



# FUTURE CITY INDEX 2025

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A benchmark of the future preparedness of global cities in talent, innovation, and environment

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# PREFACE

The Future City Index (FCI) is a global, city-level benchmark designed to assess cities' preparedness for long-term development in an increasingly technology-driven and interconnected world. Developed by the Global Talent Flow Data Hub at City University of Hong Kong, the FCI employs a data-driven methodology built on high-resolution, near-real-time data and transparent, reproducible analytics to evaluate cities' future capacity across three major pillars: **Future Talent, Future Innovation, and Future Environment**.

The FCI adopts a three-pillar analytical framework. The first pillar, **Future Talent**, captures a city's capacity to attract, develop, and mobilize human capital for future growth. It reflects the role of education, research training, talent inflow, and skilled workforce formation in sustaining long-term competitiveness.

The second pillar, **Future Innovation**, captures a city's ability to produce knowledge, translate research into technological and economic outputs, and build strength in emerging technologies. It brings together knowledge production, technological innovation, and future positioning in frontier fields such as artificial intelligence(AI), biotech, fintech, semiconductors, and other strategic technologies.

The third pillar, **Future Environment**, captures the broader urban conditions that enable talent and innovation to circulate, scale, and remain resilient under uncertainty. It includes global connectivity, international embeddedness, institutional openness, urban resilience, and the capacity to adapt to economic, environmental, social, and technological change.

Together, these three pillars provide a comprehensive framework for understanding how cities prepare for the future. Rather than focusing primarily on current economic size or historical advantage, the FCI emphasizes forward-looking capacity: the ability to develop talent, strengthen innovation systems, position themselves in emerging technological areas, connect with global networks, and sustain resilience in the face of uncertainty. In this framework, a future city is understood as a **talent-centred, innovation-driven, technologically forward-looking, globally connected, and resilient urban system**.

The FCI has three distinctive strengths. First, it provides a city-level benchmark for assessing future competitiveness, with attention to how cities build momentum, position themselves in emerging technological areas, respond to uncertainty, and support resilient growth. Second, it evaluates 100 major cities and metropolitan regions worldwide using 39 indicators across six strategic dimensions covering talent, research, innovation, frontier technologies, connectivity, and resilience. Third, it is informed by an international advisory committee and cross-sector engagement, incorporating perspectives from academia, industry, and public institutions.

Looking ahead, the FCI is intended to serve as a practical reference for policymakers, researchers, and other stakeholders seeking to understand how cities can strengthen their position in the global competition for talent, innovation, technology leadership, and long-term urban resilience.

# Advisory Committee

The Advisory Committee plays a central role in shaping the vision, integrity, and global relevance of the Future City Index. Bringing together distinguished scholars, thought leaders, and senior executives from diverse regions and institutional backgrounds, the committee provides strategic insight and independent guidance throughout the development of the FCI. Their diverse expertise ensures that the index reflects the evolving landscape of global innovation, talent mobility and the complex realities facing cities today. We are deeply grateful for their commitment, thoughtful contributions, and continued support in advancing the FCI as a trusted international benchmark.

## Advisory Committee members

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# CHAPTER ONE

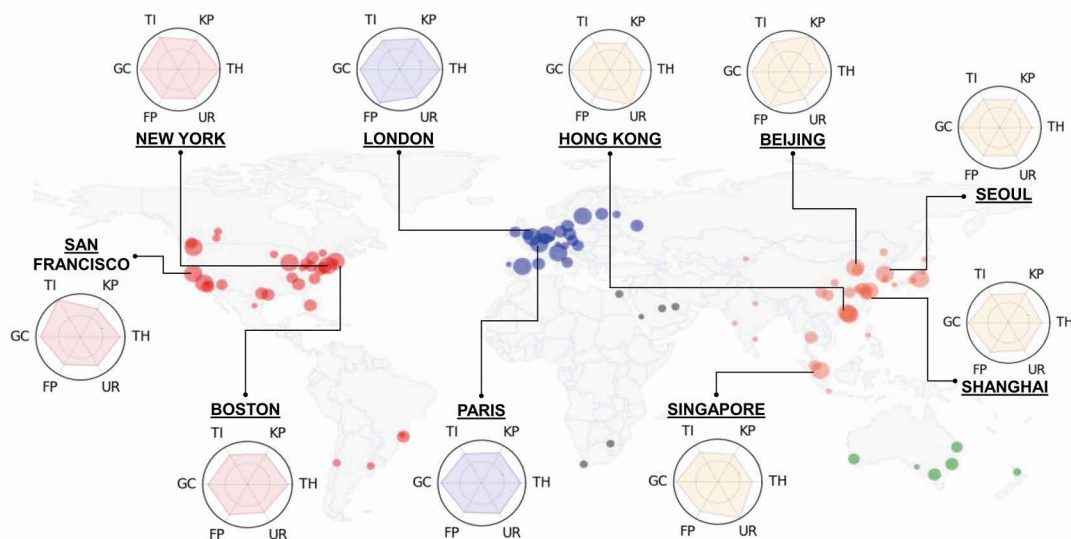
## An Overview of the Global Landscape

# 1.1 The Global Landscape of Future Cities

Cities are increasingly at the centre of global competition for talent, innovation, investment, and strategic influence. In this context, future competitiveness depends not only on current economic strength, but also on a city's ability to build momentum in emerging technologies, adapt to shifting global networks, manage uncertainty, and sustain long-term growth. The Future City Index (FCI) is designed to assess these capabilities in a systematic and comparative way. By integrating large-scale data on talent, innovation, and urban environment, the FCI provides a multidimensional assessment of cities across several core dimensions: talent hub, knowledge production, technological innovation, future-positioning, global connectivity, and urban resilience.

The leading future cities in FCI are **Beijing, Boston, Hong Kong, London, New York, Paris, San Francisco, Seoul, Shanghai, and Singapore** (in alphabetical order).

From a geographical perspective, the current global landscape of future-ready cities is highly concentrated. Leading cities such as Beijing, Hong Kong, London, New York, Paris, and San Francisco are located within major urban corridors in North America, East Asia, and Europe. These cities benefit from strong research institutions, advanced infrastructure, international connectivity, and sustained investment in human capital. Together, these factors reinforce their long-term advantages in the global knowledge economy.



Note: TH = Talent Hub; KP = Knowledge Production; TI = Technological Innovation; FP = Future-Positioning; GC = Global Connectivity; UR = Urban Resilience.

Among the **100 cities** covered by the FCI, **Asia and the Americas each account for 32 cities**, followed by **Europe (24)**, **Oceania (6)**, and **Africa and the Middle East (6)**. Overall, cities with strong economic foundations continue to perform well. Urban centres such as **Boston, London, New York, Paris, San Francisco, and Shanghai** remain highly competitive because they combine scale with strong talent systems, research capacity, and resilience. At the same time, the results also show that **East Asian cities are gaining ground quickly**, supported by sustained public and private investment in education, technology, and infrastructure. Notably, East Asian cities account for **half of the top-tier group**, indicating a broader regional shift in the geography of urban competitiveness.

## Key Takeaways

### **1. A tiered global structure is emerging, with established North American hubs remaining strong and East Asia rising rapidly .**

The distribution of future-ready cities shows a clear tiered structure across the major global regions. North American cities continue to dominate the top tier, with consistently strong performance across talent formation, research excellence, technological innovation, and urban resilience. East Asian cities form a strong second tier and perform particularly well in global connectivity and future positioning. Taken together, these patterns suggest that urban competitiveness is becoming increasingly multipolar.

### **2. Established global hubs retain important long-term advantages.**

Cities such as London, New York, Paris, and San Francisco continue to rank highly because they combine legacy strengths with adaptive capacity. Their advantages extend beyond size alone: they also benefit from mature innovation systems, dense institutional networks, high-quality infrastructure, and policy capacity. These features allow them to remain competitive across multiple dimensions of future readiness.

### **3. East Asia is becoming a major centre of urban future competitiveness.**

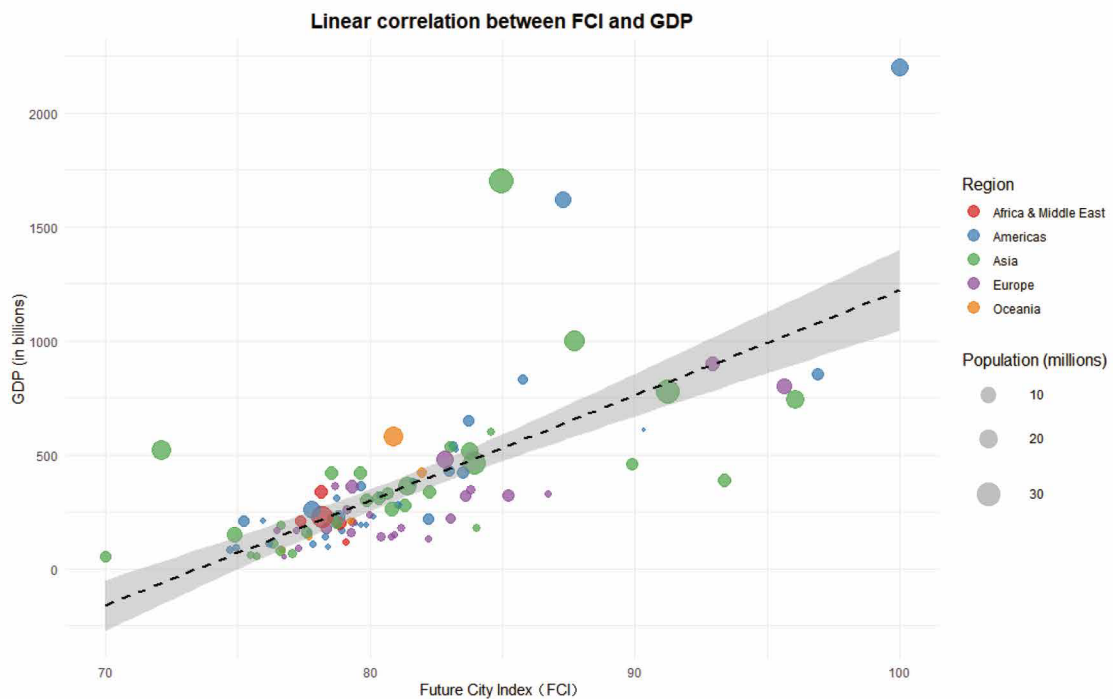
East Asia now accounts for nearly half of the top 30 cities in the FCI ranking, indicating the region's growing role in shaping the future geography of innovation and talent. Cities such as Beijing, Hong Kong, Shanghai, and Singapore perform strongly in areas including global connectivity, talent attraction, and resilience. Their progress reflects the combined effects of research capacity, industrial upgrading, international linkages, and long-term investment in strategic sectors.

## Linking the FCI with the GDP

The relationship between economic scale and future readiness remains important, but it is not absolute. As shown in the scatterplot comparing the FCI with gross domestic product (GDP), wealthier urban centres such as **London, New York, Paris, San Francisco, and Shanghai** continue to occupy leading positions in future competitiveness. Economic resources still matter because they support investment in infrastructure, education, research, and innovation.

At the same time, the relationship between GDP and future readiness is roughly linear. Among the top cities, Asian and U.S. cities form a dense cluster of high performers, but their positions are shaped not only by economic output, but also by differences in talent systems, research excellence, and resilience. This suggests that GDP remains an important enabling condition, but not a sufficient explanation for future competitiveness on its own.

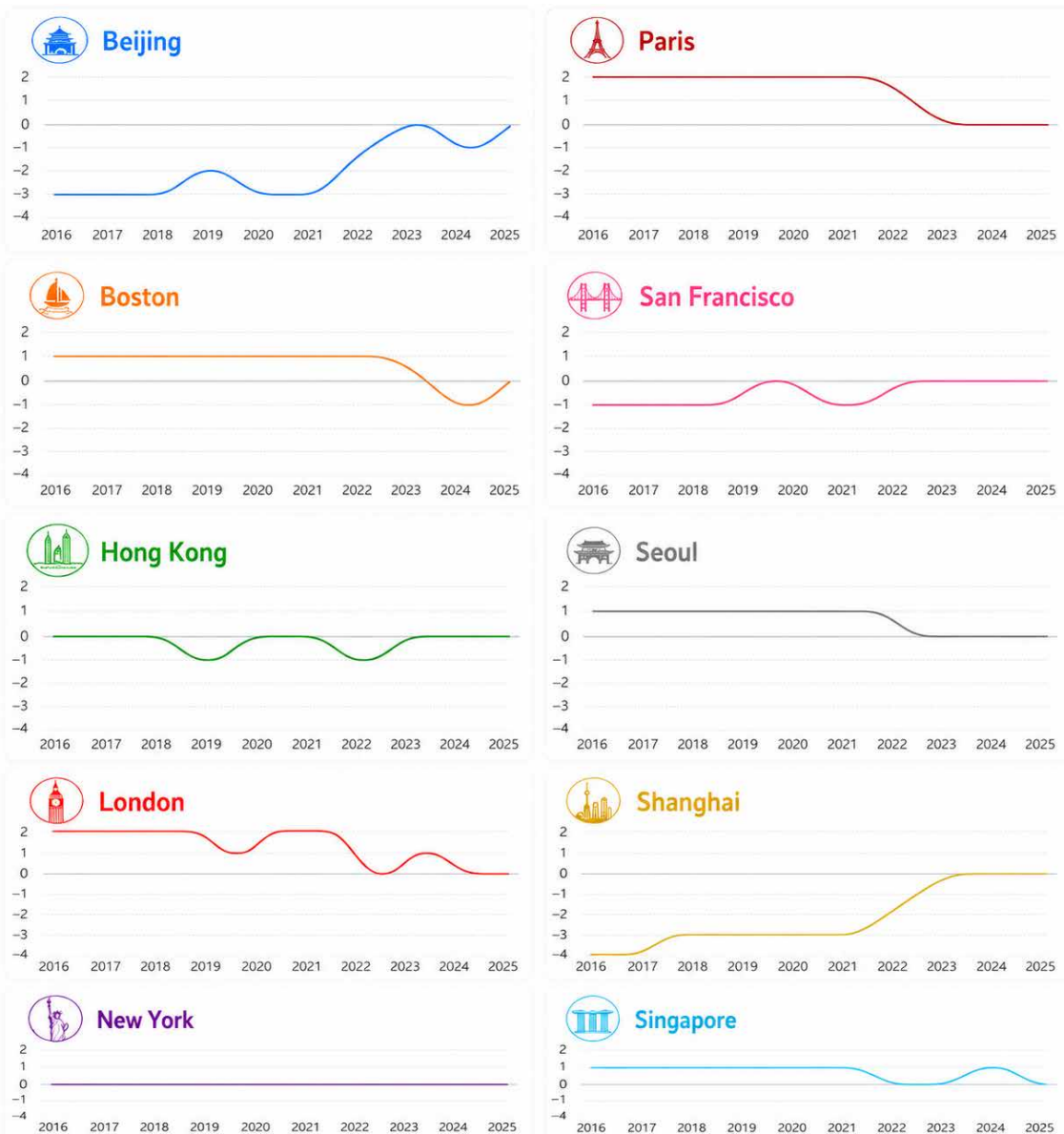
A notable development in recent years is the rapid progress of Asian cities, particularly in China. Supported by regional economic dynamism and long-term investment in education, technology, and urban infrastructure, these cities have significantly narrowed the gap with more established global leaders.



## Evolution of the FCI

The FCI rankings from 2016 to 2025 show a high degree of stability, reflecting the reliability of our index. Over the past decade, **Beijing, Hong Kong, London, New York, and San Francisco** have consistently remained among the leading future cities, reflecting their long-standing strengths in talent, research, innovation, global connectivity, and urban resilience.

At the same time, the decade has also witnessed the rapid rise of Chinese cities. Beijing and Shanghai have recorded notable growth, especially during and after the pandemic period. Their improved performance reflects China's expanding role in the global research and innovation network. These cities are no longer only regional growth centres; they are becoming increasingly important actors in shaping the global landscape of future urban competitiveness.

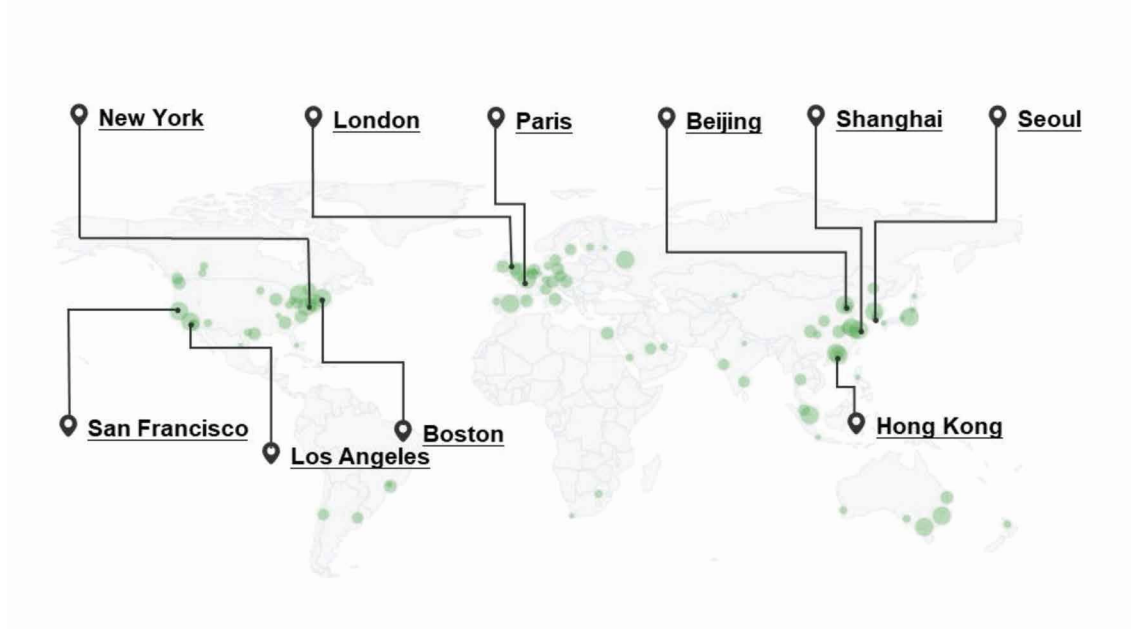


## 1.2 Sub-Clusters of Future Cities

To provide a more comprehensive understanding of urban strengths, the FCI identifies four strategic city clusters: **Talent Hub**, **Connection Hub**, **Resilience**, and **Future-Positioning**. These clusters highlight different pathways through which cities build future competitiveness. Rather than treating all leading cities as broadly similar, this cluster approach shows that cities may reach strong overall performance through different combinations of strengths. Together, these clusters form an integrated framework for understanding how cities generate knowledge, attract and retain talent, connect to global networks, withstand shocks, and position themselves for emerging opportunities.

### Talent Hub

Talent Hub measures a city's capacity to attract, cultivate, and retain high-end human capital. This cluster covers talent formation, international mobility, the concentration of top researchers, and the vitality of frontier research, reflecting both a city's talent competitiveness and its cutting-edge research and innovation dynamism. Based on these dimensions, the global Talent Hub cluster includes **Beijing, Boston, Hong Kong, London, Los Angeles, New York, Paris, San Francisco, Seoul, and Shanghai** (in alphabetical order).

