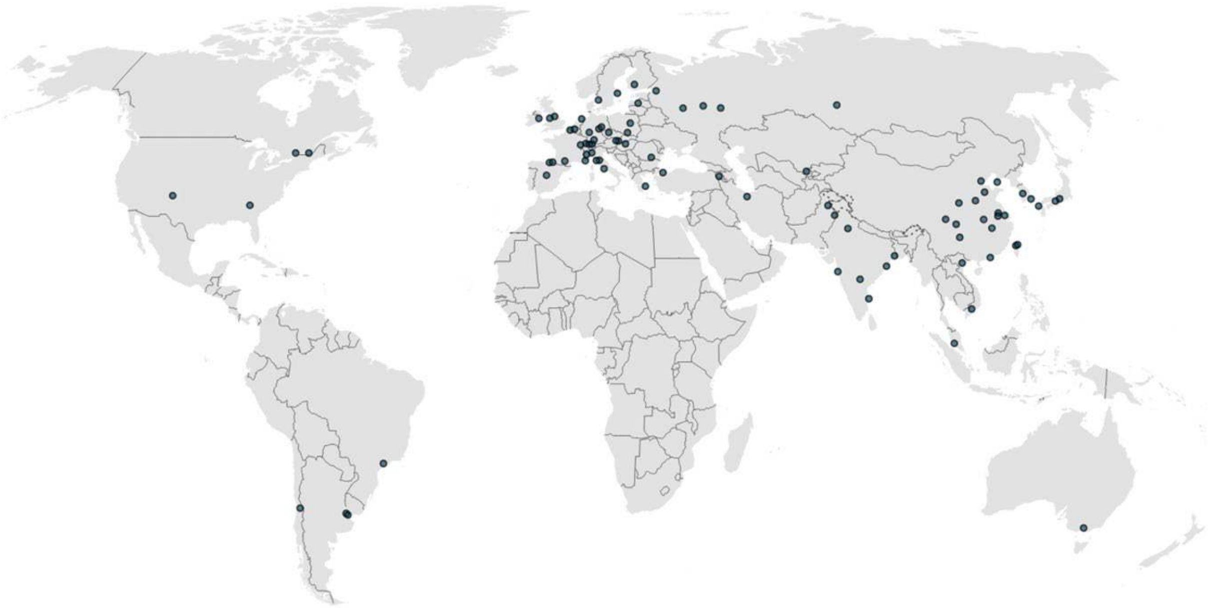
The remaining 30 quasi-clusters are distributed across other regions, representing emerging quantum ecosystems still in the earlier stages of development. Their institutional strength

[24] For full list refer to Annex 3.

[25] The designation of a region as a fully formed cluster does not imply that the innovation system is finished or self-sustaining. It simply indicates that the core structural elements - dense commercial activity, translational capacity, capital availability, and specialised talent are already in place. Sustaining leadership in quantum still requires ongoing investments in talent pipelines, infrastructure, and industry-academia linkages. The fact that US cities appear lesser in the quasi-cluster category should not be interpreted as suggesting that the US can now "wait for business to come," but rather that US clusters already possess the structural conditions that enable research, industry, and investment to co-evolve as the quantum industry matures.

and capacity vary, but collectively they embody the early conditions defined by both tiers: the coexistence of nascent research networks and emerging entrepreneurial initiatives.

FIGURE 14: DISTRIBUTION OF QUASI-CLUSTERS GLOBALLY



Source: ECIPE Quantum Database.

6.1 What Would Turn a Quasi-cluster into a Cluster?

For a quasi-cluster to evolve into a fully established cluster, the three dimensions outlined in the previous sections – market orientation, collaboration intensity, and ecosystem maturity – must deepen and interact in self-reinforcing ways. Crucially, the transition from quasi-cluster to full cluster requires both strong horizontal connections (collaboration among local research groups and early-stage firms) and vertical connections (linkages to corporates, investors, and downstream users). Horizontal integration creates local density, while vertical integration enables commercialisation, together forming the structure of a fully developed cluster. Regional advantages emerge when proximity fosters knowledge exchange and joint experimentation, enabling research capacity to mature into commercial capability.