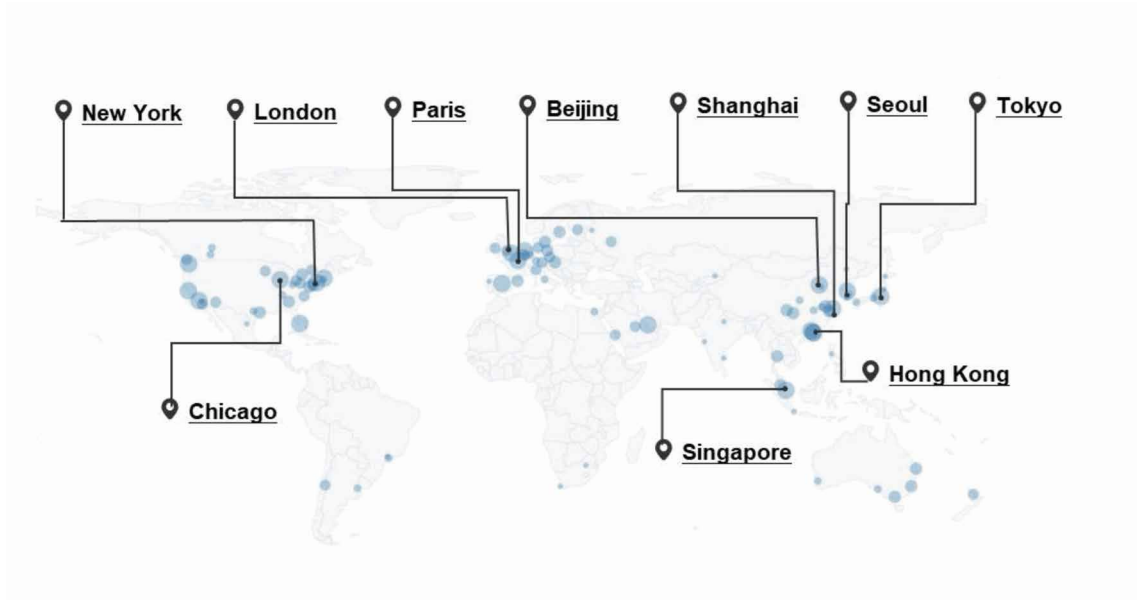


### Highlights

- The global talent hub ecosystem exhibits a highly balanced tripolar structure. North America—centred on hubs such as Boston, Los Angeles, New York, and San Francisco—and Europe—anchored by London and Paris—have maintained their long-standing leadership, while the Asia-Pacific region, led by Beijing, Hong Kong, Shanghai, and Seoul, is rapidly emerging as a powerful talent magnet.
- Beijing, London, and New York are at the forefront, each with distinct strengths. Beijing excels in high-impact researchers; London stands out for its high-quality universities and the inflow of researchers; while New York performs strongly in both high-quality, high-efficiency and high-impact researchers.

## Connection Hub

Connection Hub measures the efficiency with which key factors move through global networks. This cluster captures how deeply and effectively a city is integrated into global systems of people, goods, and information by assessing international connectivity and internal transportation efficiency. The leading Connection Hubs are **Beijing, Chicago, Hong Kong, London, New York, Paris, Seoul, Shanghai, Singapore, and Tokyo** (in alphabetical order).

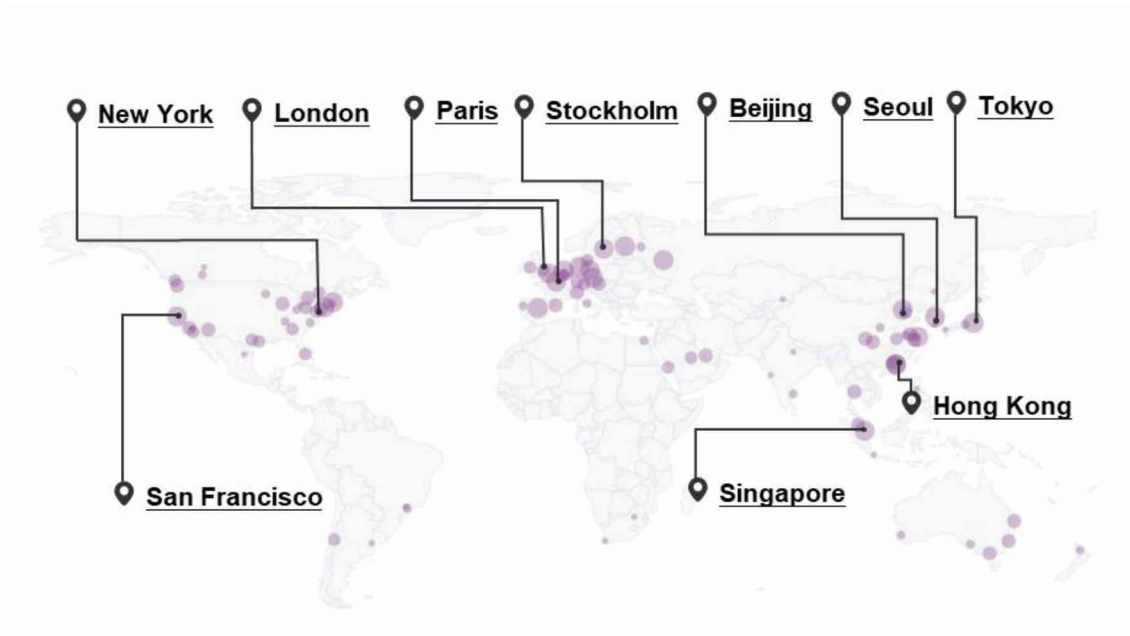


## Highlights

- The global pattern of Connection Hub is clearly multipolar. Asia-Pacific and Europe have emerged as major anchors of global connectivity alongside North America. This suggests that international exchange is increasingly organised through several major regional systems rather than one dominant centre alone.
- East Asian cities play an especially important role in this landscape. Hong Kong, Seoul, Shanghai, and Singapore stand out for their strengths in international air travel, digital connectivity, and international collaboration. Their performance indicates that connectivity remains a core component of urban competitiveness, particularly in a global economy shaped by mobility, logistics, and information flows.

# Resilience

Resilience measures a city's ability to respond to unforeseen risks while maintaining stable core functions. This cluster combines indicators of urban operational safety, the support provided by high-quality educational resources, digital infrastructure connectivity, and the stability of research institutions, reflecting both a city's capacity to absorb shocks and its foundation for sustainable development. Based on these dimensions, the Resilient City cluster includes **Beijing, Hong Kong, London, New York, Paris, San Francisco, Seoul, Singapore, Stockholm, and Tokyo** (in alphabetical order).

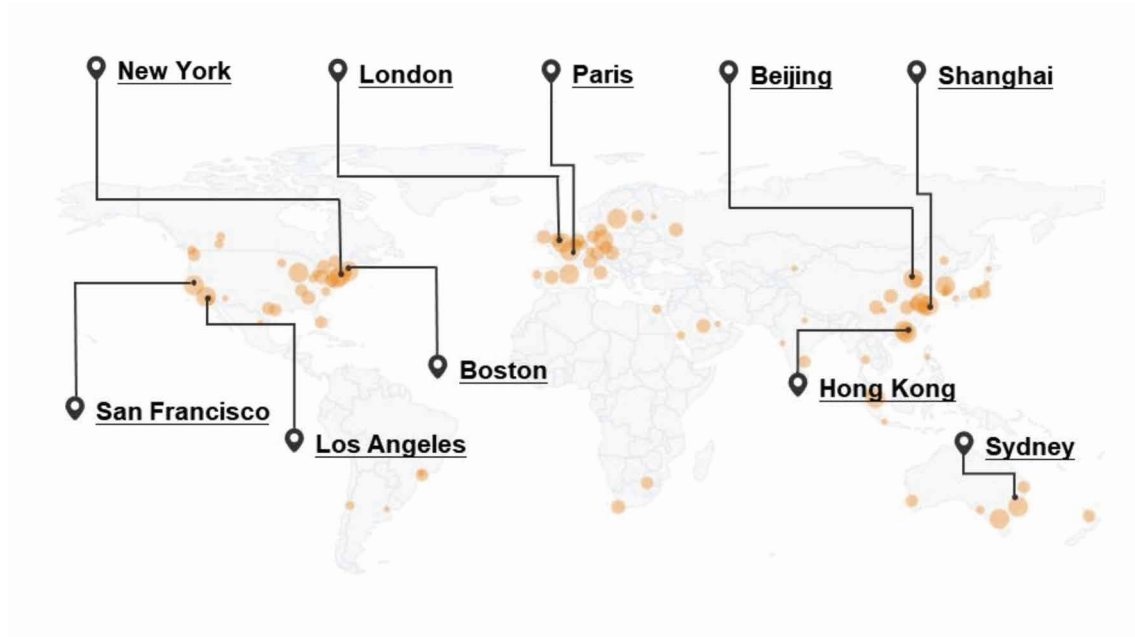


## Highlights

- Leading Resilient Cities are most concentrated in East Asia and the Asia-Pacific, with the greatest number of top-tier hubs: Beijing, Hong Kong, Seoul, Singapore, and Tokyo, and dense regional clusters. Europe and North America host key resilience hubs including London, New York, Paris, San Francisco, and Stockholm, but East Asia has solidified its position as the global epicentre of urban resilience.
- These cities perform well not only because of infrastructure quality, but also because of their broader capacity to adapt under pressure. Their results suggest that resilience is closely tied to institutional continuity, digital readiness, and the ability to sustain education and research functions during periods of uncertainty.

## Future-Positioning

Future-Positioning measures a city's ability to anticipate future development trends and to position itself strategically in response. By evaluating forward-looking capacity in emerging domains such as artificial intelligence, fintech, biotech, and semiconductors, this cluster reflects a city's potential to seize new opportunities and shape future urban development. Based on performance across these dimensions, the Future-Positioning City cluster includes **Beijing, Boston, Hong Kong, London, Los Angeles, New York, Paris, San Francisco, Shanghai, and Sydney** (in alphabetical order).



## Highlights

- Asia-Pacific region is particularly prominent in this cluster, forming a dense network of cities with strong forward-looking capacity. Beijing and Shanghai serve as major anchors, while Hong Kong and Sydney also demonstrate strong positioning in emerging technological fields.
- Western cities, including Boston, London, Los Angeles, New York, Paris, and San Francisco, remain highly competitive due to their established innovation systems, research depth, and strategic capacity to align with new technological trajectories.

# The Full List of the Top 50 Future Cities

City	Future City Index
Beijing	★★★★★
Boston	★★★★★
Hong Kong	★★★★★
London	★★★★★
New York	★★★★★
Paris	★★★★★
San Francisco	★★★★★
Seoul	★★★★★
Shanghai	★★★★★
Singapore	★★★★★

Amsterdam	★★★★
Chicago	★★★★
Guangzhou	★★★★
Los Angeles	★★★★
Madrid	★★★★
Milan	★★★★
Seattle	★★★★
Shenzhen	★★★★
Stockholm	★★★★
Tokyo	★★★★

Atlanta	★★★
Barcelona	★★★
Berlin	★★★
Hangzhou	★★★
Houston	★★★
Miami	★★★
Moscow	★★★
Philadelphia	★★★
Sydney	★★★
Toronto	★★★
Austin	★★
Baltimore	★★
Bangkok	★★
Copenhagen	★★
Hamburg	★★
Helsinki	★★
Melbourne	★★
Nanjing	★★
San Diego	★★
São Paulo	★★
Chengdu	★
Cleveland	★
Dublin	★
Kuala Lumpur	★
Pittsburgh	★
Prague	★
Tianjin	★
Vancouver	★
Vienna	★
Wuhan	★

City	Talent Hub	Connection Hub	Resilience	Future-Positioning
Beijing	●	●	●	●
Boston	●			●
Hong Kong	●	●	●	●
London	●	●	●	●
New York	●	●	●	●
Paris	●	●	●	●
San Francisco	●		●	●
Seoul	●	●	●	
Shanghai	●	●		●
Singapore		●	●	

Amsterdam				
Chicago		●		
Guangzhou				
Los Angeles	●			●
Madrid				
Milan				
Seattle				
Shenzhen				
Stockholm			●	
Tokyo		●	●	

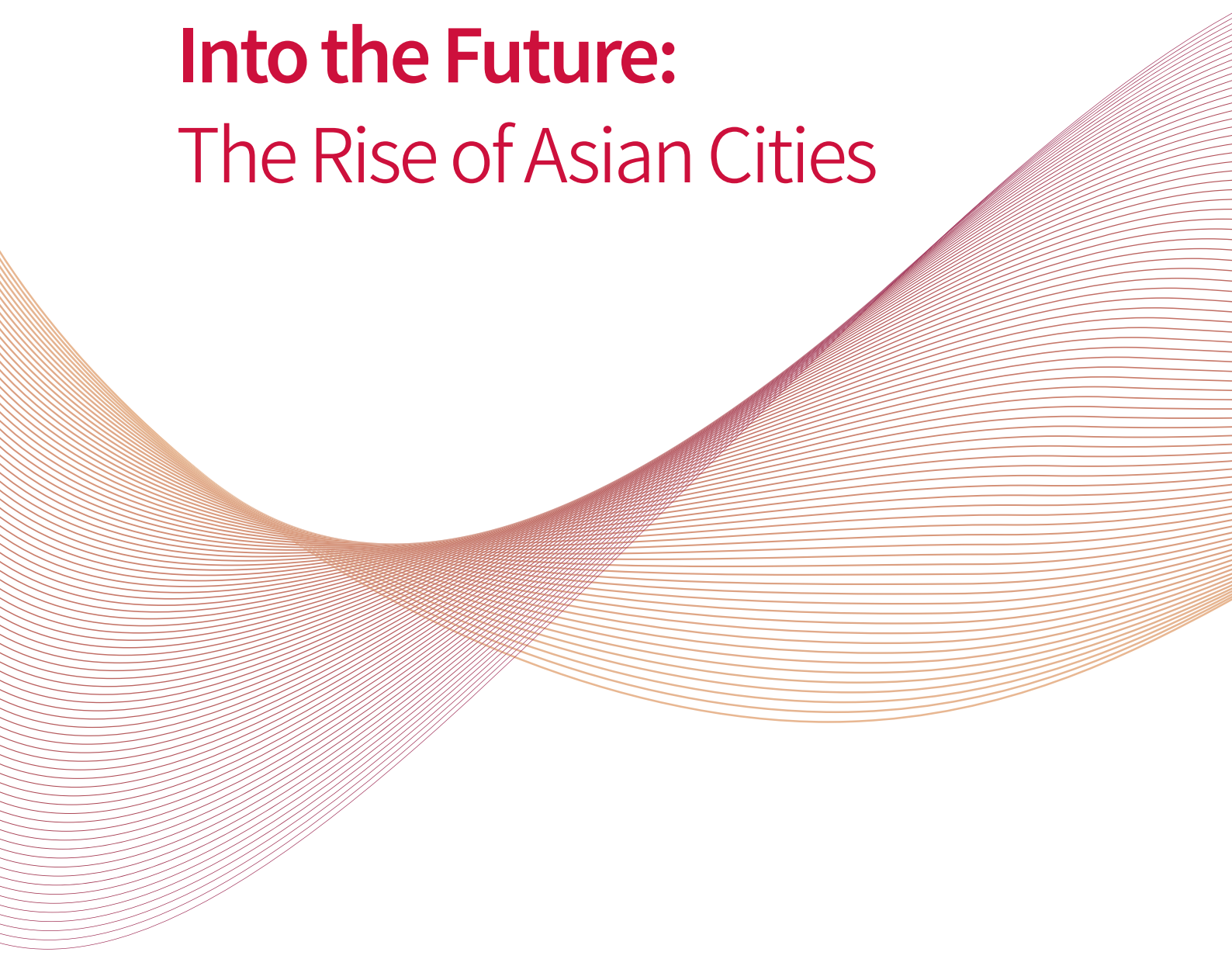
Atlanta				
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Moscow				
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Melbourne				
Nanjing				
San Diego				
São Paulo				
Chengdu				
Cleveland				
Dublin				
Kuala Lumpur				
Pittsburgh				
Prague				
Tianjin				
Vancouver				
Vienna				
Wuhan				

Note: Cities are listed in alphabetical order.



# CHAPTER TWO

## Into the Future: The Rise of Asian Cities



# The Rise of Asian Cities

For much of the past several decades, global technological leadership was concentrated in major hubs in North America and Europe. However, this pattern is changing. As the global innovation landscape evolves, Asian cities are playing an increasingly important role in shaping research, technology development, and industrial transformation. The FCI pays particular attention to these cities because they are becoming major contributors to the global innovation system and important sites of future urban competitiveness.

This shift is visible across multiple indicators. In many Asian cities, the FCI identifies strong growth in high-impact research output, the concentration of top researchers, technological innovation and the formation of research-intensive ecosystems. These trends are especially notable in emerging fields such as AI, fintech, biotech, and semiconductors. In other words, Asian cities are not only adopting new technologies quickly, but are also strengthening their capacity to generate original research and frontier innovation.

A key driver behind this development is human capital. While investment and infrastructure remain important, long-term innovation capacity depends heavily on the ability to attract, cultivate, and retain highly skilled researchers and technical talent. In this sense, talent has become one of the most important foundations of urban competitiveness in the knowledge economy. Cities that are able to build dense, internationally connected, and resilient talent ecosystems are better positioned to sustain technological advancement over time.

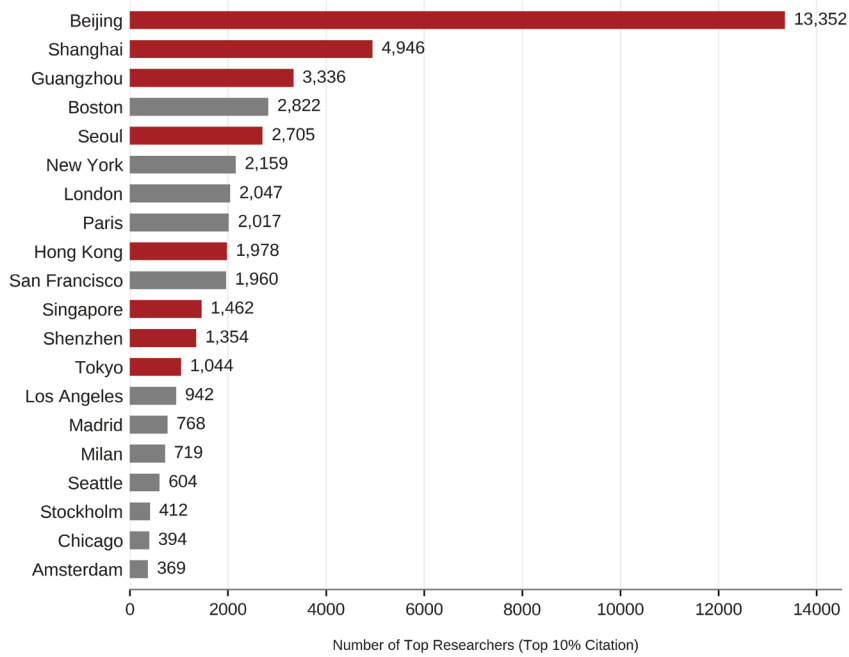
Against this background, this chapter focuses on the research talent base underpinning Asia's rise. The FCI examines the global distribution of top-tier researchers, particularly those working in emerging technological domains. By analyzing patterns of talent concentration, growth momentum, and resilience, the chapter provides a clearer understanding of how Asian cities are strengthening their position within the changing global innovation landscape.