Many quasi-clusters already possess dense institutional networks; their next step is to translate these collaborations into entrepreneurial activity through mechanisms that lower the barriers between laboratories, startups, and investors. Quasi-clusters can thus serve as incubators of innovation. The emergence of even a single high-performing startup can catalyse expansion through technological spillovers, competition, and cooperation. Strong spillover effects reinforce regional networks, boost knowledge diffusion, and stimulate innovation across firms. Yet because spillovers are unevenly distributed, the transformation potential of each quasi-cluster depends on its ability to convert institutional collaboration into entrepreneurial momentum.

Another key accelerator is industrial spillover from adjacent sectors.[26] In the quantum context, this is particularly significant because neighbouring industries, such as finance, pharmaceuticals, advanced materials, and semiconductors, are among the earliest adopters of quantum technologies.[27] Collaborations between research institutions and established firms in these sectors can create demand-pull environments, where applied research transitions into proofs of concept, pilot deployments, and early commercialisation.

Targeted reforms for accelerating cluster maturity include:

1. **Establishing quantum acceleration funds:** providing multi-year co-investment programmes supporting startups from prototype to deployment, reducing early-stage financing gaps.

2. **Creating shared testbeds and facilities:** building regional quantum labs accessible to startups, universities, and corporates to foster co-location and rapid prototyping.

3. **Incentivising research–industry partnerships:** offering collaboration grants for joint R&D between universities and private firms.

4. **Supporting cross-sector pilots:** launching applied projects with early-adopting industries (e.g., quantum simulation in materials or optimisation in finance).

[26] Basel, for instance, is a global pharmaceutical and biotech hub where quantum computing applications in drug discovery and molecular simulation align directly with existing R&D priorities. Similarly, the Frankfurt Metropolitan Area, Europe's leading financial centre, offers fertile ground for quantum applications in portfolio optimisation, risk-weighted asset (RWA) modelling, XVA and Monte Carlo acceleration, and fraud analytics. In Toulouse, a major aerospace hub, the potential lies in quantum sensing, navigation, and anomaly detection for GNSS-denied environments, reflecting the intersection of quantum innovation with aerospace engineering.

[27] As seen earlier in Chengdu and Ottawa, where sectoral strengths in photonics, semiconductors, and cybersecurity underpinn the ecosystem surrounding the quasi clusters, these examples illustrate how industrial adjacency can convert research capability into market-driven demand.

ANNEX 1: METHODOLOGY AND ROBUSTNESS

Detecting quantum clusters

To identify geographic clusters without relying on administrative boundaries, we use DBSCAN, a density-based spatial clustering algorithm. DBSCAN groups institutions into clusters when they are spatially close and part of a sufficiently dense concentration of actors.
The final parameters used are:

- Radius (eps): 20 km
- Minimum institutions: 10
- Distance metric: Haversine (great-circle distance on the Earth's surface)

These settings ensure that a region is recognised as a cluster only when it contains a meaningful, geographically coherent concentration of quantum-active organisations, rather than scattered individual points. Institutions that do not belong to any dense grouping are labelled as noise and excluded from cluster formation.

DBSCAN can sometimes detect two neighbouring clusters that are geographically close but in practice belong to a single integrated ecosystem. To correct this, we apply a merging step based on collaboration intensity, which ensures that the final clusters reflect both geographic proximity and functional connectivity.

Two DBSCAN clusters are merged if all the following conditions apply:

- Geographic proximity: their centroids are within 20 km of one another
- Collaboration link: there are at least 5 collaborations between institutions in the two clusters
- Relative intensity: these cross-cluster collaborations account for at least 20% of internal collaborations in either cluster

This merging logic ensures we do not artificially split metropolitan areas or densely connected regions (e.g. universities, labs, and startups working across a single urban basin).

Robustness rankings

Each dimension in the Quantum Cluster Index is built from several indicators. To test whether the resulting rankings are stable and not sensitive to the choice of weighting or aggregation method, we conduct a series of robustness checks for every dimension.

The example below describes the robustness procedure for Dimension 1, but the same logic is applied to all dimensions.

To ensure that cluster positions are not driven by any single aggregation method, we compute three alternative rankings:

(i) Z-score composite (equal-weight)

- Each indicator is standardised (z-score).
- A composite score is calculated as the simple average of the available z-scores.
- This produces a ranking that assumes equal importance of indicators.