## 2.1 Asia's Standing as Global Research Hub

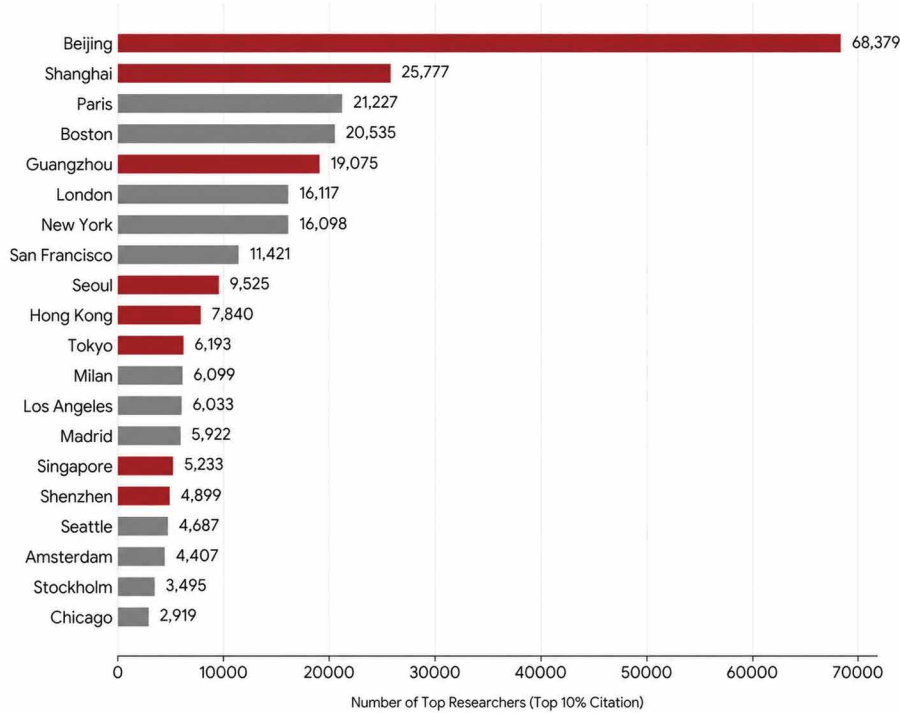
As global technological competition and academic innovation deepen, the geography of top research talent is being reshaped. The FCI examines the distribution of top researchers across twenty global technology hubs in 2024, distinguishing between emerging fields—including AI, fintech, biotech, and semiconductors—and general fields, including life sciences and biomedicine, social sciences, and science and technology. The results show that Asian cities are gaining ground in both areas: they are strengthening their presence in broad-based research while establishing clear momentum in frontier sectors.

This pattern suggests that Asia's rise is not confined to applied innovation or industrial scale. It increasingly reflects a deeper transition toward research-intensive growth, with stronger capabilities in knowledge production and original innovation. At the same time, established hubs in North America and Europe continue to retain major advantages in institutional depth, long-term academic prestige, and broad foundational research capacity. The current landscape is therefore less a simple transfer of leadership than a rebalancing of the global system.

### Number of Top Researchers (Emerging)



### Number of Top Researchers (General)



Note: Emerging areas are identified through keyword matching in publication records in 2024. Top researchers in emerging fields (AI, fintech, biotech, and semiconductors) are defined as the top 10% of researchers ranked by their citation each year. Similarly, top researchers in general fields represent the top 10% within broader disciplinary areas, including life sciences and biomedicine, social sciences, and science and technology. City-level data are aggregated based on researchers' institutional affiliation, as described in the Methods section.

## Key Takeaways

### Asian cities have become major centres of emerging research talent.

- The global frontier research landscape is increasingly characterized by a more balanced distribution across Asia, Europe, and the United States. Asia accounts for 8 of the top 20 global hubs, followed by Europe (6) and the United States (6). While the scale of **Beijing, Shanghai, and Guangzhou** illustrates China's rapid build-up of frontier research capacity, the sustained performance of **Hong Kong, Singapore, and Seoul** highlights the strategic importance of highly connected urban systems. Together, these patterns suggest that Asia is becoming an important pillar of the global knowledge economy.

### Broad scientific capacity continues to matter.

- The presence of top researchers across diverse fields in cities such as **Beijing, Boston, Guangzhou, London, New York, Paris, and Shanghai** indicate that leadership in emerging technologies is rarely an isolated phenomenon. It is rooted in a mature, multi-disciplinary ecosystem. For the 20 leading cities globally, the ability to sustain talent pipelines and absorb technological breakthroughs depends less on narrow specialisation and more on the depth and breadth of their foundational research base.

### Urban competitiveness is becoming more differentiated.

- Urban innovation leadership is becoming increasingly differentiated rather than converging on a single model. Cities such as **Beijing, Shanghai, and Guangzhou** leverage scale and comprehensive academic infrastructure to anchor innovation. In contrast, agile and globally connected hubs such as **Hong Kong, Singapore, and Seoul** rely more heavily on talent density and cross-border linkages. Established Western cities continue to benefit from historically deep university–industry integration. Together, these patterns suggest that metropolitan scale, network connectivity, and institutional specialisation can each support strong global competitiveness when aligned with local structural advantages.

Taken together, these findings point to a significant rebalancing of the global frontier research landscape, with Asian cities emerging as one of its most important drivers. This rise is supported by differentiated but effective models of urban competitiveness: large metropolitan hubs such as Beijing, Shanghai, Seoul, and Tokyo draw strength from scale and broad-based research ecosystems, while highly connected hubs such as Hong Kong, Singapore, and Shenzhen benefit from international linkages and dense talent networks. Asian cities have therefore become increasingly important contributors to global innovation.

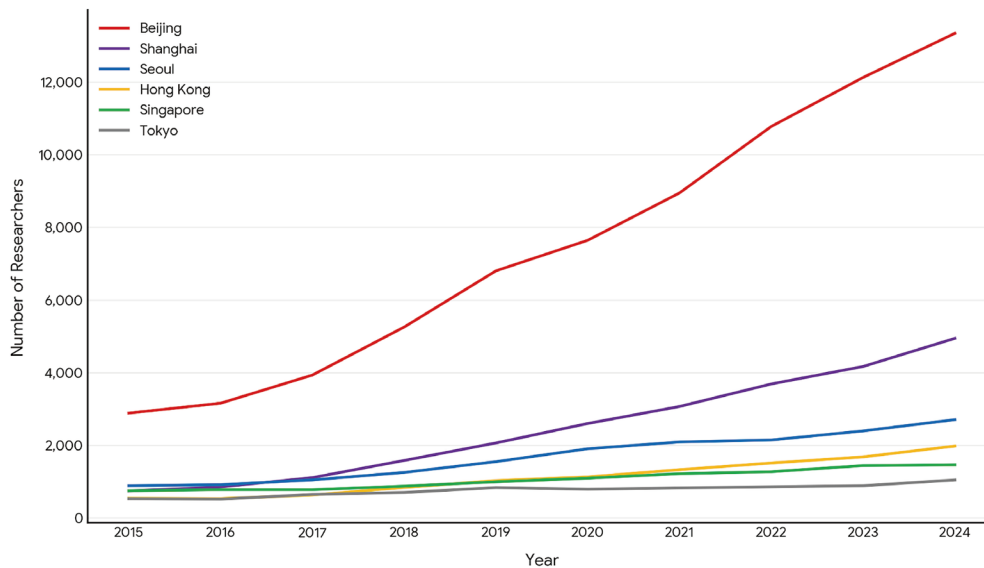
## 2.2 Evolution of Asia as a Research and Innovation Hub

To provide a more granular view of talent agglomeration in Asia, the FCI tracks the growth of top researchers across six Asian technology hubs from 2015 to 2024<sup>[1]</sup>. The trajectories show both shared momentum and increasingly differentiated development paths. Some cities have expanded rapidly through scale, while others have moved toward consolidation, specialisation, or resilience-based growth.

<sup>[1]</sup> Due to the incomplete publication data for 2025, all statistics based on publication records are calculated up to 2024.

## Trend in Emerging Fields

Top Researchers in Emerging Fields (2015-2024)



### The Rise of China as a Research Talent Hub

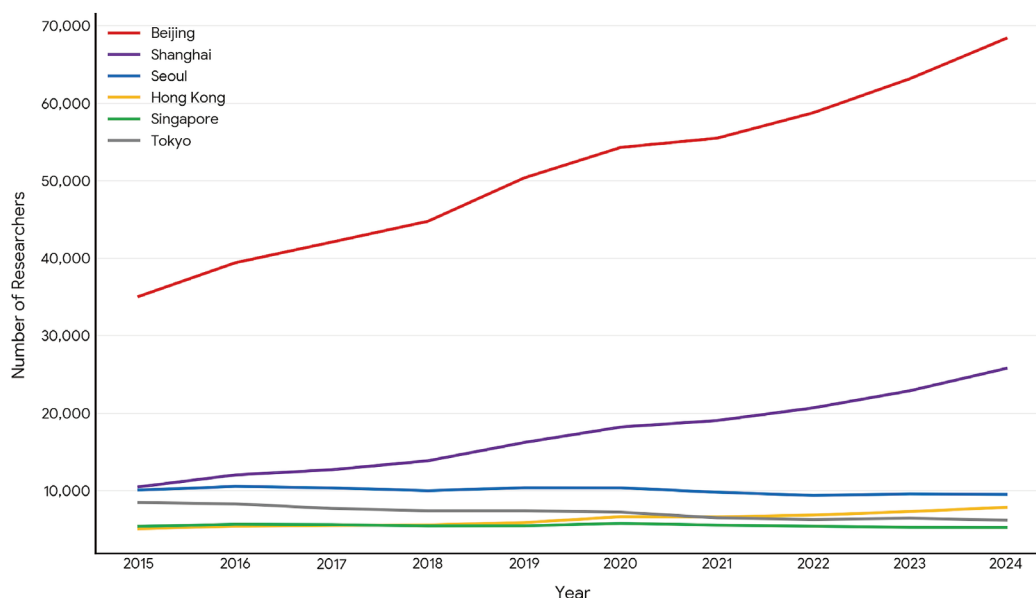
- **Beijing** has shown remarkable talent agglomeration capacity. Its top researcher base in emerging fields grew from 2,886 in 2015 to 13,352 in 2024, reaching nearly five times its 2015 level. This expansion is notable given its already large base, consolidating Beijing's role as the region's central innovation node.
- **Shanghai** has followed a similarly striking trajectory. Its number of top researchers in emerging fields increased from 741 in 2015 to 4,946 in 2024, reaching more than six times its 2015 level. This growth has moved the city decisively into the top tier of Asian hubs. The scale and speed of this growth suggest that the region's innovation landscape is no longer concentrated in a single dominant centre, but is increasingly supported by multiple high-capacity nodes.

### High Growth in Strategic Nodes

- **Hong Kong** has also recorded strong growth, rising from 536 in 2015 to 1,978 in 2024. Particularly notable is the acceleration after 2019, by which point the figure had reached 1,026. This pattern suggests that Hong Kong's role is shaped not by scale alone, but also by its ability to attract, connect, and retain global talent within a highly international research environment.
- **Singapore** has taken a steadier path. Its top researcher count increased from 747 in 2015 to 1,462 in 2024. While this trajectory is less dramatic than that of Beijing or Shanghai, it reflects sustained accumulation rather than short-term fluctuation, reinforcing Singapore's profile as a stable and strategically managed knowledge hub.
- **Seoul** and **Tokyo** also continued to grow, reaching 2,705 and 1,044 top researchers, respectively, in 2024. Seoul showed particularly strong expansion, while Tokyo followed a more gradual upward trajectory. Together, these patterns indicate enduring institutional strength and a continuing ability to retain advanced research capacity in an increasingly competitive regional environment.

## Trend in General Fields

Top Researchers in General Fields (2015-2024)



### Scale-Driven Talent Agglomeration

- **Beijing** again demonstrates very substantial scale in general fields. Its top researcher count increased from 35,076 in 2015 to 68,379 in 2024. This sustained expansion indicates not only strong capacity in frontier domains, but also a broad and deep scientific base that can support long-term research productivity and interdisciplinary development.
- **Shanghai** has also reshaped the regional hierarchy. Its total rose from 10,485 in 2015 to 25,777 in 2024, more than doubling over the period. This shift allowed Shanghai to widen its lead over other regional cities and establish itself as one of the most important centres of general research talent in Asia.
- **Hong Kong** expanded from 5,086 to 7,840 over the same period. Although the scale is smaller than that of the largest Chinese Mainland cities, the trend reflects strong continuity and resilience. It also suggests that cities with limited land and population can maintain competitiveness when their institutions remain internationally connected and research-intensive.

### From Scale to Network Quality

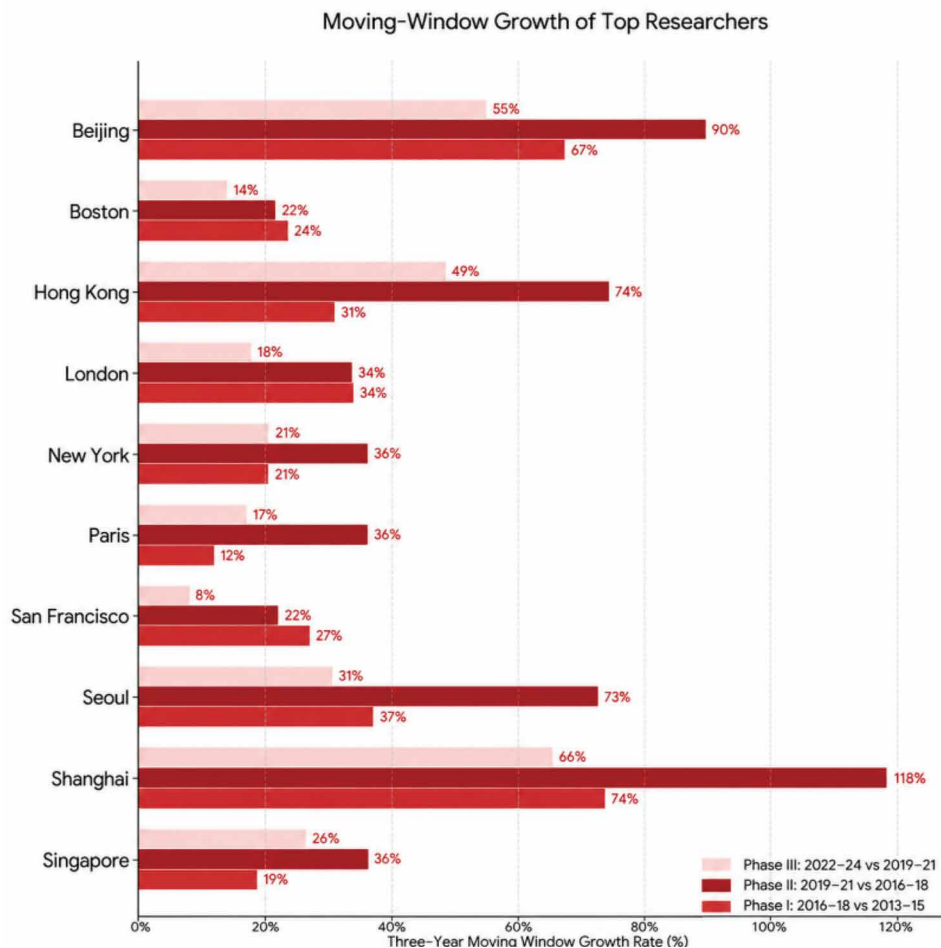
- **Seoul** represents a balanced transition model. Its talent pool of top researchers in general fields shifted toward a more consolidated core, moving from 10,070 in 2015 to 9,525 in 2024. At the same time, the city reached 2,705 top researchers in emerging fields in 2024, indicating a strong capacity to translate broad-based research depth into frontier innovation.
- **Singapore** exemplifies a talent-density strategy. Its general top researcher base remained highly concentrated, adjusting slightly from 5,405 in 2015 to 5,233 in 2024. Rather than pursuing explosive scale alone, Singapore appears to have strengthened the quality and connectivity of its research ecosystem, reaching 1,462 top researchers in emerging fields by 2024. This pattern suggests that large general-field volume is not the only path to global competitiveness in frontier sectors.
- In contrast to the expansion seen in other regional hubs, **Tokyo** presents a distinct demographic trend, with its general research volume decreasing from 8,449 in 2015 to 6,193 in 2024. This reduction suggests a shift from broad scale expansion toward a more consolidated and concentrated talent structure.

Taken together, these trends show that Asia's technology hubs are not following a single model. Some are expanding through large-scale accumulation, while others are adapting through specialisation, consolidation, and higher-value network positioning.

## 2.3 Growth Momentum

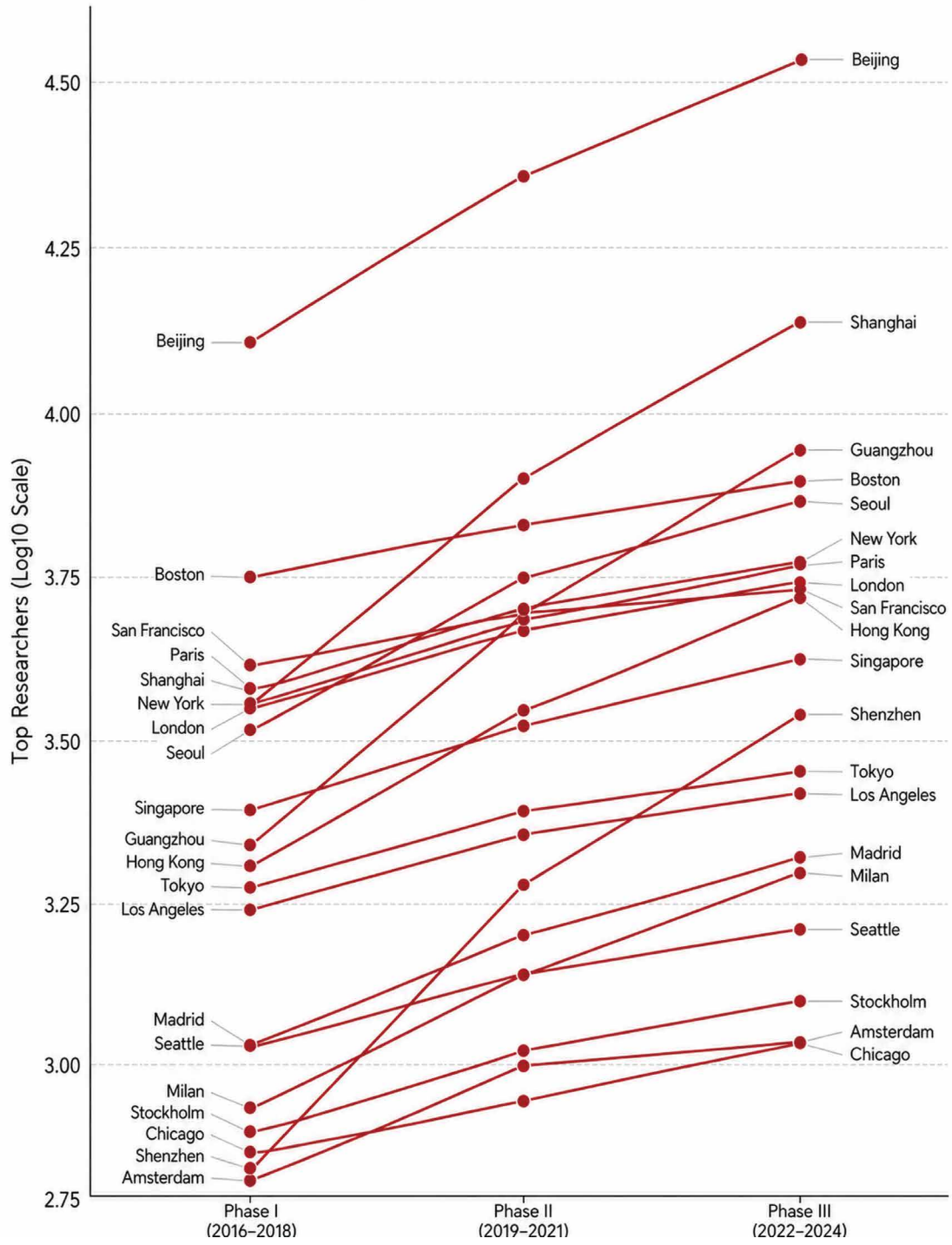
Future competitiveness depends not only on current scale, but also on whether cities can sustain research growth over time. The pace at which cities gain or lose momentum is an important component of future competitiveness.

To capture this dynamic, this section applies a three-year moving-window method across the cities examined, covering three strategic periods: Phase I (2016-2018), Phase II (2019-2021), and Phase III (2022-2024). The resulting comparisons provide a more stable view of growth trajectories and help identify which cities have sustained their expansion over time.



*Note: Top researchers are defined as the top 10% of researchers, without distinguishing across disciplinary fields. Growth is measured using a three-year moving window, with results normalised into a standardised score.*

### Comparative Growth Momentum



Note: Values refer to the average total number of top researchers observed within each three-year phase. All values in y-axis are reported in log form.

### Phase I: Initial Expansion

- During Phase I, **Shanghai (74%)** and **Beijing (67%)** recorded the strongest growth among the cities examined. This early acceleration indicates that major Asian hubs were already on a path of rapid structural expansion. Established Western centres, including **London (34%)**, **San Francisco (27%)**, **Boston (24%)**, and **New York (21%)**, also maintained robust growth, although at a more moderate pace consistent with mature, high-baseline research ecosystems.

### Phase II: Growth Divergence

- In Phase II, city trajectories became more differentiated as growth patterns diverged across hubs. **Shanghai** emerged as a clear outlier with a growth rate of **118%**, effectively more than doubling its research scale relative to the previous window. **Hong Kong** also accelerated markedly, with growth rising from 31% in Phase I to **74%** in Phase II. At the same time, mature innovation hubs in North America and Europe such as **New York (36%)** and **Paris (36%)** recorded stronger momentum, indicating that highly concentrated innovation ecosystems were still able to sustain, and in some cases strengthen, their expansion during a period of global disruption.

### Phase III: Competitive Realignment

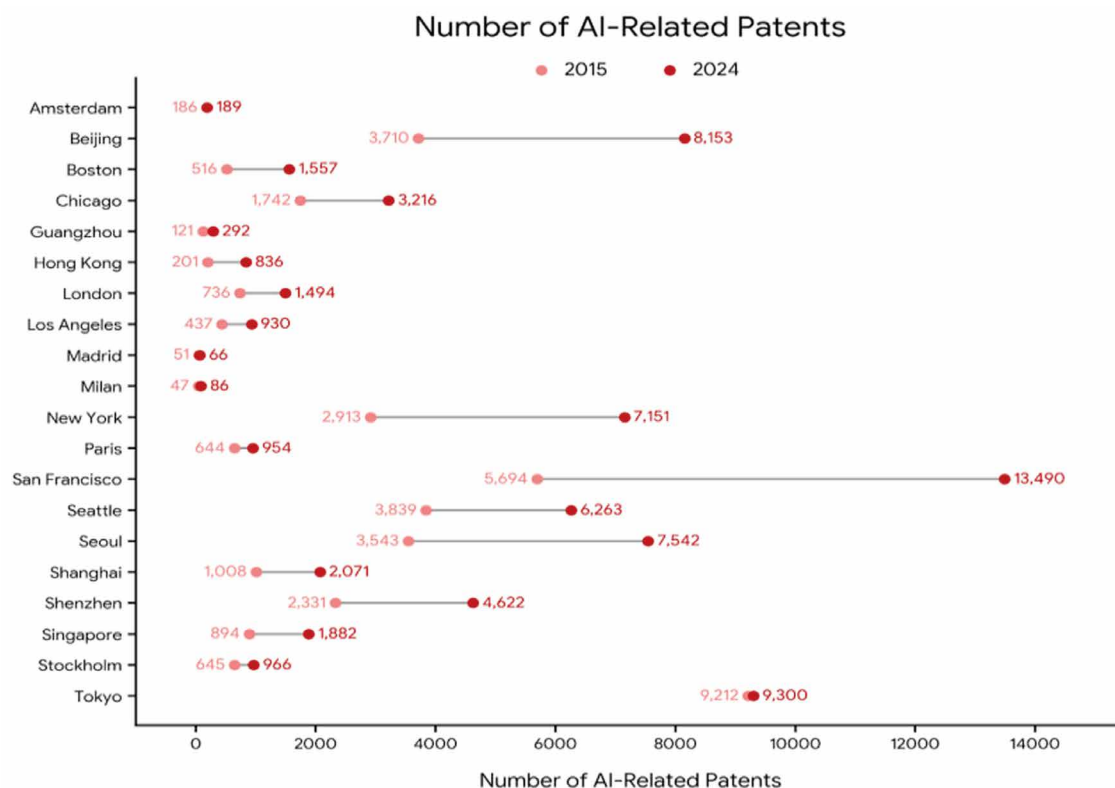
- In Phase III, growth moderated globally from the exceptionally high rates recorded in the previous window, but the leading Asian hubs remained strongly positioned. **Shanghai (66%)**, **Beijing (55%)**, and **Hong Kong (49%)** continued to record the fastest growth among the cities compared, indicating sustained capacity building rather than a return to earlier, lower levels of growth. **Singapore (26%)** also maintained steady momentum. By contrast, Western hubs experienced a more pronounced relative cooling of growth rates, with **New York (21%)**, **London (18%)**, **Boston (14%)**, and **San Francisco (8%)** showing more moderate expansion as competition for top-tier research talent intensified.

Overall, this section points to a significant restructuring of the global research landscape. Long-established research centres in North America and Europe such as New York and London continue to display the stability associated with mature ecosystems, but the most consistent pattern across all three phases is the sustained rise of Asian innovation centres. The continued strong performance of Shanghai, Beijing, Hong Kong, and Singapore suggests that the centre of gravity in research momentum is increasingly shifting toward Asia.

## 2.4 Steady Growth in AI Areas

AI has become one of the most important arenas of global technological competition. To understand how cities are positioning themselves in this field, the FCI tracks developments from **2015 to 2024** across two indicators: **AI-related top publications** and **AI-related patents**. Together, these indicators capture different stages of the AI ecosystem, from talent concentration and knowledge creation to commercialisation and application.

## AI-Related TOP Publications

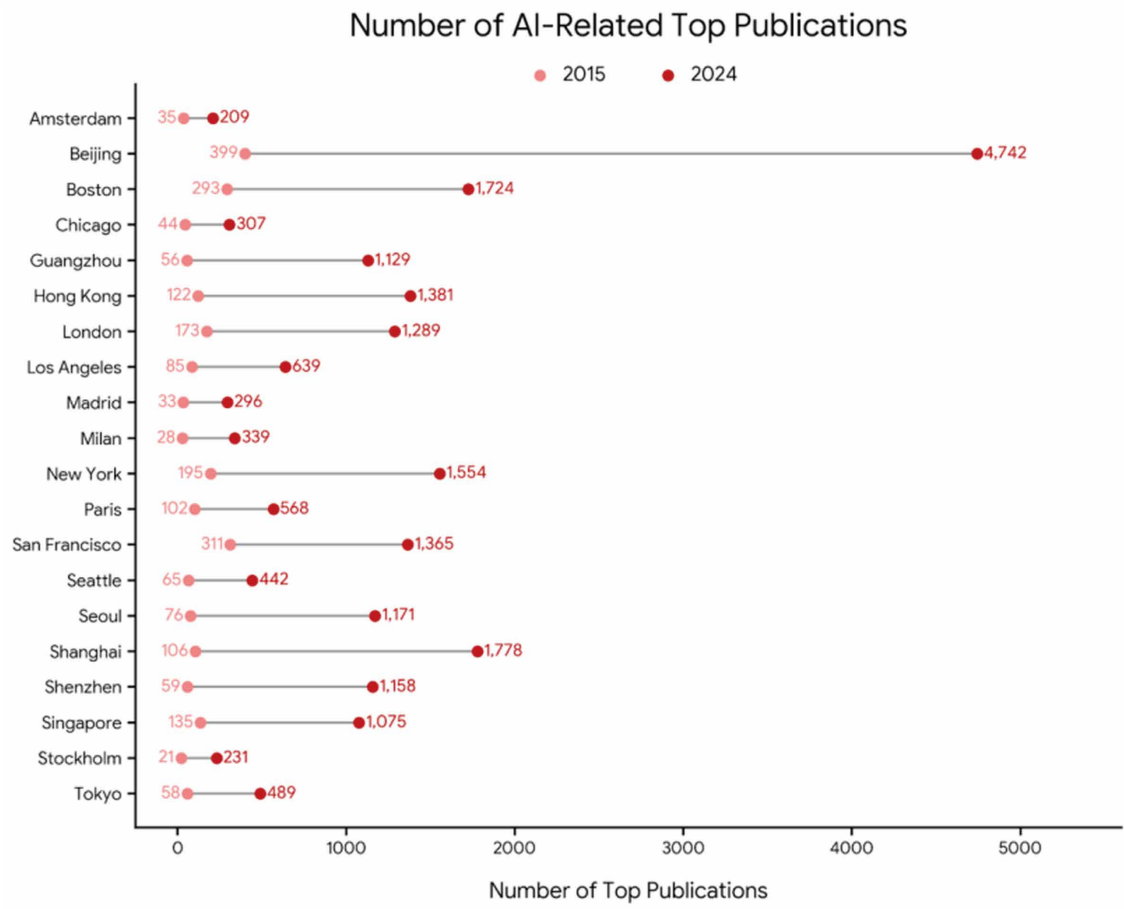


Note: Top publications are defined as articles ranked within the top 10% by citation impact in each publication year. Values indicate the number of top publications in the AI field.

Publication output reflects a city's capacity to contribute to the global knowledge base in AI. Over the 2015–2024 period, the landscape of AI-related academic publishing demonstrates substantial development across multiple global regions:

- **Beijing** recorded the most notable expansion, with the number of AI-related top publications rising from 399 to 4,742 over the period an almost twelve-fold increase. **Shanghai** also posted substantial gains, reaching 1,778 publications by 2024. **Hong Kong**, **Seoul**, **Shenzhen**, and **Singapore** also registered strong growth, reinforcing the region's position as a major centre of AI research output.
- **Boston** leads North America in overall volume, expanding its output from 293 to 1,724 AI-related top publications over the decade. **New York** remains a highly influential hub, climbing from 195 to 1,554 publications. Concurrently, **San Francisco** and **Los Angeles** maintain strong and stable positions in the academic publishing landscape, driven by their dense concentrations of elite universities and tech institutions.
- **London**, **Paris** and **Madrid**, maintain a solid presence in the global academic landscape, continually contributing specialised knowledge and foundational theories to the community.

## AI-Related Patents



Note: The calculation of patent counts is described in the Methods section.

Patent output serves as an important indicator of the transition from scientific knowledge to industrial application and commercialisation. The global landscape of AI-related patenting reflects diverse institutional strengths and evolving strategies for securing intellectual property:

- Patent data for several U.S. cities suggest a strong capacity for translating AI-related knowledge into proprietary technologies. The strongest patent activity is visible in **San Francisco**, whose AI patent volume increased sharply, highlighting the capacity to convert AI research into products, enterprise applications, and proprietary technologies. Other major hubs, including **New York** and **Seattle**, have also developed substantial patent portfolios, supported by a synergy between large-scale technology firms and specialised innovation labs.
- Beijing** and **Seoul** have both recorded substantial increases in their patenting output, reflecting a strategic emphasis on domestic technology development. **Shenzhen** has emerged as a notable centre of applied AI innovation, while **Guangzhou** shows a smaller but growing patent base. Meanwhile, **Tokyo** continues to maintain a high level of AI-related patent activity, although its growth between 2015 and 2024 was relatively limited.

- **Hong Kong** is also noteworthy: its AI-related patents increased from 201 in 2015 to 836 in 2024, representing growth of over 315%. This suggests a strengthening environment for intellectual property generation and research commercialisation, although the relatively small initial base should also be noted.
- **London** and **Paris** maintain consistent patenting activities, often centred around software services and industrial automation. Other hubs, such as **Amsterdam**, **Madrid**, and **Stockholm**, contribute to the regional diversity of AI applications, reflecting a steady integration of AI into the broader European technological framework.

Taken together, these trends indicate a global movement toward the industrialisation of AI. While different regions exhibit distinct trajectories—some focused on early-stage commercialisation and others on broad-scale patent accumulation—the evidence points to a closer connection between research output and proprietary applications. As various hubs continue to refine their innovation ecosystems, the global distribution of AI-related patenting activity continues to diversify.



# CHAPTER THREE

## Hong Kong: Past and Present



# Hong Kong in the Global Arena

As the world navigates an era of unprecedented technological advancement and geopolitical realignment, certain cities have emerged as pivotal engines of global innovation. Hong Kong stands prominently among these, not merely as a regional financial centre, but as a highly competitive global talent hub and future-positioning city whose evolution is actively reshaping the landscape of talent and fostering vigorous innovation in cutting-edge research fields. Its strategic position as a world-leading hub of global connectivity—a critical gateway for the seamless international movement of people, goods, and information—has been instrumental in this transformation, allowing it to leverage global networks to drive local growth and contribute to global progress.

Hong Kong's outstanding performance in both basic scientific research and technological translation serves as a microcosm of China's swift emergence as a global leader in science and technology. Its universities and research institutions consistently produce high-impact publications and attract top-tier researchers, reflecting a robust and internationalized innovation environment. These features reinforce Hong Kong's indispensable role as a hub linking global knowledge, capital, and talent flows, acting as a bridge between the vast resources of the Chinese Mainland and the global innovation community.

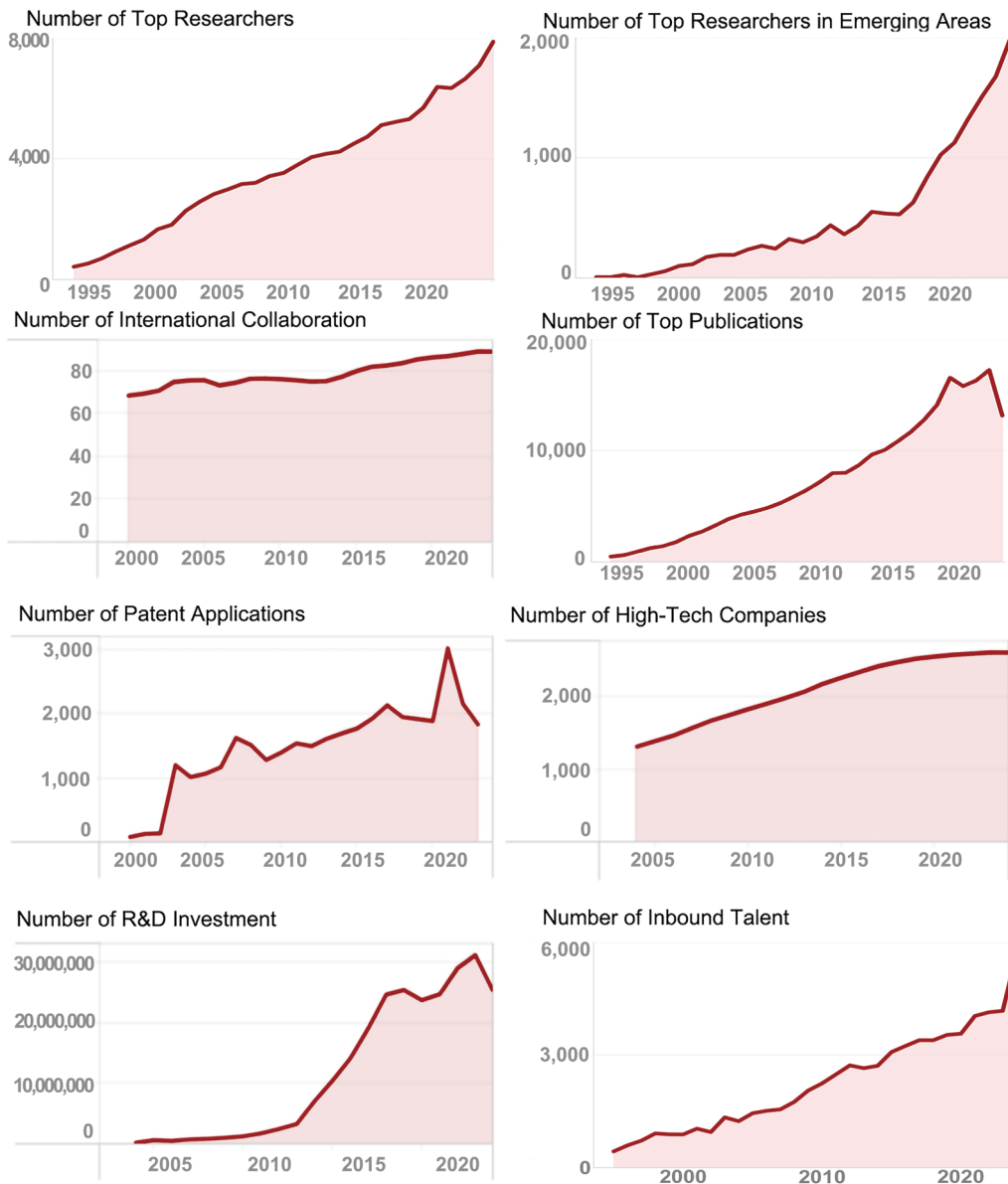
The true measure of Hong Kong's global standing, however, lies in its resilience. The city has emerged as a global leader in this regard, underscoring its exceptional capacity to adapt and thrive amid profound global challenges, from economic volatility to the unprecedented disruptions of the COVID-19 pandemic. Hong Kong has not merely weathered the storm but has demonstrated remarkable adaptability in navigating uncertainties and maintaining its role as a global innovation hub. Despite significant disruptions to physical mobility during this period, the city sustained international research partnerships and maintained research momentum. This hyper-acceleration indicates a successful transition from “resisting” the pandemic to “leading” the new innovation cycle, particularly in frontier areas like AI.