(ii) PCA-based ranking (data-driven weights)

- A principal component analysis (PCA) is applied to the raw indicators.
- The first principal component (PC1) captures the maximum common variance across indicators.
- If PC1 is negatively correlated with the z-score composite, it is flipped to ensure comparability.
- This yields a ranking whose weights are derived automatically from the data.

(iii) Average of individual indicator ranks (Borda-type)

- Each indicator is ranked separately.
- A cluster's overall score is the average of these ranks.
- This avoids assumptions about underlying distributions.

The key test is whether all three produce similar rank orders.
We compute Spearman rank correlations between the three ranking methods. High Spearman correlations indicate that clusters appear in similar positions regardless of methodology. This is the first measure of robustness.

To test whether rankings hold under any reasonable choice of weights, we run a Monte Carlo simulation:

- 5,000 random triplets of weights are generated (w_1, w_2, w_3).
- We normalise them so they sum to 1.

For each simulation, a new composite score is computed:

$$\text{Score}_{sim} = w_1 \cdot \text{Rank}_{funding} + w_2 \cdot \text{Rank}_{\frac{VC}{GDP}} + w_3 . \text{Rank}_{\frac{Industry\ collabs}{GDP}}$$

A ranking is generated for each simulated score, and simulated ranking is compared with the baseline Borda-type ranking using Spearman **ρ**. This produces a distribution of 5,000 Spearman correlation values between the baseline ranking and all possible random-weight rankings.

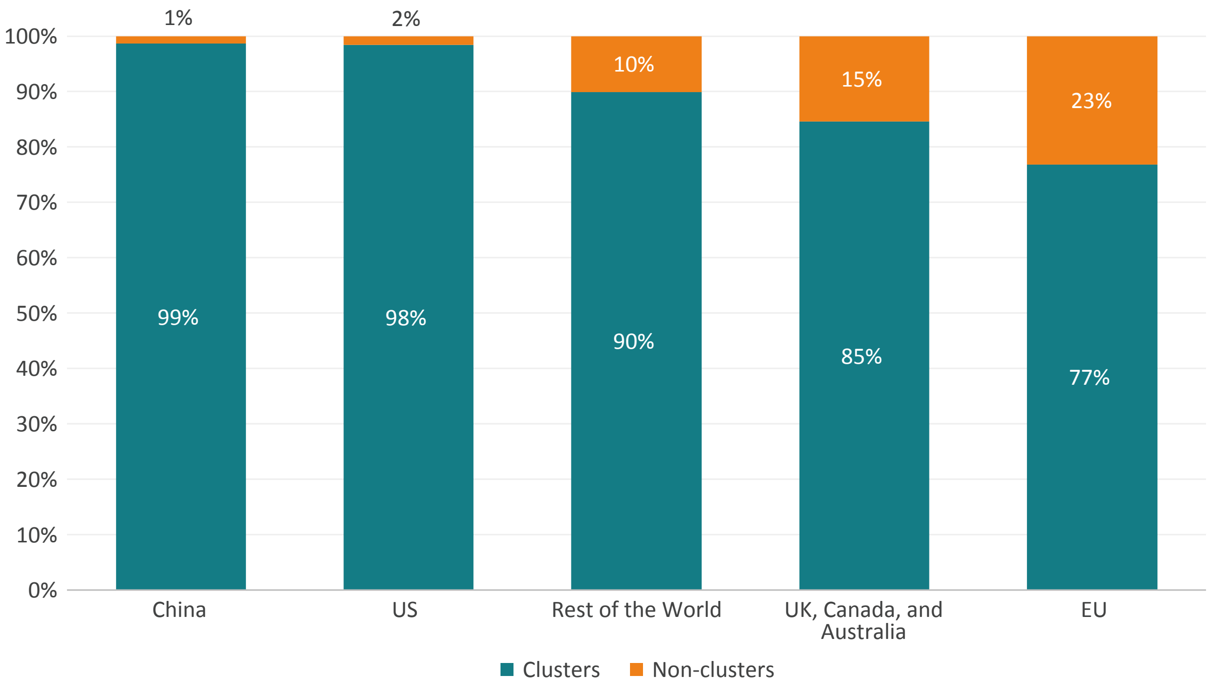
Across most dimensions, the rankings show strong stability: Dimension 1 and Dimension 3 display very high agreement between methods (Spearman correlations above 0.95) and remain highly consistent under random reweighting, with most simulations producing correlations above 0.90. Dimension 2 is more sensitive, reflecting genuine structural differences in collaboration volume, openness and brokerage, but still exhibits a coherent underlying ordering.

ANNEX 2: DEEPER INSIGHTS INTO CLUSTER DEVELOPMENT (FOR READER'S INTEREST)

Part of our research also accounted for geographic variation by using the concentration of quantum funding as a proxy to illustrate regional differences in the degree of clustering. Our findings suggest that: **China** (99 per cent) and the **US** (98 per cent) have almost entirely consolidated their ecosystems into clusters. This provides strong coordination, efficient knowledge transfer, and rapid industrial uptake. The **EU** (77 per cent) lags behind, with nearly a quarter of quantum funding raised outside clusters. This reflects Europe's limited ability to aggregate activity into strong local clusters. While research centres exist across the continent, too many remain small, dispersed, and insufficiently connected to startups, corporates, and investors. Other **English-speaking economies** (UK, Canada, Australia) also show higher non-cluster funding activity (15 per cent) than the US or China, though significantly less than the EU.

The global picture is one of near-universal consolidation into clusters, with Europe standing out as the least concentrated major ecosystem.

FIGURE 15: GLOBAL QUANTUM COMPANY FUNDING BY REGION – CLUSTERS VS. NON-CLUSTERS



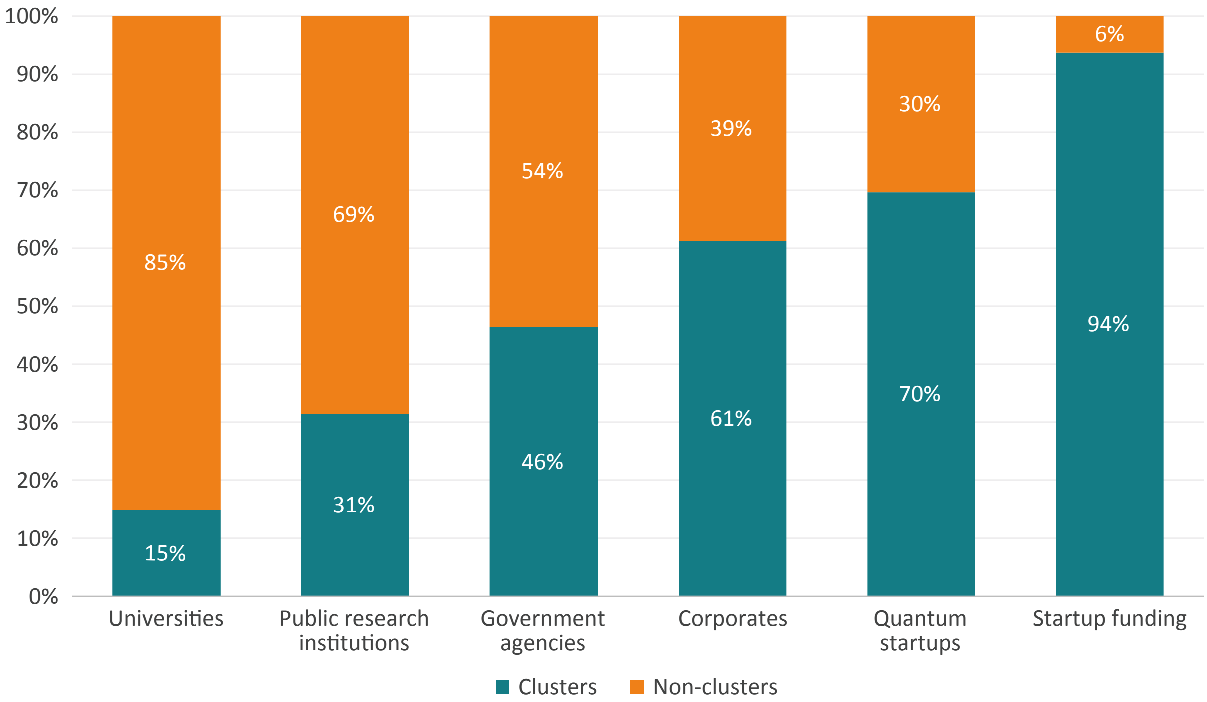
Source: ECIPE Quantum Database. Note: The figures reflect funding recorded up to July 31, 2025. The "Rest of the World" category includes quantum clusters from India, Israel, Japan, Singapore, South Korea, Switzerland, and the UAE.