Several key indicators underscore this progress. During 2015-2024, the number of top researchers in emerging fields such as biotech and fintech increased by an impressive 269%, while the number of inbound talent expanded substantially by 133%. Research output and quality remained strong, with top publications increasing by 31% and international collaboration rising by 15%, suggesting that the growing research community successfully sustained productivity through hybrid work arrangements and digital collaboration. The number of high-tech companies also increased by 20%, indicating continued development of the city's research and innovation ecosystem. These trends collectively demonstrate that through continued investment in talent and international collaboration, Hong Kong maintained and even strengthened its innovation capacity during a period of global disruption.

Crucially, the data also highlights a significant global shift: the “**Talent Gravity**” is moving Eastward. Top-tier Asian cities—led by Shanghai, Beijing, and Hong Kong—are demonstrating explosive post-pandemic momentum, challenging traditional Western centres of innovation. Hong Kong, alongside cities like Singapore, has proven to be a highly resilient talent anchor. Despite severe pandemic-era mobility disruptions, it rapidly accelerated its talent acquisition, successfully converting crisis management into a competitive advantage for future innovation.

### 3.1 Trend Over Two Decades

Historical analysis confirms that Hong Kong has developed pronounced and enduring strengths in several vital areas over the past 30 years.



*Note: Authors ranked in the top 10% by total citations of their published articles are identified as top researchers for that year. Articles containing keywords related to emerging areas—including AI, fintech, biotech, and semiconductors—are classified as field-related articles. Top researchers in emerging fields refer to authors who have published articles in these related categories. International collaboration measures each city's centrality in global research collaboration networks by assigning scores based on both the quality and quantity of collaborative ties. Top publications are identified by year, with the top 10% of most-cited articles in each year classified as top publications. The number of patents refers to patents filed in each city. High-tech companies capture the number of high-technology companies headquartered in each city. Total R&D investment is calculated as the aggregate R&D expenditure of large enterprises in each city, measured in thousands of US dollars. Inbound talent measures the number of cross-border inflows of research talent.*

## Hong Kong's Competitive Edge

Longitudinal data from the past two decades confirm Hong Kong's successful transformation into a dynamic knowledge economy. The city has demonstrated remarkable growth in attracting top talent, producing high-impact research, and fostering a burgeoning high-tech ecosystem, solidifying its critical position for global innovation.

- **Number of Top Researchers** in both general sectors and emerging areas grew over the last two decades. The number of researchers in emerging area increased significantly after 2016.
- **International Collaboration** remained around 80 to 90 during the twenty years, indicating Hong Kong's robust and continued international research networks.
- **Number of Top Publications** was minimal in 1995 and began to increase steadily to a peak in 2022 before declining, reflecting a rise in both the quality and quantity of research output.
- **Number of High-Tech Companies** saw stable but slight growth. This trend is indicative of Hong Kong's development toward a more technology-oriented economy.
- **Number of Inbound Talent** maintained a steady growth rate from 1995 to 2020. However, after 2021, the growth rate doubled, which indicates the emergence of a highly dynamic and globally interconnected research community focused on knowledge exchange and cross-border collaboration.

## Substantial Fluctuations and Challenges

While Hong Kong has demonstrated remarkable success in talent acquisition and academic output, its innovation ecosystem reveals areas of volatility that require strategic attention. Key metrics for commercial transfer and sustained funding show significant fluctuations, indicating the ongoing challenge of turning research excellence into stable, market-driven innovation.

- From 2003, **the Number of Patents** gradually increased from a low starting point of 1,218 to 3,049 in 2021, before declining to 1,855. As a direct measure of innovation output, the fluctuations mirror the unstable trend in the commercial application of research.
- The amount of **R&D investment** also showed significant increase from 2013 to 2018, followed by a sharp decline in 2019 and 2023. Although the total number increased compared with that in 2005, potential challenges still exist in future funding support.

Collectively, these positive trends confirm Hong Kong's rise as a centre for knowledge generation, talent gathering, and research breakthroughs—key pillars of regional competitiveness. Though each metric follows its own path, the collective picture reveals a region that has strengthened its position through sustained investment in people, innovation infrastructure, and strategic partnerships.

## 3.2 Hong Kong Then and Now

Over recent years, Hong Kong has exemplified resilience and adaptability in its evolution as a global hub of innovation. Notwithstanding a period of significant challenges—including the COVID-19 pandemic—the city has registered substantial progress across multiple facets of its innovation ecosystem. This chapter presents a longitudinal analysis of Hong Kong’s performance from from 2015 to 2024, outlining its core competencies, persistent challenges, and prospective trajectory for continued development.

### From 2015 to 2024

<b>Top Researchers</b>	<b>Top Researchers In Emerging Areas</b>	<b>International Collaboration</b>	<b>Top Publications</b>
<b>+67%</b>	<b>+269%</b>	<b>+15%</b>	<b>+31%</b>
4,740 → 7,896	536 → 1,978	77.8 → 89.8	10,069 → 13,154
<b>High-Tech Companies</b>	<b>R&amp;D Investment</b>	<b>Inbound Talent</b>	<b>Patent Applications</b>
<b>+20%</b>	<b>+254%</b>	<b>+133%</b>	<b>+14%</b>
2,202 → 2,635	7.2B → 25.5B	3,237 → 7,528	1,632 → 1,855

*Note: High-tech companies are estimated based on medium and large enterprises operating within the technology sector. R&D investment is measured in US dollars.*

### Extraordinary Research Progress during the Past Decade

The data paints a picture of a dynamic and rapidly evolving research and innovation ecosystem in Hong Kong. There is exceptionally strong growth in the core research talent pool and research output.

- A 67% increase in the overall pool of **Top Researchers**—from 4,740 to 7,896—signals significant achievements in drawing and retaining elite academic minds. This trend is more pronounced in emerging areas, where researcher numbers skyrocketed by over 269% (536 to 1,978).
- **Number of Inbound Talent** figures (3,237 to 7,528) reveal a more active and globally connected research community. This 133% surge in “brain gain” reflects the city’s growing appeal as a dynamic, international, and competitive environment for scientific work.
- **Top publications rose 31% (10,069 to 13,154)**, indicating that Hong Kong’s research output is not only growing but also achieving recognition in leading international journals. This points to a research community producing work of both quantity and quality.

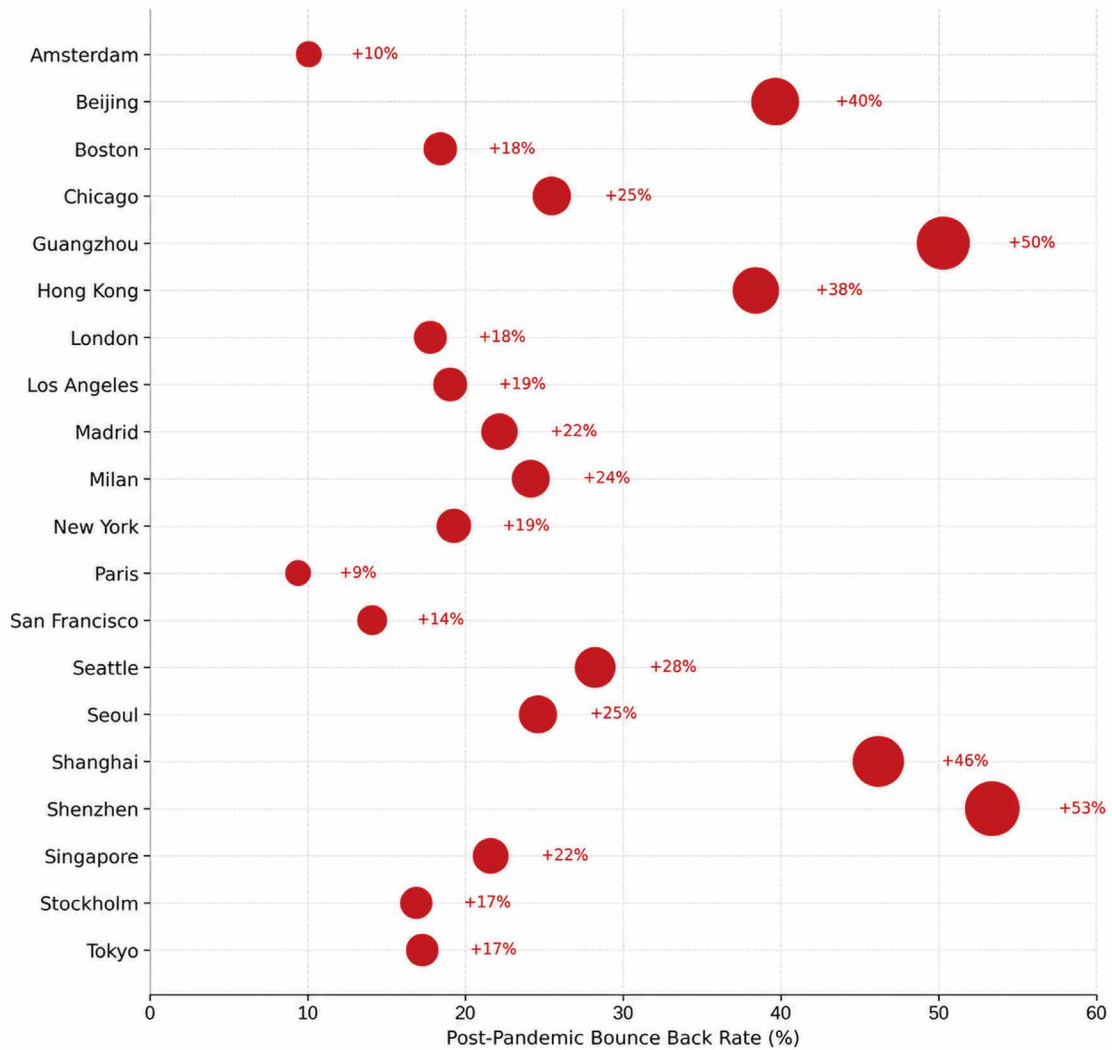
## Growing Innovation Atmosphere in Hong Kong

- **R&D investment** (7.2B to 25.5B) at **254%** growth is the fuel for the entire innovation engine, enabling progress seen in top researchers, facilities, and publications.
- A solid increase of **20%** in **the Number of High-tech Companies** (2,202 to 2,635) shows growth in the vibrant start-up ecosystem, fostering a culture of entrepreneurship, and contributes directly to economic diversification.
- A **15%** increase in **collaboration** (77.8 to 89.8) indicates that the level of the international network of Hong Kong has become stronger. The city is well-connected with other global regions and has more possibilities to attract top-tier talent.
- The **14%** progress in **the Number of Patents** (1,632 to 1,855) suggests the commercialisation of research outcomes in Hong Kong has been well developed with sufficient incentives.

## Pandemic Recovery

The pandemic served as a systemic stress test for global research hubs, exposing significant differences in their structural resilience. Beyond short-term operational disruptions, the crisis challenged the capacity of urban ecosystems to retain emerging talent, restore developmental momentum, and sustain competitive positioning in the frontier research landscape. This section benchmarks the post-pandemic recovery trajectories of the 20 cities, focusing specifically on the rebound of emerging research talent.

### Rate of Pandemic Recovery

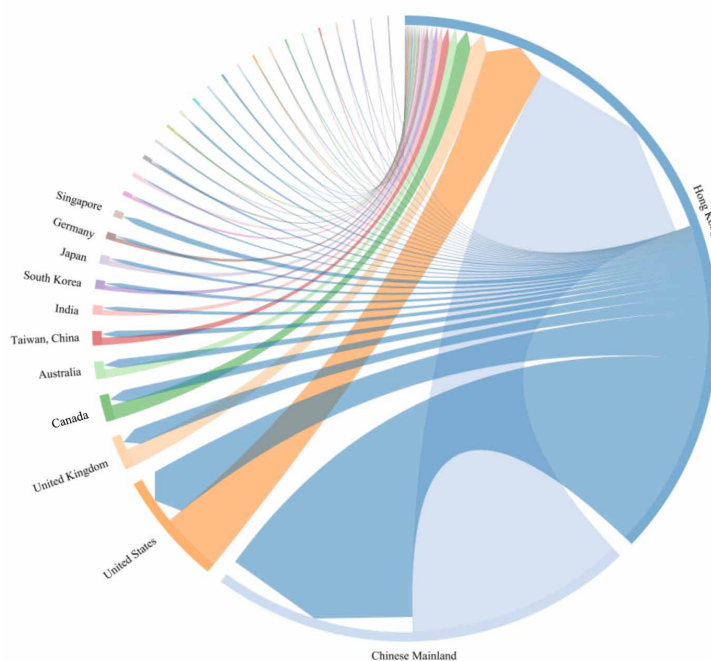


Note: The rate of pandemic recovery is measured as the post-pandemic bounce-back rate, calculated as  $[(\text{Post-Pandemic Average} / \text{Pandemic Period Average}) - 1] \times 100\%$ . Higher values indicate a more robust recovery and greater talent resilience.

- Mainland Chinese cities exhibit highly robust recovery momentum. **Shenzhen** leads the cohort with a post-pandemic bounce-back rate of +53%, followed closely by **Guangzhou** (+50%), **Shanghai** (+46%), and **Beijing** (+40%). The strong performance across these hubs indicates effective navigation of macro-level disruptions, supported by swift interventions to repair talent pipelines, robust policy support, and a rapid restoration of local research activity.
- **Hong Kong** demonstrates strong institutional resilience, recording a solid rebound rate of +38%. This reflects the city's enduring fundamentals as a deeply connected international research centre, buoyed by established academic linkages, strategic funding deployments, and a sustained capacity to attract high-potential scientific talent.
- Other key global hubs showcase steady and progressive talent revitalization. Cities such as **Seattle** (+28%), **Seoul** (+25%), and **Chicago** (+25%) exhibit solid upward trajectories. Concurrently, major centres including **Milan** (+24%), **Singapore** (+22%), **Madrid** (+22%), **New York** (+19%), **Los Angeles** (+19%), and **Boston** (+18%) maintain a consistent pace of recovery. This measured revitalization is likely underpinned by targeted regional innovation initiatives, proactive talent attraction programs, and the inherent stability of their mature research infrastructures.

## 3.3 Talent Mobility in Hong Kong

### Talent flow in Hong Kong – An overview



### Talent inflow in Hong Kong, China (2020-2024)

Top 10 Inflow Regions	Inflow Number	% of talent inflow in Hong Kong
Chinese Mainland	15,019	58.8%
United States	3,465	13.6%
United Kingdom	952	3.7%
Canada	765	3.0%
Australia	465	1.8%
Taiwan, China	367	1.4%
Singapore	300	1.2%
Japan	270	1.1%
India	266	1.0%
Germany	249	1.0%
Others	3,409	13.4%
<b>Total</b>	<b>25,527</b>	<b>100 %</b>

Note... All talent flow statistics are calculated based on researcher mobility flows over 2020-2024.

## Hong Kong, China as a key talent hub with major flows to and from Chinese Mainland, the United States, and the United Kingdom.

Over the last five years, Hong Kong, China has attracted significant talent from around the world. Chinese Mainland leads as the top source, contributing 15,019 professionals—58.8% of total inflow. The United States follows with 3,465 (13.6%), highlighting both deep cross-border ties and Hong Kong's appeal to the United States-based talent.

Other regions also play meaningful roles. The United Kingdom, Canada, Australia each contribute between 3.7%, 3.0%, and 1.8% respectively. This diverse geographic mix reflects Hong Kong's ability to draw professionals globally, strengthening its innovation capacity, fostering international collaboration, and cementing its position as an Asia-Pacific talent hub.

### Talent Outflow of Hong Kong, China (2020-2024)

Top 10 Outflow Regions	Outflow Number	% of talent outflow in Hong Kong
Chinese Mainland	13,361	59.1%
United States	2,799	12.4%
United Kingdom	905	4.0%
Canada	691	3.1%
Australia	474	2.1%
Taiwan, China	354	1.6%
Singapore	329	1.5%
South Korea	239	1.1%
India	222	1.0%
Japan	212	0.9%
Others	3,035	13.4%
<b>Total</b>	<b>22,621</b>	<b>100 %</b>

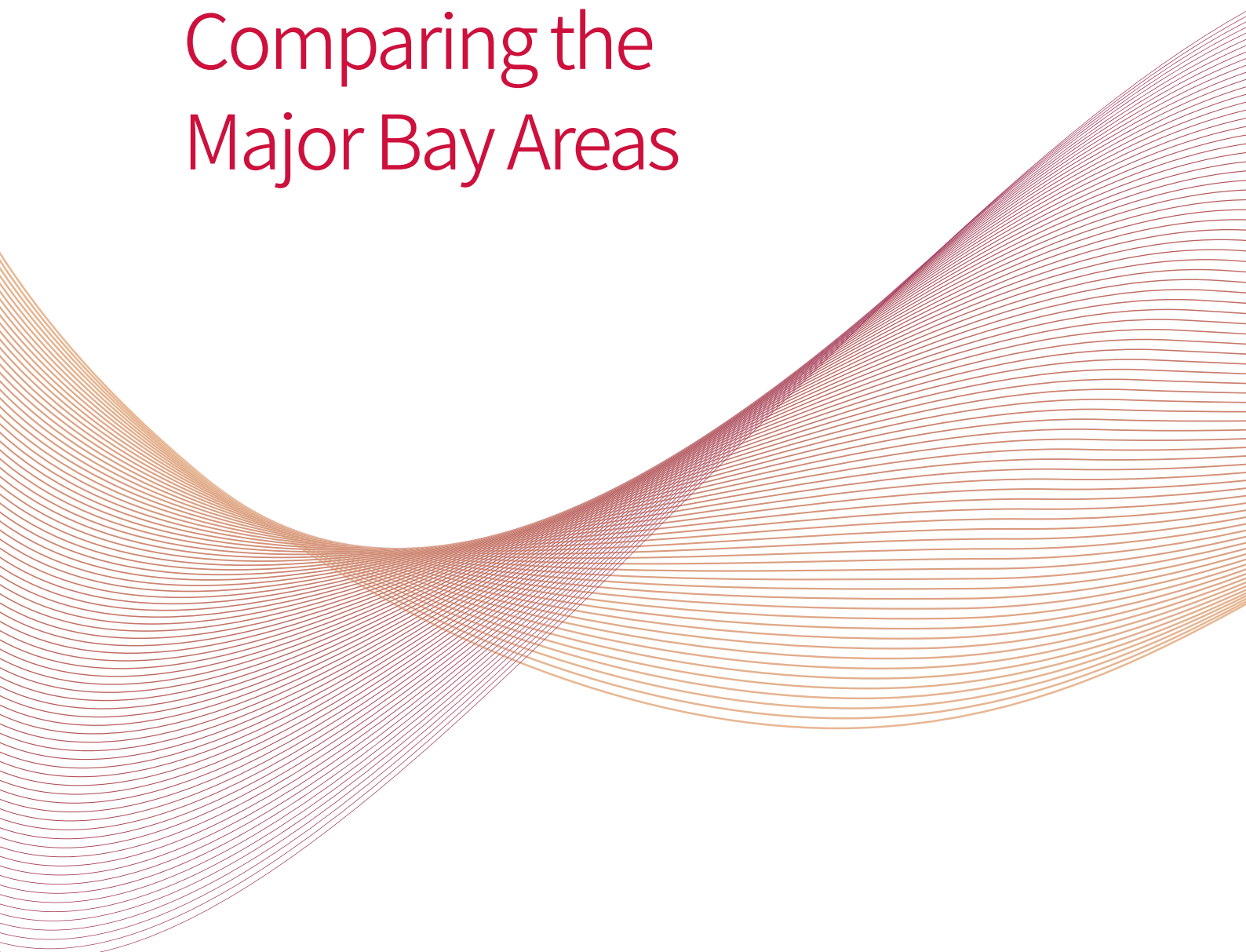
While Hong Kong successfully attracts talent from around the world, its patterns of talent outflow offer equally important insights. Chinese Mainland is the top destination for departing professionals, receiving 13,361 individuals (59.1% of total outflow). The United States follows with 2,799 (12.4%). This close mirroring of inflow sources highlights strong bilateral mobility with the Chinese Mainland and the United States' continued pull on Hong Kong talent.