We delved deeper by examining the institutions that drive cluster formation. Figure 16 illustrates how different types of quantum-active institutions are distributed between clusters and non-cluster locations worldwide. The chart should be read as follows: for each institutional category, the bars show the share of all global institutions of that type that are located inside clusters versus outside them. For example, only 15 per cent of all universities active in quantum worldwide are based in clusters, while the remaining 85 per cent operate outside cluster environments. Public research institutions show a similar pattern, with only 31 per cent located in clusters. Government agencies are more evenly distributed, with 46 per cent inside clusters.

In contrast, industry-driven actors are far more concentrated in clusters. Around 70 per cent of all quantum startups and 61 per cent of corporates engaged in quantum activity are based in clusters, indicating that commercial activity gravitates strongly towards cluster ecosystems. Finally, as already shown in Section 2, startup funding is overwhelmingly cluster-centred, with 94 per cent of recorded quantum startup funding going to companies located within clusters.

Overall, the figure highlights a clear divide: research institutions remain more globally dispersed, whereas commercial quantum activity – startups, corporates, and funding – is strongly clustered, pointing to the role of clusters as hubs of market-oriented innovation.[28]

FIGURE 16: DISTRIBUTION OF QUANTUM-ACTIVE INSTITUTIONS BY TYPE – CLUSTERS VS. NON-CLUSTERS



Source: ECIPE Quantum Database. Note: The "Startup funding" figures reflect funding recorded up to July 31, 2025.

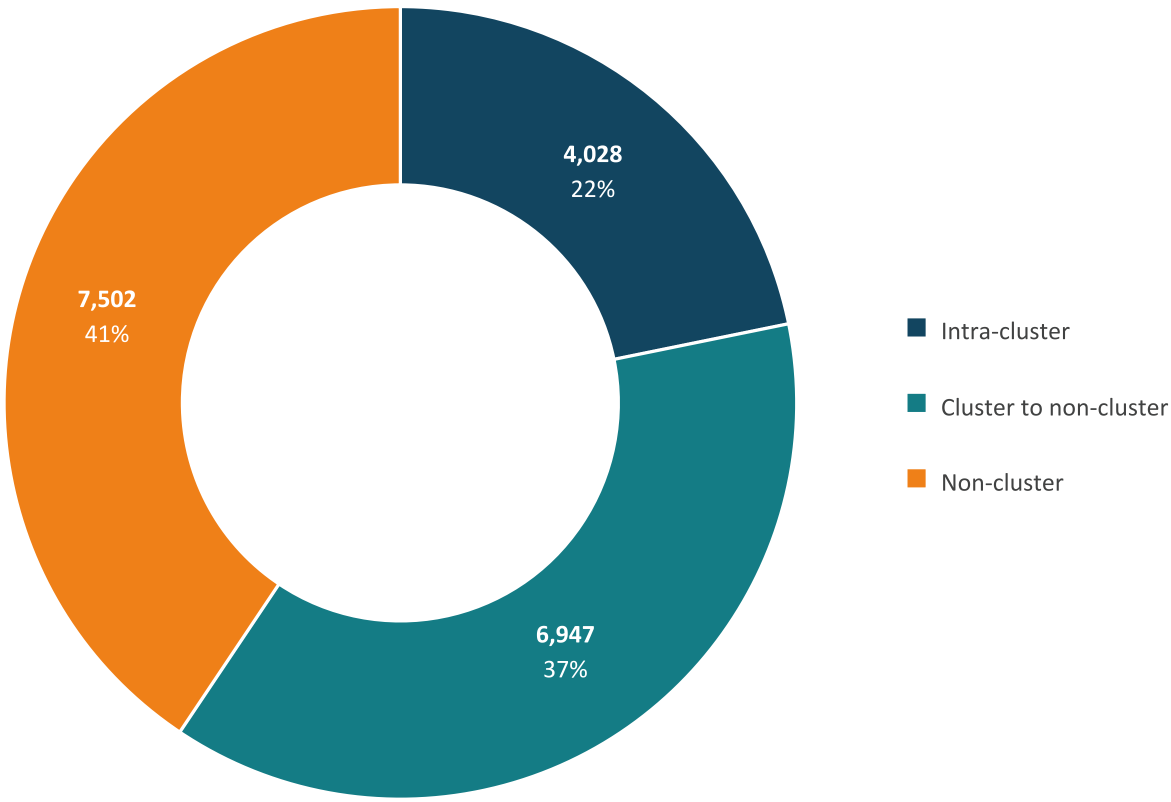
Against this institutional backdrop, the network dynamics of clusters become even more revealing (see Figure 17 below). What is analytically more significant is the role that clusters play within the network. When intra-cluster collaborations (22 per cent, 4,028 collaborations) are combined with cluster-to-non-cluster collaborations (37 per cent, 6,947 collaborations), clusters are involved in