Outflow also reaches the United Kingdom, Canada, Australia—each accounting for 2.1% to 4.0%. Such geographic spread reflects the global ambitions of Hong Kong's workforce and the city's deep integration into international talent networks.

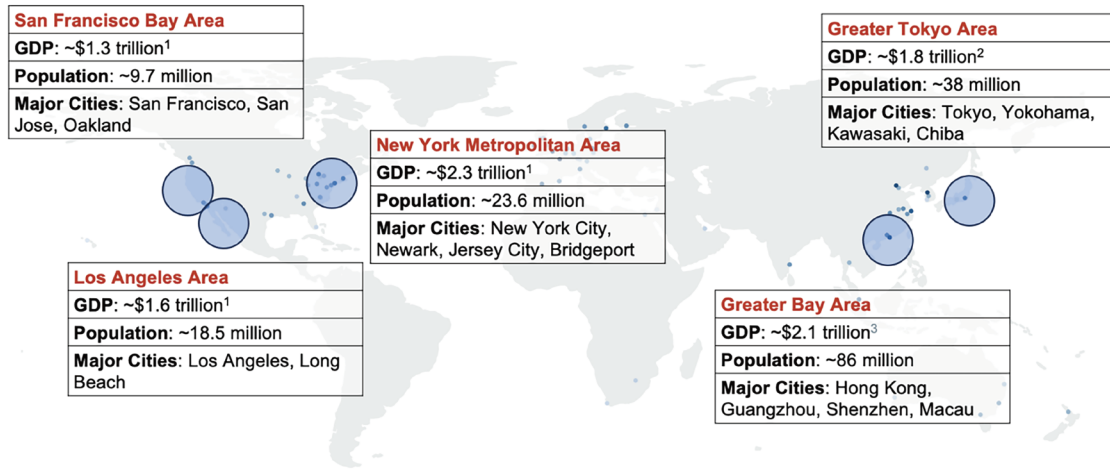


# CHAPTER FOUR

## Comparing the Major Bay Areas



## 4.1 Comparing Major Bay Areas: A Global Analysis



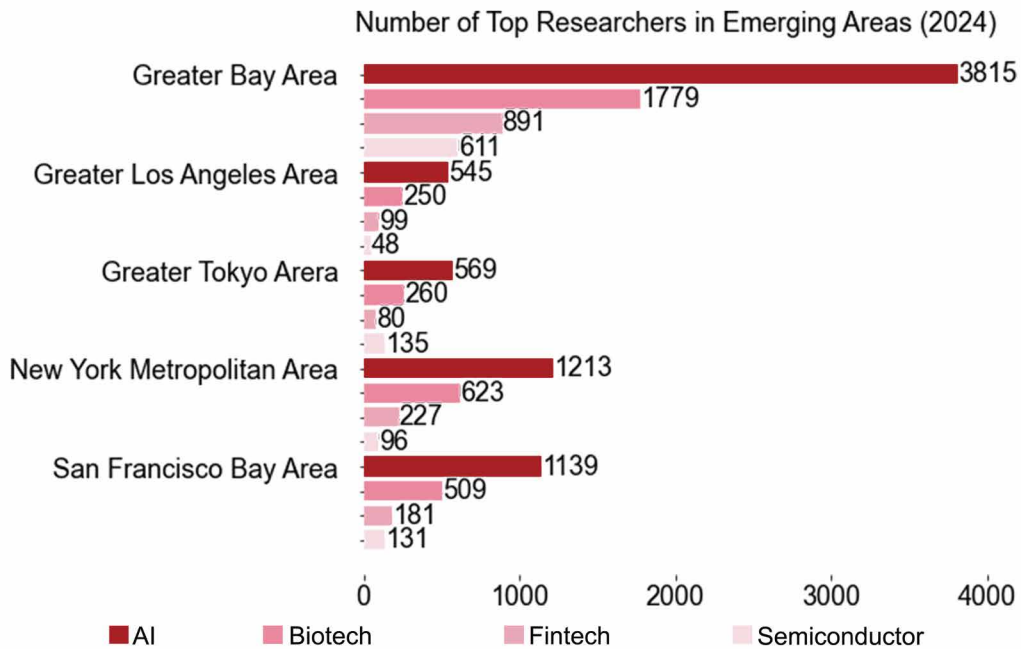
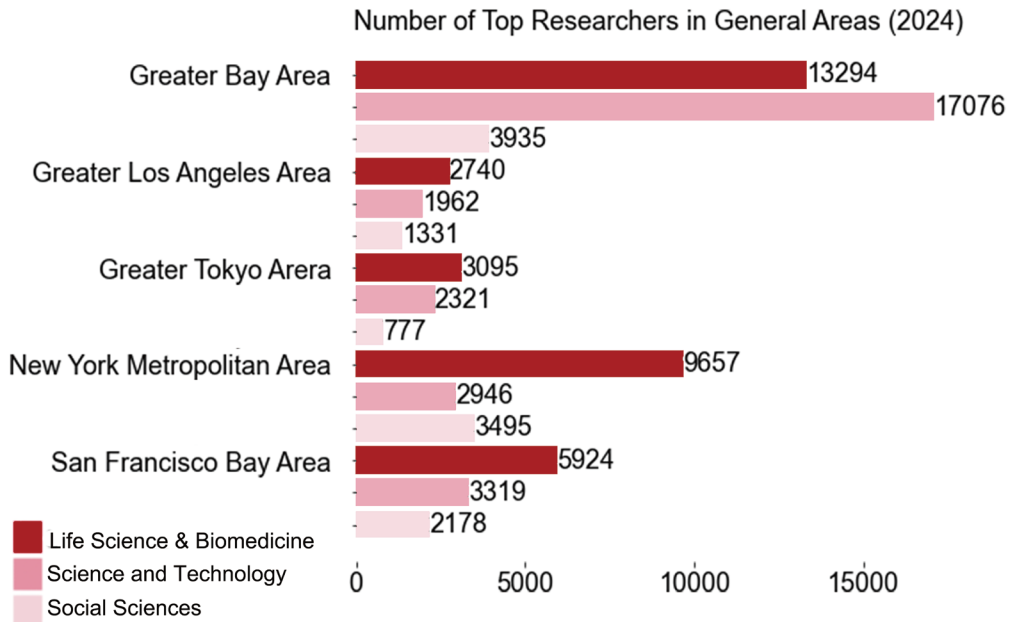
*Note: Unless otherwise stated, data refer to 2022–2024 or the latest available period. GDP figures are denominated in US dollars at current market prices, converted using annual average exchange rates. Sources include government statistical departments in the relevant jurisdictions and HKTDC.*

In the global economic landscape, major bay areas (including the **Greater Bay Area**, the **Greater Tokyo Area**, the **New York City Metropolitan Area**, the **San Francisco Bay Area**, and the **Greater Los Angeles Area**), with their distinctive geographic and economic advantages, have become key drivers of innovation and development.

As iconic urban clusters that have shaped and continue to drive global economic and innovation trajectories, major world bay areas—including the **San Francisco Bay Area**, **New York Metropolitan Area**, **Greater Tokyo Area**, **Greater Los Angeles Area**, and the **Greater Bay Area**—are far more than geographic agglomerations of cities. These clusters boast urban development, industrial evolution and institutional innovation that have cultivated their unique competitive edges, positioning them as global pioneers in charting future-oriented development pathways across technology, finance, advanced manufacturing and scientific research. As such, a systematic comparative analysis between the GBA and these pivotal bay areas offers invaluable insights into the core drivers of urban cluster competitiveness in the global arena. Building on a foundational overview of core economic and demographic metrics, this chapter will zoom in to a targeted comparison of these major bay areas through a series of critical, globally comparable indicators spanning top researchers, international collaboration, publications and impact, innovation enterprise, patents, and talent mobility. First, these indicators cover key dimensions of global competitiveness and reflect the comprehensive strength of world-class bay areas, ensuring holistic and robust analysis. Second, they are globally recognized and comparable, supporting objective, data-driven, and academically rigorous cross-regional assessment. Third, they directly measure the core drivers of bay-area economies—talent, innovation, and industrialization.

## Top Researchers

The distribution of top researchers offers an important window into the knowledge foundations of major bay areas. Research talent not only reflects the strength of universities and laboratories, but also indicates whether a regional economy can sustain long-term scientific output, technological adaptation, and innovation-led industrial development.



Note: There is overlap between the number of top researchers in emerging areas and general areas.

**The GBA is the Largest Global Hub of Top Researchers.**

- The GBA has emerged as the world’s most significant hub for top researchers. This figure places it well ahead of every other major innovation cluster globally, including the New York Metropolitan Area and the San Francisco Bay Area. Regions such as the Greater Tokyo Area and the Greater Los Angeles Area continue to host vibrant research communities but remain much smaller in scale. The data clearly shows that the GBA is no longer just an emerging force. It is now the global leader in research talent concentration.

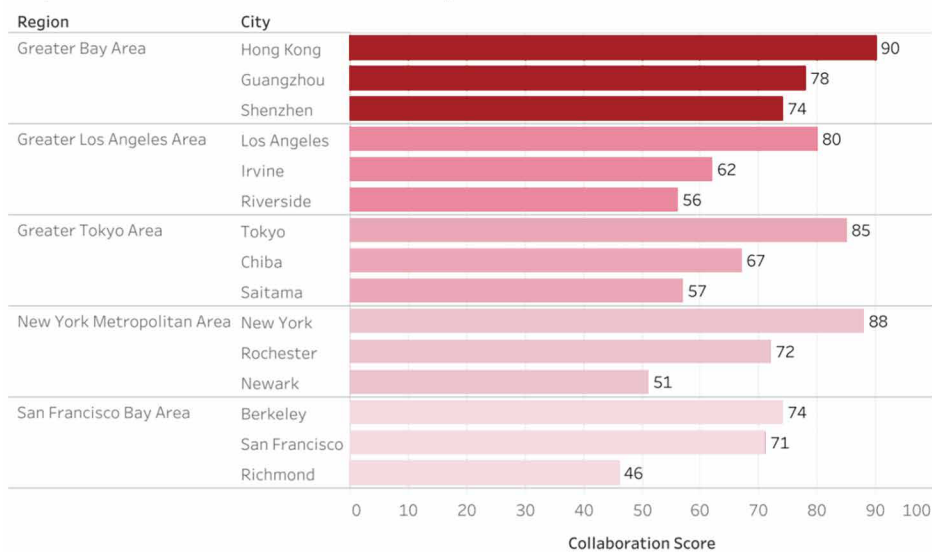
**Emerging Fields Reveal China’s Strategic Edge.**

- When considering emerging areas such as **AI, Fintech, Biotech, and Semiconductor**, the GBA again takes a commanding position, highlighting its dominance in the most transformative technologies of the decade. Fintech also shows a strong presence in both GBA and the New York Metropolitan Area. These trends show that China’s innovation hub is not only keeping pace but setting the tone for the future in several cutting-edge domains.

## International Collaboration

International collaboration provides insight into how deeply a bay area is connected to global knowledge networks. Strong collaboration patterns often reflect international visibility, openness to research exchange, and the presence of institutions able to operate effectively across borders. Among the selected top three GBA cities, international collaboration is relatively balanced, with Hong Kong leading, followed by Guangzhou and Shenzhen.

**Top 3 Collaboration Cities in Five Bay Areas**



*Note: The international collaboration score of cities is calculated based on the quality and quantity of academic paper collaborations between cities.*

## Key Takeaways

### GBA: Balanced and Globally Engaged

- The GBA (Hong Kong-Guangzhou-Shenzhen) demonstrates the most balanced international profile among the five regions. Hong Kong leads with a high score, followed by Guangzhou and Shenzhen. The narrow 16-point range suggests that international collaboration is not solely concentrated in one city, but rather distributed across multiple globally connected urban centres. This reflects the region's multi-nodal structure, where international ties are cultivated broadly rather than bottlenecked through a single gateway.

### San Francisco Bay Area: Dual Global Cores

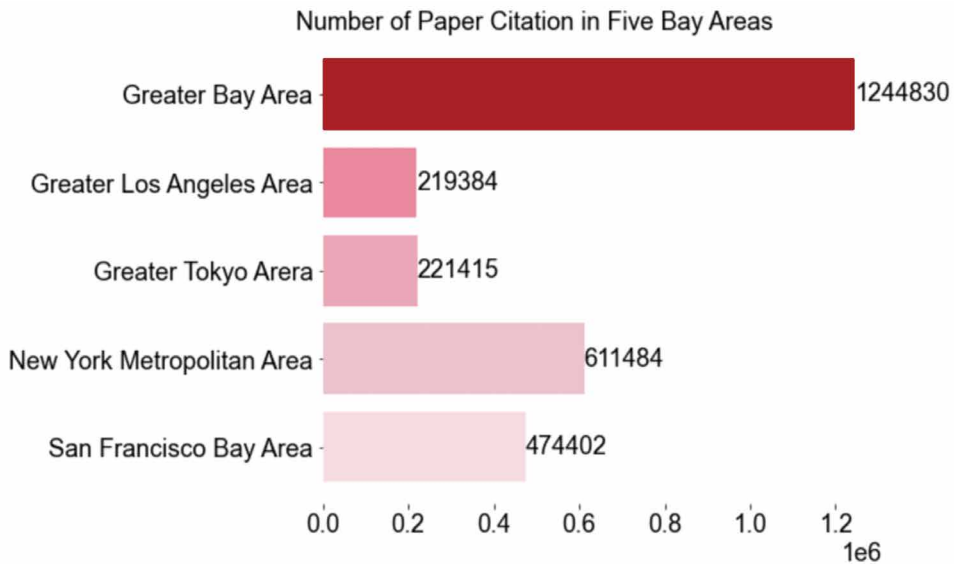
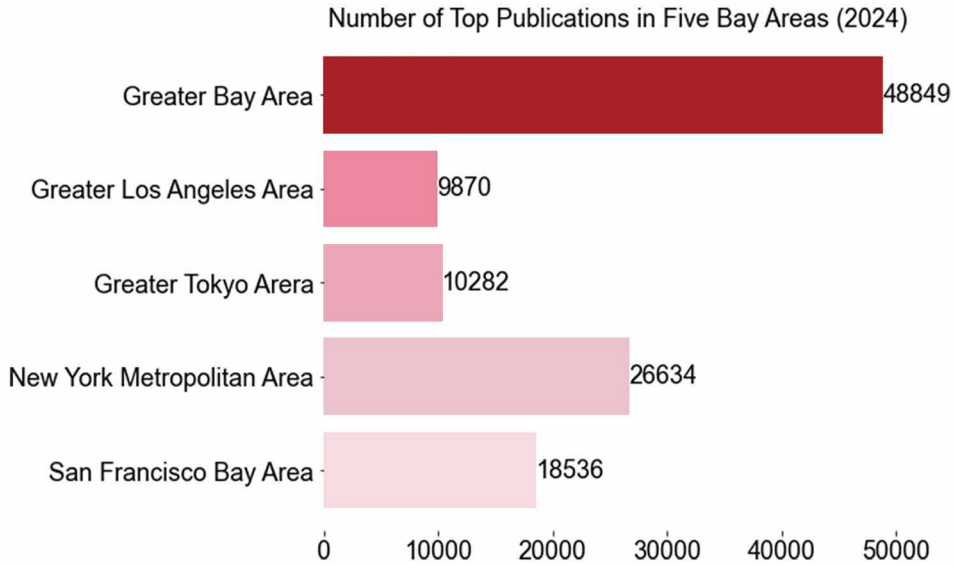
- The San Francisco Bay Area presents a unique “dual-core” configuration in international collaboration. Berkeley and San Francisco perform nearly equally, suggesting shared global engagement at the top. However, the sharp drop to Richmond reveals a lack of broader regional diffusion. This indicates that while top-tier institutions and international networks are strong in a few cities, the overall reach of international collaboration is not yet deeply rooted throughout the region.

### Greater Tokyo Area, New York Metropolitan Area, and Greater Los Angeles Area

- In the Greater Los Angeles Area, Los Angeles scores 80, while Irvine and Riverside lag behind. These secondary cities are developing stronger global ties, but they have not yet reached the level of international visibility needed to fully support the region's global presence.
- The Greater Tokyo Area and the New York Metropolitan Area are both anchored by a single city with dominant international collaboration scores—Tokyo at 85 and New York City at 88. However, the second and third cities in each region fall well behind. Chiba and Saitama in Tokyo, and Rochester and Newark in New York, illustrate the sharp contrast.

## Publications and Impact

Publications and citations help capture both the volume and influence of research produced within a bay area. Together, they indicate not only how much knowledge a region generates, but also whether that knowledge reaches and shapes wider scientific communities. The GBA leads by a wide margin in both metrics, showing strong global research influence.



### GBA Records the Highest Volume of Top Publications.

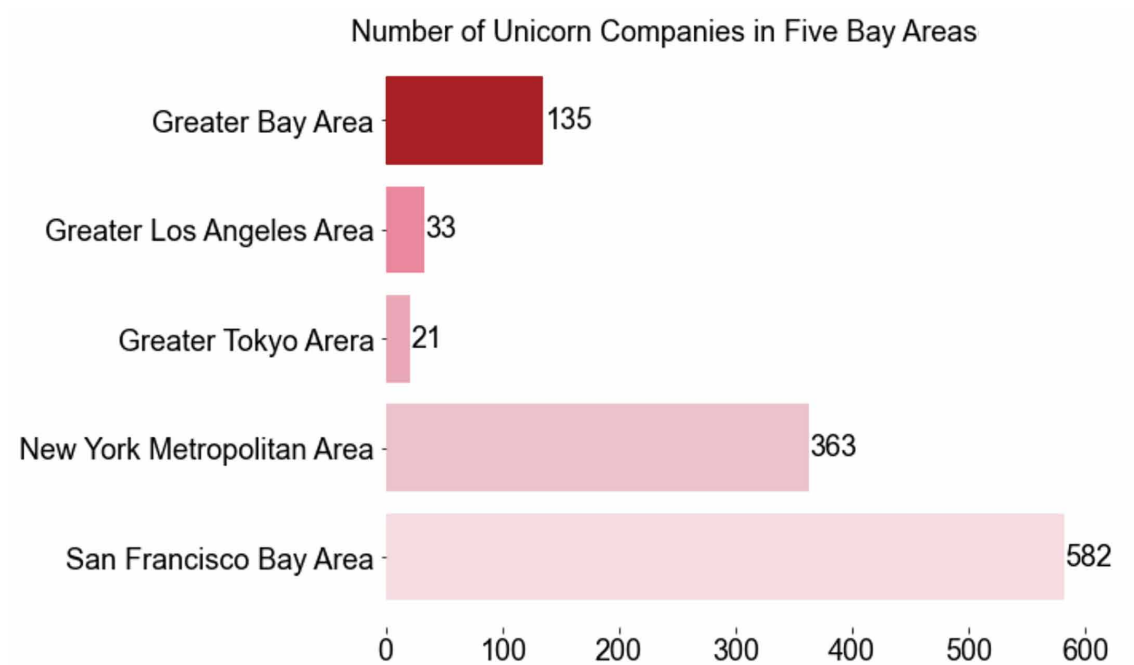
- The GBA led all five major bay areas with 48,849 top publications, nearly two times that of the New York Metropolitan Area, which ranked second. The San Francisco Bay Area, Greater Los Angeles Area, and Greater Tokyo Area trailed further behind. This suggests that the GBA has developed a substantial research capacity, reflecting both the scale of its research community and its growing momentum in knowledge production.

### Citation Volume Confirms Global Research Influence.

- The GBA also led in paper citations, followed by the New York Metropolitan Area and the San Francisco Bay Area. The data overall reflects the expanding global reach of research produced in the GBA.

## Innovation Enterprise

The presence of high-growth firms provides a different perspective on bay-area competitiveness. While universities and research institutes are central to knowledge creation, innovation enterprises indicate whether a region can also convert knowledge into entrepreneurial activity, market value, and industrial renewal. GBA ranks 3rd globally, strong in fintech/ advanced manufacturing with room to narrow gaps with leaders.



**The GBA has built a sizeable innovation enterprise base.**

- In 2024, the GBA recorded 135 unicorn companies, indicating a strong capacity to generate high-growth technology firms. This suggests that the region has moved beyond a narrow focus on manufacturing and is increasingly supporting entrepreneurial activity in sectors linked to digital transformation and advanced technology.

**The region’s enterprise profile reflects sectoral diversification.**

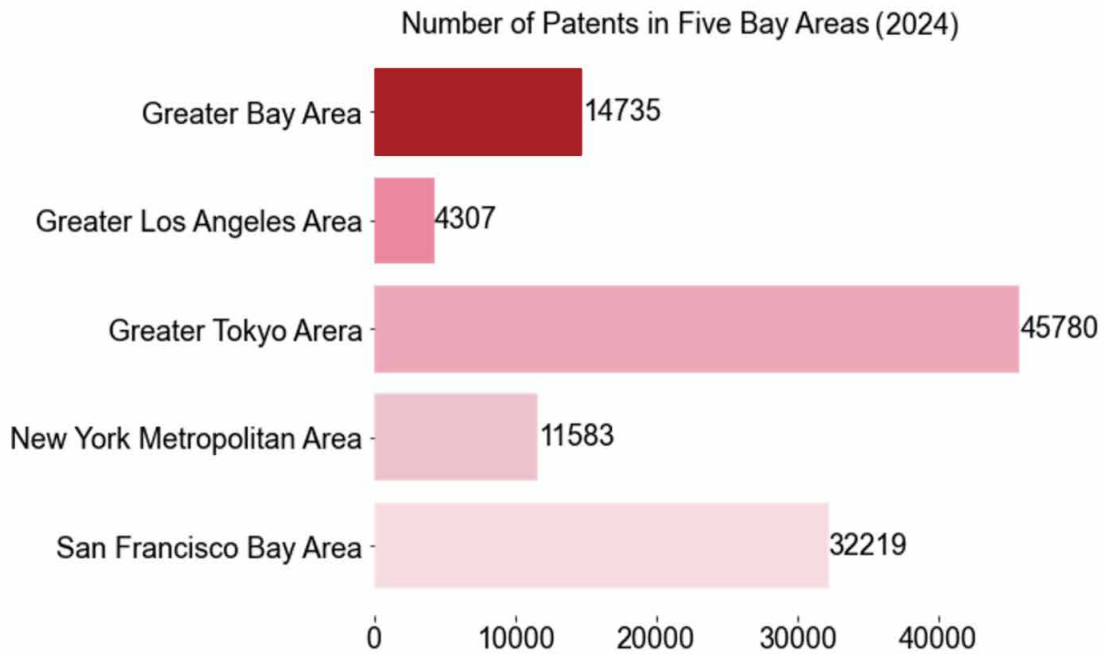
- The GBA’s strengths in areas such as fintech, advanced manufacturing, and the digital economy indicate a mixed innovation model in which industrial production, applied technology, and platform-oriented business growth reinforce one another. This diversified structure may provide greater long-term stability than growth concentrated in only one or two sectors.

**There is still room to strengthen the commercialisation environment.**

- Compared with the most mature global innovation clusters, the GBA still has scope to deepen the conditions that support scaling, capital formation, startup talent development, and cross-city resource integration. The current pattern points to strong momentum, but also suggests that institutional coordination and ecosystem development will continue to shape how far entrepreneurial capacity can expand in the future.

## Patents

Patents provide an important indicator of how effectively research and technical knowledge are being translated into applied technologies and commercializable outputs. They therefore offer a useful perspective on the industrial side of bay-area innovation. GBA ranks 3rd globally, with a solid foundation and growth potential.



Data Source: USPTO

**Patent activity remains concentrated in a few mature innovation regions.**

- Across the five bay areas, patent volumes vary substantially. The **Greater Tokyo Area** records particularly strong patent activity, reflecting its dense ecosystem of major technology firms, applied R&D capacity, and well-developed commercialisation pathways. The **San Francisco Bay Area** also shows a very substantial patent base, consistent with its long-established strengths in industrial technology and engineering.

**The GBA has established a solid platform for commercialisation.**

- With 14,735 patents, the GBA shows a significant level of technology application and commercialisation activity. This suggests that the region's research and industrial systems are increasingly connected, especially in fields related to information technology and advanced manufacturing. While the GBA does not yet match the most mature patent-intensive ecosystems in full scale, its current patent portfolio points to a strong base on which further commercialisation capacity can be built.

**The next stage depends on stronger conversion mechanisms.**

- Patent counts alone do not guarantee industrial impact. Their long-term significance depends on whether regions can support licensing, scaling, startup formation, and industry-academia collaboration. In the GBA, the current patent profile suggests meaningful progress, while also highlighting the importance of improving the channels through which research outcomes move into markets and production systems.

The broader comparison indicates that commercialisation remains a distinguishing feature of major bay areas. Regions that perform well are typically those able to connect strong research capacity with firm-level innovation and industrial application.

## 4.2 Talent Mobility in the GBA

Cross-border talent mobility offers a closer look at how the GBA functions as a regional system. While total talent stock reflects accumulated capacity, movement into and across borders helps reveal where opportunity is expanding, where institutions are attracting attention, and how balanced regional development remains.

### Profile of Inbound Talent in GBA (2020-2024)

City	Total Inflow	Gender		General Areas			Emerging Areas			
		Male	Female	Life Science & Biomedicine	Science & Technology	Social Science	Fintech	AI	Biotech	Semiconductor
Hong Kong	25527	0.62	0.38	9558	12095	3280	544	2025	1006	686
Guangzhou	15837	0.62	0.38	7205	7165	1142	283	1003	877	331
Shenzhen	5929	0.66	0.34	1714	3784	329	130	584	284	147
Macau	7994	0.62	0.38	1050	2026	846	66	358	212	1
Foshan	465	0.64	0.36	172	256	25	9	31	15	11
Dongguan	918	0.65	0.35	95	337	21	4	26	12	1
Zhuhai	155	0.67	0.33	42	103	10	10	17	9	1
Zhaoqing	114	0.64	0.36	30	56	25	1	6	7	1
Jiangmen	101	0.68	0.32	44	54	1	1	6	5	0
Huizhou	96	0.66	0.34	26	54	15	1	4	2	1
Zhongshan	180	0.64	0.36	49	7	3	0	0	0	0

### Number of Top Researchers in GBA Cities

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Guangzhou	7039	8255	9390	10682	13001	15370	16101	17459	18952	21908
Hong Kong	4740	5124	5230	5324	5703	6394	6354	6665	7107	7896
Shenzhen	905	1118	1455	1824	2514	3253	3773	4209	4689	5528
Macau	430	494	570	686	750	876	998	1110	1366	1632
Dongguan	23	43	39	70	120	147	171	217	233	307
Foshan	16	27	43	63	93	133	182	230	303	387
Zhuhai	3	3	1	5	4	12	18	26	33	41
Zhongshan	4	6	5	5	6	13	13	11	16	17
Jiangmen	2	4	6	9	23	42	51	62	70	75
Huizhou	6	7	13	13	19	25	25	31	41	53
Zhaoqing	2	4	4	3	5	17	14	22	19	34

Note: Top researchers refer to the top 10% researchers in terms of total citations of their published articles by sorting all the articles published each year.

### The GBA combines concentration with internal differentiation.

- Within the GBA, Guangzhou records the largest concentration of top scholars, while Hong Kong shows especially strong performance in talent mobility. This distinction is important. It suggests that stock and flow do not necessarily align: some cities serve as large reservoirs of research talent, while others function more strongly as gateways for attracting and circulating talent across the region.

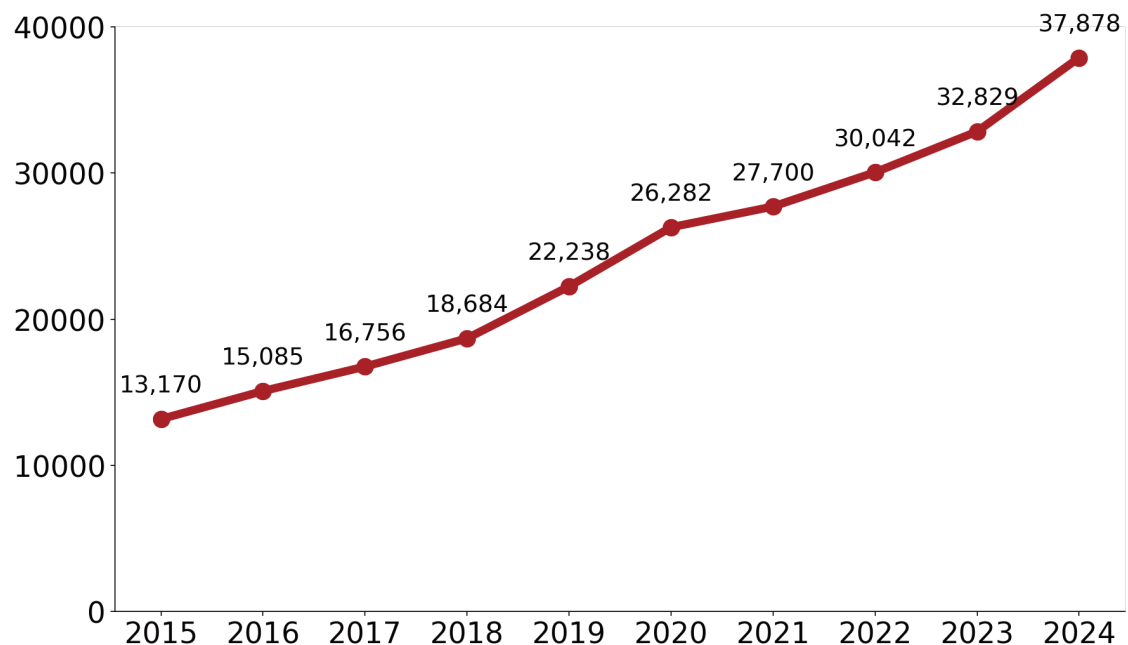
### Secondary cities are growing at different speeds.

- Cities such as Foshan, Dongguan, and Zhuhai have smaller total talent pools, but they are expanding relatively quickly. By contrast, Jiangmen, Huizhou, and Zhongshan continue to show more limited scholar counts. These differences suggest that the GBA's development remains uneven, with some cities moving into higher-value research and innovation roles faster than others.

### Regional integration remains a central challenge.

- The GBA's talent landscape points to a familiar pattern in large urban clusters: concentration in leading cities can drive overall competitiveness, but it may also widen internal disparities if surrounding cities do not develop complementary functions. The long-term strength of the region will therefore depend not only on whether major hubs continue to attract talent, but also on whether other cities can build distinctive niches and stronger pathways into the broader regional innovation system.

## Number of Top Researchers in GBA (2015-2024)

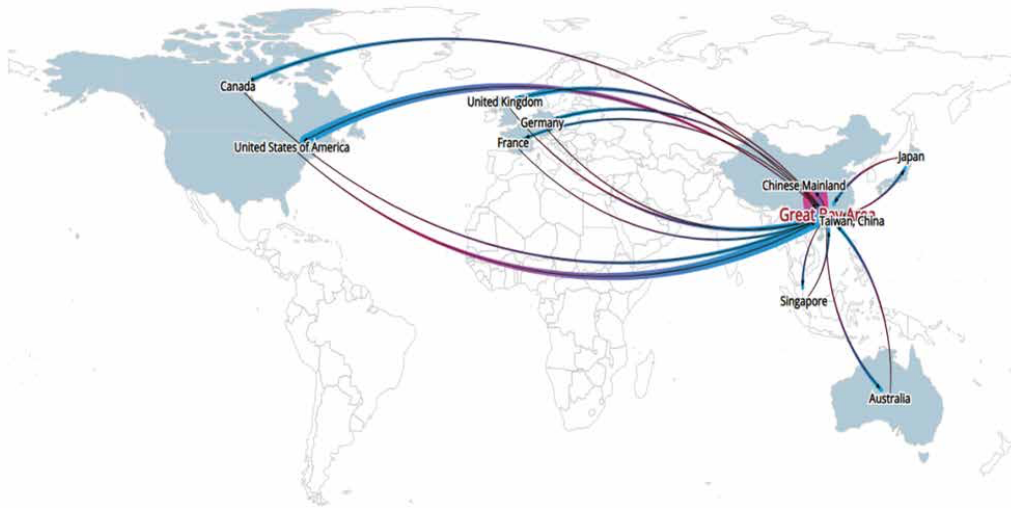


From 2015 to 2024, the GBA's top talent pool grew from 13,170 to 37,878. This sustained increase indicates a major expansion in the region's research base over the past decade. At the same time, talent remains concentrated in a relatively small number of cities, especially Guangzhou, Shenzhen, and Hong Kong. This concentration has helped the GBA gain scale quickly, but it also underscores the importance of developing stronger complementarities across the region if growth is to become more balanced and durable.

## Comparing GBA with San Francisco Bay Area

A comparison of talent flow patterns in the GBA and the San Francisco Bay Area highlights two different models of regional attractiveness and mobility.

### Talent Flow in the GBA (2020-2024)



### Talent Flow in the San Francisco Bay Area (2020-2024)



## Key Takeaways

### The GBA benefits from a strong regional talent base.

- The GBA's talent inflow pattern shows that its growth is closely connected to regional networks, especially within the Chinese Mainland and neighbouring parts of Asia. This suggests that the region's competitiveness is closely tied to its role as a major node within a broader regional system. At the same time, smaller inflows from Europe and the Americas add diversity to the talent base and strengthen the GBA's international profile.

### The San Francisco Bay Area relies heavily on domestic mobility.

- The San Francisco Bay Area's talent pattern reflects the strength of internal U.S. circulation. Its attractiveness is supported by a mature ecosystem in which talent moves fluidly among startups, large technology firms, venture capital networks, and research universities. This creates a highly dynamic regional environment, even when much of the movement remains domestic rather than international.

The contrast between the two regions is revealing. The GBA appears to depend more on regional integration across multiple cities and on its ability to connect domestic and Asia-Pacific talent networks. The San Francisco Bay Area, by contrast, reflects a highly mature innovation system built around deep internal circulation and strong industry-academia linkages. Both models can be highly competitive, but they rely on different institutional foundations and talent pipelines.

## 4.3 Talent Mobility in Chinese Economic Zones

The final section places the GBA in the wider context of China’s three major economic zones: the Guangdong-Hong Kong-Macao Greater Bay Area, the Yangtze River Delta, and the Bohai Rim. Comparing talent inflow, outflow, and net flow across these zones helps illustrate how different city systems are positioning themselves within the national innovation landscape.

### Cross-border Talent Mobility in Bohai Rim, Yangtze River Delta, and GBA



City	Inflow	Outflow	Inflow+OutFlow	NetFlow
Beijing	48429	38405	86834	10024
Shanghai	20745	13851	34596	6894
Guangzhou	15837	9249	25086	6588
Nanjing	13458	9324	22782	4134
Hangzhou	9535	5926	15461	3609
Hong kong	25527	22621	48148	2906
Hefei	6444	3619	10063	2825
Tianjin	6960	4454	11414	2506
Shenzhen	5929	3630	9559	2299
Shijiazhuang	1949	1105	3054	844

Note: . Talent flows are calculated between 2020 and 2024.

## Key Takeaways

### Core cities continue to dominate talent circulation.

- Between 2020 and 2024, cities such as Beijing, Shanghai, Guangzhou, and Nanjing recorded particularly large talent flows. This indicates that the national talent system remains strongly centred on a small number of major urban hubs, each of which plays a different role in attracting, circulating, and retaining highly skilled people.

### Net flow reveals different forms of regional attractiveness.

- While Hong Kong records the second-highest gross flow, its net flow ranks only sixth among the above cities. This distinction is important because total movement and net gain measure different aspects of a city's position. Large gross flows may reflect centrality and visibility, while net inflows may suggest growing attractiveness and stronger retention capacity.

### Hong Kong remains highly active in cross-boundary circulation.

- Hong Kong recorded particularly strong levels of both inflow and outflow, indicating its continued importance as a highly mobile node within the broader regional and national talent system. This pattern reflects its ongoing role as a connector city, where the movement of talent itself is an important feature of its competitiveness.

Taken together, these patterns show that talent mobility within China's major economic zones is not simply a matter of attracting more people. It also reflects changing relationships between scale, openness, regional integration, and long-term retention. The GBA's future development will depend in part on how well it can deepen these connections while strengthening complementarities among its own cities.



# **CHAPTER FIVE:** **Methodology**



# Theoretical Framework

Dimensions	Sub-Dimension	Indicator
1. Talent Hub	1. University Students	1T_Graduate_Students
	2. Advanced Talent	1T_Linkedin_PhD
	3. University Ranking	1T_QS_Average
	4. STEM Programms	1T_STEM_Programs
	5. Inbound Talent	1T_Researcher_Inbound
2. Knowledge Production	1-4. Top Researchers	2K_Top_Researchers_AllArea
		2K_Top_Researchers_LifeBioMedicine
		2K_Top_Researchers_SciTech
		2K_Top_Researchers_SocialSciences
	5. Top Publications	2K_Top_Publication
	6. Paper Citations	2K_Paper_Citations
	7. Research Insititutes	2K_Research_Institutes
3. Technological Innovation	1. HighTech Workers	3I_HighTech_Employees
	2. HighTech Companies	3I_HighTech_Companies
	4. Patent Impacts	3I_Non_Patent_Citations
		3I_Patent_Citations
	3. Patents	3I_Patents
	5. R&D Investment	3I_R&D_Investment
	6. Startups	3I_StartUpCompanies
7. Unicorns	3I_Unicorns	
4. Future Positioning	1-4. Frontier Research (AI, fintech, biotech, and semiconductors)	4F_AI_Top_Researcher
		4F_Biotech_Top_Researcher
		4F_Fintech_Top_Researcher
		4F_Semiconductor_Top_Researcher
	5. Interdisciplinary Integration	4F_Interdisciplinary
	6. Emerging Field Growth	4F_Growth_Rate
5. Global Connectivity	1. International Air Network	5C_Airline
		5C_Air_Cargo
	2. Graduate Mobility	5C_Graduate_Inbound_Value
	4. International Collaboration	5C_International_Collaboration
4. Digital Connection	5C_ICT_Weighted	
6. Urban Resilience	1. Gender Inclusiveness	6R_Female_Manager_Ratio
		6R_Female_Researcher_Ratio
	2. Economic Inclusiveness	6R_Diversity_ForeignCompanies
		6R_Number_ForeignCompanies
	3. Quality of Life	6R_Library
		6R_Museum
	4. Urban Safety	6R_Safety_Index
	5. Urban Mobility	6R_Urban_Mobility

## Scope and Data Source

The overall city ranking is derived from a comprehensive evaluation framework comprising six dimensions which include 39 total indicators. The six dimensions are Talent Hub, Knowledge Production, Technological Innovation, Future Positioning, Global Connectivity, and Urban Resilience. These six dimensions are further grouped under three broader pillars: Future Talent, Future Innovation, and Future Environment.