28 Quasi-clusters are included in the non-cluster category for comparison purposes because, although they exhibit emerging quantum activity, they do not meet the minimum thresholds of startup funding or institutional density required to qualify as full clusters under the ECIPE definition.

nearly 60 per cent of all collaborations despite representing only a small fraction of all regions. This indicates that clusters act as structural hubs: they anchor research activity, attract collaborators, and channel knowledge flows both within and beyond their immediate geography.

The prevalence of cluster-to-non-cluster collaborations is particularly revealing. Rather than signalling dispersion, it shows that emerging or peripheral regions tend to link into the system through clusters. In network terms, clusters serve as high-centrality nodes: they are the points through which much of the global quantum research graph is connected. This is consistent with the history of other deep-tech fields, where early-stage regions typically collaborate with established hubs before building their own critical mass.[29] Taken together, the data indicates not that quantum knowledge is evenly distributed across regions, but that clusters retain a dominant, integrative role in shaping and sustaining collaboration patterns, even if they do not dominate in absolute numerical volume.

FIGURE 17: DISTRIBUTION OF QUANTUM COLLABORATIONS BY CLUSTER INVOLVEMENT



Source: ECIPE Quantum Database.

[29] This reflects a well-known hub-and-spoke pattern in deep-tech fields: early or emerging centres tend to link into established hubs, leveraging their expertise, networks, and credibility before developing sufficient local density to function as clusters in their own right.

ANNEX 3: QUANTUM QUASI-CLUSTERS

TABLE 8: QUANTUM QUASI-CLUSTERS, BY REGION (TIER 2)

Region	Quantum quasi-clusters
US	Atlanta, GA and Los Alamos, NM
China	Chongqing, Dalian, Greater Bay Area: Macau-Zhuhai, Guiyang, Jinan, Nanchang, Nanjing, Tianjin, Wuhu, Wuxi, Xi'an, Zhengzhou
UK, Canada, and Australia	Leeds, Liverpool, Melbourne, Sherbrooke
EU	Athens, Basel, Besançon, Bilbao, Bratislava, Brussels, Bucharest, Budapest, Florence, Frankfurt Metropolitan Area, Gothenburg, Greater Nice, Greater Zurich Area, Groningen, Kraków, Leipzig, Lille Metropolitan Area, Madrid, Pisa, Prague, Riga, Rome, San Sebastian, St. Gallen, Stockholm, Tampere, Toulouse, Turin, Ulm, Warsaw
Rest of the World	Bhubaneswar, Buenos Aires, Busan, Chennai, Daejeon, Delhi-NCR Region, Fukuoka, Greater Kuala Lumpur, Greater Nagoya Region, Greater Yerevan Area, Hanoi, Ho Chi Minh City, Hsinchu, Hyderabad, Islamabad, Istanbul, Kazan, Kolkata, La Plata, Lahore, Moscow, Mumbai, Nizhny Novgorod, Osaka, Santiago, Sao Paulo, St. Petersburg, Taipei, Tashkent, Tehran, Tomsk

Source: ECIPE Quantum Database.