### Talent Hub

**Number of Graduate Students:** We used the number of students enrolled in the QS database as a proxy indicator. By counting the number of students enrolled in higher education institutions within each city, it was possible to extrapolate the number of graduates in that city. Source: QS World University Rankings. Data years: 2017–2024.

**Number of PhD Holders:** The number of users with PhD degrees located in each city was retrieved via LinkedIn Recruiter and standardised by assigning 100 points to the maximum value and 60 points to the minimum value for normalisation to infer the number of PhD holders in each respective city. Source: LinkedIn. Data years: 2024

**QS Average Ranking:** Calculates the average score of the top three universities in each city based on the QS World University Rankings. For cities with fewer than three universities listed in the global top 1,000, the sum of the scores of the listed universities was divided by three, assigning a score of zero to non-listed institutions. Source: QS World University Rankings. Data years: 2017–2024.

**Number of STEM Programs:** Based on the names of specific STEM majors offered by each institution in the QS data. The number of institutions offering STEM majors in each city was counted by city level to assess the reach and diversity of STEM education in that city. Source: QS World University Rankings. Data years: 2017–2024.

**Researcher Inbound:** Academic researcher mobility tracks changes in scholars' affiliated institutions based on their academic outputs over the course of their careers. For each scholar, we identify their affiliated institution in each year and map that institution to its corresponding country or region. When a scholar's affiliation changes between two consecutive periods, the change is recorded as a mobility event. Mobility may occur at the institutional, city, national, or regional level. In this report, we focus only on cross-border mobility. Source: Global Talent Flow Data Hub. Data years: 1994-2024.

## Knowledge Production

**Number of Top Researchers:** This indicator identifies the top 10% of researchers by citation impact in the designated year. All authors who published at least one article in that year are included in the candidate pool. For each author, their most recent three publications are retrieved and their citation counts are aggregated. Authors ranked in the top 10% by total citations are counted as top researchers for that year. Source: ORCID, OpenAlex. Data years: 1994-2024.

**Life and Biomedicine Top Researchers:** This indicator identifies the top 10% of researchers by citation impact in the field of life sciences and biomedicine. The field is defined based on OpenAlex article labels, including articles categorized under Biology, Medicine, and Environmental Science. Source: ORCID, OpenAlex. Data years: 1994-2024.

**Science and Technology Top Researchers:** This indicator identifies the top 10% of researchers by citation impact in the field of life sciences and biomedicine. The field is defined based on OpenAlex article labels, including articles categorized under Chemistry, Geology, Physics, Mathematics, Computer science, Materials science, and Engineering. Source: ORCID, OpenAlex. Data years: 1994-2024.

**Social Sciences Top Researchers:** This indicator identifies the top 10% of researchers by citation impact in the field of life sciences and biomedicine. The field is defined based on OpenAlex article labels, including articles categorized under Psychology, Geography, Sociology, Political science, Philosophy, Business, Economics, and Art. Source: ORCID, OpenAlex. Data years: 1994-2024.

**Number of Top Publications:** We extracted the top 10% of the articles cited in each year as top publications. Source: ORCID, OpenAlex. Data years: 1994-2024.

**Number of Paper Citations:** The total number of citations of each article in each year was aggregated to cities/metropolitan areas based on its affiliations. Source: ORCID, OpenAlex. Data years: 1994-2024.

**Number of Research Institutions:** This indicator measures the number of research institutions that have published at least one academic publication. It reflects the scale of the institutional research infrastructure underlying scientific publication activities. Source: ORCID, OpenAlex. Data years: 1994–2024.

## Technological Innovation

**High-Tech Companies:** The number of high-technology companies headquartered in each city. High-tech firms were identified based on their classification within 269 predefined industries closely associated with advanced technology. Source: Orbis. Data years: 2004–2024.

**High-Tech Workers:** Total number of employees of high-technology companies headquartered in each city. Source: Orbis. Data years: 2004–2024

**Patents:** Number of patents filed in each city. Source: USPTO; Clarivate. Data years: 2022-2024  
**Patent Impacts:** Number of citations received from subsequent patents for patents filed in each city. Source: USPTO; Clarivate. Data years: 2022-2024

**R&D Investment:** The total amount of research and development investment (in thousands of dollars) by all large enterprises in each city. Source: Orbis. Data years: 2004–2024.

**Startups:** Number of start-up high-technology companies headquartered in each city. Source: Orbis. Data years: 2004–2024.

**Unicorns:** The number of unicorn companies valued at \$1B+. Source: Hurun Global Unicorn Index 2025. Data year: 2024.

## Future-Positioning

**AI Top Researchers:** This indicator identifies the Ntop 10% researchers by citations in the field of AI. Researchers' field was defined by their publications in the field of AI, by matching AI-related keywords in publication titles and abstracts (see appendix for full list of keywords). Source: Global Talent Flow Data Hub. Data years: 1994-2024.

**Biotech Top Researchers:** Number of top 10% researchers in terms of citations in Biotech field. Source: Global Talent Flow Data Hub. Data years: 1994-2024.

**Fintech Top Researchers:** Number of top 10% researchers in terms of citations in Fintech field. Source: Global Talent Flow Data Hub. Data years: 1994-2024.

**Semiconductors Top Researchers:** Number of top 10% researchers in terms of citations in Semiconductors field. Source: Global Talent Flow Data Hub. Data years: 1994-2024.

**Interdisciplinary Integration:** Number of interdisciplinary publications. Source: Global Talent Flow Data Hub. Data years: 1994-2024.

**Emerging Field Growth:** The growth rate of publications in AI, fintech, biotech, and semiconductors areas. Source: Global Talent Flow Data Hub. Data years: 1994-2024.

## Global Connectivity

**Air Route Connectivity:** This indicator measures the number of civil air routes connected to a city, based on route data from OpenFlights, an open database that provides airport, airline, and route information. Source: OpenFlights Route Database. Data year: 2024.

**Air Cargo Volume:** This indicator measures the volume of air cargo handled by airports, based on data from Airports Council International (ACI) World. Source: Airports Council International (ACI) World, World Airport Traffic Dataset. Data year: 2024.

**Number of Graduate Inbounds:** Total inbound international mobile students. The concept of graduate inbound students refers to the inflow of international graduate students who choose to pursue higher education in a host country. According to UNESCO's data on internationally mobile students, the number of inbound internationally mobile students in each city is inferred by multiplying the country's total number of internationally mobile students (from UNESCO) by the proportion of the city's population in the country's total population. This phenomenon not only reflects the dynamic changes in global education but also has profound impacts on the economic, social, and cultural development of the host country. Source: United Nations Educational, Scientific and Cultural Organisation (UNESCO). Data years: 2001-2024

**International Collaboration:** This dimension captures the centrality of each city in the global collaboration efforts, highlighting its role in driving global academic and research partnerships. Using academic papers, a collaboration network at the city level is constructed, with nodes representing cities and edges representing the volume and intensity of co-authorship connections between them. PageRank algorithm was adopted to assign scores to cities based on the quality and quantity of their collaborative connections. Source: Global Talent Flow Data Hub. Data years: 1994-2024.

**ICT (weighted):** This indicator is constructed as the sum of the ICT Development Index score and the logarithm of patent citations. The ICT Development Index score is obtained from the International Telecommunication Union (ITU), which publishes country-level assessments of information and communication technology development. Since the ICT measure is available at the national level, each country's IDI score is directly assigned to its corresponding cities. To capture within-country variation across cities, the logarithm of city-level patent citations is incorporated as a proxy for innovation diffusion. The two components are then added together to generate the final score. Source: ICT Development Index; Global Talent Flow Data Hub. Data year: 2024.

## Urban Resilience

**Ratio of Females in Research:** This process involved collecting all the researchers' names, calling the Python API to identify each name, predicting the author's gender, and finally counting the proportion of female researchers. Source: Global Talent Flow Data Hub. Data years: 1994-2024.

**Ratio of Female Managers:** The proportion of female directors in large enterprises compared to the total number of employees in each city. Source: Orbis. Data years: 2004–2024.

**Number of Foreign Companies:** Number of foreign high-technology companies headquartered in each city. Source: Orbis. Data years: 2004–2024.

**Diversity of Foreign Companies:** The number of different countries or regions from which foreign companies in each city originated. Source: Orbis. Data years: 2004–2024.

**Number of Museum:** The number of museums in each city. Source: Openstreetmap. Data years: 2025.

**Number of Library:** The number of libraries in each city. Source: Openstreetmap. Data years: 2025.

**Urban Mobility:** measures cities on public transit density, efficiency, and utilisation rate and the extent to which they can adapt to address competition from emerging mobility services. Source: Urban Mobility City Ranking Report. Data years: 2019-2024.

**Safety Index:** assess urban safety levels across dimensions such as digital, health, infrastructure, personal, and environmental security. Source: Safety city index report. Data years: 2015-2024.

## Configuration of Weight

The dimension weights for the FCI integrate four complementary methodologies to balance data-driven objectivity with expert insights: (1) Principal Component Analysis (PCA), (2) Coefficient of Variation (CV), (3) Entropy Weighting (EW), and (4) Analytic Hierarchy Process (AHP).

Specifically, for PCA, we first identify the principal components based on the correlation matrix of the original sub-indices and rank the components according to their eigenvalues. Next, the weights of each sub-index were determined based on their contribution to the dominant components. Consequently, a sub-index receives a high final weight if it correlates strongly with those components. This approach captures the intrinsic correlation structure among sub-indices rather than treating them as a collection of isolated indicators.

For CV, we assume that sub-indices with greater discriminatory power should contribute more to differentiating final scores. We therefore assign weights directly according to relative variability: the CV for each sub-index is calculated and then normalised proportionally to obtain formal weights, which are subsequently applied in the index aggregation.

For EW, weights are assigned through an information-theoretic process that quantifies the “usefulness” or “information content” of each sub-index’s data distribution. Unlike CV, EW measures uncertainty (entropy) in the data. We first normalise the data to create a probability distribution for each sub-index, then calculate its entropy using Shannon’s formula to obtain a degree of divergence. Final weights are derived in proportion to these divergence values. For AHP, weights are derived through a structured judgment-elicitation and matrix-algebra process that transforms expert subjective comparisons into objective priority weights.

In contrast to the data-driven methods above, AHP is fundamentally value-driven. We first construct a three-level decision hierarchy: Goal (determining optimal weights for the final score), Criteria (the sub-indices to be weighted), and Alternatives (the sub-indices themselves competing for priority). Domain experts are then invited to compare each pair of sub-indices relative to their contribution to the overall goal using Saaty’s 1–9 scale, and a pairwise comparison matrix is built. The priority weights are calculated via the eigenvector method, and a Consistency Ratio (CR) is computed to ensure that the judgments are logically coherent.

The final synthesized weights simultaneously preserve intrinsic data relationships, maximize inter-city differentiation, embed policy relevance, and ensure statistical robustness, yielding a transparent framework validated by high rank stability.

## Inclusion Criteria

The index covers 100 global megacities with populations exceeding one million. For selected U.S. cases, metropolitan statistical areas were used in indicator construction and in determining eligibility for inclusion in the final ranking (see Appendix I for details).

## Missing Values

To ensure data completeness, forward imputation was applied to address missing values. Cities with remaining missing values after imputation were excluded from the final aggregation process.

## Outlier Detection and Treatment

To mitigate the undue influence of outliers on the final ranking, the following measures were implemented

### Outlier Detection

The interquartile range (IQR) method was employed to identify outliers for each indicator annually.

### Outlier Treatment

Indicators with one to five outliers were winsorized. Outliers on the right side of the distribution were assigned the maximum value within the IQR, while those on the left side were assigned the minimum value within the IQR.

Indicators with more than five outliers were transformed using natural logarithms after scaling by a factor  $f$ , following the methodology of the Global Innovation Index. The transformation formula is as follows:

$$\ln \left[ \frac{(max \times f - 1)(value - min)}{max - min} + 1 \right]$$

Where  $f$  is set to 1 for simplicity, and "min" and "max" represent the minimum and maximum sample values of the indicator, respectively.

## Normalization

The 39 indicators were normalised to a standardised range of [60, 100], where higher scores denoted more favourable outcomes. Normalization was performed using the min-max scaling method, with the "min" and "max" values corresponding to the minimum and maximum values observed in the indicator dataset following outlier treatment. This approach ensures uniformity across all indicators, aligning them to a consistent scale and enabling their equitable contribution to the composite index.

## Scope of Administrative Divisions of U.S. Metropolitan Areas

Metropolitan area	Administration division	State
New York	New York	New York
	Staten Island	New York
	Paterson	New Jersey
	Bridgeport	Connecticut
	Edison	New Jersey
	New Haven	Connecticut
	Stamford	Connecticut
	Brooklyn	New York
	Bronx	New York
	Queens	New York
	Newark	New Jersey
	Jersey City	New Jersey
	Yonkers	New York
	ithaca	New York
buffalo	New York	
Los Angeles	Torrance	California
	Santa Ana	California
	Rancho Cucamonga	California
	Pomona	California
	Pasadena	California
	Orange	California
	Los Angeles	California
	Long Beach	California
	Huntington Beach	California
	Glendale	California
	Fullerton	California
	El Monte	California
	Downey	California
	Costa Mesa	California
	Anaheim	California
	Garden Grove	California
	Ontario	California
Inglewood	California	
Burbank	California	
Miami	Miami	Florida
	Fort Lauderdale	Florida
	Hollywood	Florida
	Miramar	Florida
	Pompano Beach	Florida
	West Palm Beach	Florida
	Davie	Florida
	Pembroke Pines	Florida

## Scope of Administrative Divisions of U.S. Metropolitan Areas

Metropolitan area	Administration division	State
Houston	Houston	Texas
	Pearland	Texas
	Pasadena	Texas
Atlanta	Sandy Springs	Georgia
	Atlanta	Georgia
	Athens	Georgia
Boston	Lowell	Massachusetts
	Cambridge	Massachusetts
	Boston	Massachusetts
Phoenix	Phoenix	Arizona
	Mesa	Arizona
	Chandler	Arizona
	Gilbert	Arizona
	Glendale	Arizona
	Scottsdale	Arizona
	Tempe	Arizona
Seattle	Tacoma	Washington
	Seattle	Washington
	Renton	Washington
	Kent	Washington
	Everett	Washington
	Bellevue	Washington
San Francisco	Vista	California
	San Diego	California
	Escondido	California
	El Cajon	California
	Chula Vista	California
	Carlsbad	California
Minneapolis	Minneapolis	Minnesota
	St. Paul	Minnesota
Baltimore	Baltimore	Maryland
	Washington	District of Columbia
	Arlington	Virginia
	Alexandria	Virginia
Raleigh	Chapel Hill	North Carolina
	Durham	North Carolina
	Raleigh	North Carolina
San Diego	San Francisco	California
	San Jose	California
	Concord	California
	Oakland	California
	Antioch	California

## Scope of Administrative Divisions of U.S. Metropolitan Areas

Metropolitan area	Administration division	State
San Diego	Santa Rosa	California
	Fremont	California
	Vallejo	California
	Hayward	California
	Sunnyvale	California
	Santa Clara	California
	Berkeley	California
	Richmond	California
	San Mateo	California
	Santa cruz	California
	Stanford	California
	Rohnert park	California

## Keyword list for Emerging Areas

Field	Keywords
AI	ChatGPT; Machine Learning; Neural Network; Transformers; Unsupervised Learning; CNN; Recurrent Neural Network; Natural Language Processing; AGI; Generative Adversarial Network; AI; Transfer Learning; Large Language Model; fine-tuning; Gradient Descent; LSTM; Language Model; LLMs; AutoML; Autoencoder; self-driving cars; BERT; Generative AI; Image Recognition; NLP; Artificial Intelligence; Long Short-Term Memory; Supervised Learning; RNN; Semi-supervised Learning; GPT; GANs; Autonomous Vehicles; Computer Vision; Active Learning; Backpropagation; Reinforcement Learning; ViTs; LLaMA; Deep Learning; Convolutional Neural Network; Artificial General Intelligence
Biotech	Biomass Conversion; Synthetic Biology; Biosensors; Structural Biology; Genome Editing; Bioremediation; Bioproduction; Epigenetics; Recombinant DNA; Enzyme Engineering; Downstream Processing; Biosciences; Optogenetics; Synthetic Biofuels; Whole-genome Sequencing; Protein Purification; Protein Expression; Antibody Engineering; Computational Biology; Biopharmaceuticals; Gene Therapy; RNA Interference; Systems Biology; Molecular Modeling; Organoids; Drug Discovery; Biomanufacturing; Biofuels; Bioinformatics; Upstream Processing; Protein Folding; Drug Delivery Systems; Cell-based Therapies; Gene Silencing; Microbiome Engineering; Metabolic Engineering; Quantum Biology; Genetically Modified Organisms; Transcriptomics; Genetic Engineering; Bioengineering; Fermentation Technology; Recombinant Proteins; Biosynthesis; Molecular Docking; Nanobiotechnology; Gene Editing; Personalized Medicine; Proteomics; Bioreactor; Biomaterials; Tissue Engineering; Stem Cell Therapy; Protein Engineering; Biosimilars; CAR-T Therapy; CRISPR; Genomics; Regenerative Medicine; Bioprinting; Bioprocessing; RNA Vaccine; Genetic Modification; DNA Sequencing; Gene Drives; Cell Culture; Biopesticides; Biotechnology; Genetically Modified Crops; Functional Genomics
Fintech	Consensus Mechanisms; Ethereum; Peer-to-peer Networks; Zero-knowledge Proofs; Decentralized Storage; Proof of Work; Decentralized Governance; P2P; Altcoin; Blockchain; Digital Assets; Proof of Stake; DeFi; Tokenization; Cryptocurrency; Stablecoin; Decentralized Finance; Web3; Tokenomics; Smart Contracts; Decentralized Exchange; NFTs; Layer 2 Scaling Solutions; Non-fungible Tokens; Bitcoin; Immutable Ledger
Semiconductor	Semiconductor Fabrication; Band Gap; Carrier Mobility; SiC; Lithography; CMP; Integrated Circuit Manufacturing; GaN; Heterogeneous Integration; Thin Film Deposition; CMOS; Device Reliability; Transistor Scaling; Ion Implantation; Packaging; Etching; MOSFET

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