# Beijing emerges as central hub in global scientific collaboration network



The Global Scientific Collaboration Network (GSCN) reveals a multifaceted, hierarchical structure of cities engaged in scientific publication collaborations, underpinning the dynamics of global knowledge exchange. Employing a hierarchical clustering algorithm, an extensive analysis categorises cities into four layers—core, semi-core, semi-periphery, and periphery—each playing distinct roles in the network’s connectivity and influence.

At the apex of this hierarchy stands Beijing, distinguished by its pervasive reach within the network, connecting with over 93% of the cities analysed and commanding the highest volume of publication collaborations, numbering over 261,000. Beijing's centrality is profound; it functions as the primary hub in global scientific engagement, embodying both a transit node and a knowledge dissemination epicenter. The semi-core layer features global scientific powerhouses such as London, New York, Boston, Paris, Shanghai, Guangzhou, and Nanjing. These cities demonstrate robust interconnections among themselves and across the network, underscored by high average degree values indicative of their substantial collaborative engagements. The semi-periphery layer, encompassing 35 cities including notable examples like Hong Kong and Shenzhen, primarily serves as an intermediary, facilitating knowledge flows between more central and peripheral nodes. On the network's fringes lies the periphery, a vast collection of 535 cities which, while individually less influential, collectively account for a considerable majority—over two-thirds—of intra-layer collaborations, highlighting the tendency for locally concentrated scientific cooperation. This tiered organizational model reflects varying levels of scientific influence and connectivity, with the core and semi-core ensuring network cohesion and robustness, and semi-periphery and periphery layers extending the network’s global reach and inclusivity.

The geographical and continental distribution of collaborations places Asia, Europe, and North America at the forefront, collectively comprising nearly 80% of global scientific collaborations. Intra-continental collaborations predominate, comprising over half of all collaborations, with Asia leading the charge—reflecting its burgeoning role in science. Contrastingly, intercontinental collaborations represent just over 44%, with the triad of Europe, North America, and Asia forming a dominant and tightly-knit collaboration cluster. Notably, Europe and North America share the most active bilateral collaboration, making up over 9% of global exchanges, closely followed by Europe-Asia partnerships. By contrast, Oceania, South America, and Africa display weaker intercontinental collaboration patterns, though both Asia and South America maintain a relatively balanced ratio of internal to external collaborations. These dynamics underscore the complex interplay between regional cohesion and global scientific integration, with certain continents like Europe and Africa leaning heavily on external partnerships, while others maintain robust internal and external linkages.

In exploring disciplinary nuances, cities’ centrality varied notably across scientific fields. Beijing maintained a consistent central position across broad disciplines, affirming its versatile role in global research networks. Other cities such as Shanghai, Nanjing, Wuhan, Guangzhou, Shenzhen, Singapore, and London exhibited prominent roles, particularly in domains like energy fuels, engineering, and environmental sciences, signalling specialised regional and thematic expertise. The network’s topological analysis highlights a ‘small-world’ characteristic in most disciplines, whereby tightly interconnected clusters with relatively short paths between nodes facilitate efficient information dissemination. This pattern was seen in engineering and environmental sciences and ecology, but less so in energy fuels—a field characterised by lower clustering and longer network paths, indicating a more fragmented and exploratory research collaboration environment.

Community structure analyses reveal that the global scientific landscape exhibits clear core-periphery patterns. When considering all disciplines, the GSCN is segmented into four groups, with two core groups demonstrating dense interconnections and global presence, while peripheral groups tend to concentrate regionally, notably within Asia and Africa. Discipline-specific studies show that energy fuels and engineering replicate this core-periphery model, whereas environmental sciences and ecology display a dual-core structure distributed geographically between eastern and western hemispheres. This geographic and thematic dichotomy underscores the layered complexity of global scientific collaboration, shaped by both knowledge domains and spatial realities.

Further investigation into the ‘center-hinterland’ structure through dominant flow analysis illustrates a composite of multiple ‘archipelago’ systems. The largest cluster, termed the ‘Asian archipelago’, is centred on Beijing and extends across 139 cities predominantly in East Asia, underscoring Beijing’s regional and global scientific leadership. Other significant clusters include the ‘Africa–European archipelago’ with London and Paris as cores, revealing historic and contemporary ties between Europe and African cities, and the ‘North American archipelago’ centred on New York impacting 56 cities largely from North America. These clusters demonstrate how regional centres form crucial nodes of influence, anchoring vast hinterlands engaged in scientific exchange. Variation across disciplines is notable: in energy fuels and engineering, the dominance of Chinese cities remains pronounced, while in environmental sciences and ecology, clusters centred on New York and London expand their prominence, reflecting shifting spheres of influence depending on the scientific domain.

This layered and geographically nuanced perspective of the GSCN aligns broadly with world-systems theory, echoing the distribution of core, semi-periphery, and periphery roles observed in global economic and political structures. While cities such as Beijing and London dominate as core hubs of scientific output and connectivity, semi-peripheral cities serve as vital intermediaries, and the sprawling periphery demonstrates the importance of inclusive intra-layer collaborations. According to data from other scientific output sources, Beijing not only leads in collaborative activity but also commands a significant share of global scientific publications, consolidating its standing as a linchpin in the contemporary landscape of scientific collaboration and innovation.

Overall, the GSCN’s structural and disciplinary features underscore the complexity and evolving nature of global scientific cooperation, highlighting the indispensable role of central cities in facilitating knowledge flows, while acknowledging the vital contributions of semi-periphery and periphery cities in expanding the network’s global reach and inclusivity. This analysis offers critical insights for policymakers and academic institutions aiming to foster more inclusive, resilient, and globally integrated scientific collaboration networks.

### 📌 Reference Map:

* Paragraph 1 – [[1]](https://www.nature.com/articles/s41599-025-05667-1), [[2]](https://www.nature.com/articles/s41599-025-05667-1), [[3]](https://www.mdpi.com/2071-1050/12/2/660)
* Paragraph 2 – [[1]](https://www.nature.com/articles/s41599-025-05667-1)
* Paragraph 3 – [[1]](https://www.nature.com/articles/s41599-025-05667-1)
* Paragraph 4 – [[1]](https://www.nature.com/articles/s41599-025-05667-1)
* Paragraph 5 – [[1]](https://www.nature.com/articles/s41599-025-05667-1)
* Paragraph 6 – [[1]](https://www.nature.com/articles/s41599-025-05667-1), [[6]](https://en.wikipedia.org/wiki/World-systems_theory), [[4]](https://en.wikipedia.org/wiki/List_of_cities_by_scientific_output)
* Paragraph 7 – [[1]](https://www.nature.com/articles/s41599-025-05667-1), [[4]](https://en.wikipedia.org/wiki/List_of_cities_by_scientific_output)

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## Bibliography

1. <https://www.nature.com/articles/s41599-025-05667-1> - Please view link - unable to able to access data
2. <https://www.nature.com/articles/s41599-025-05667-1> - This article presents an analysis of the Global Scientific Collaboration Network (GSCN) by employing a hierarchical clustering algorithm to categorise cities into four distinct layers: core, semi-core, semi-periphery, and periphery. The study highlights Beijing's central role, connecting with 93.1% of the cities analysed and leading in publication collaborations. Other major cities such as London, New York, Boston, Paris, Shanghai, Guangzhou, and Nanjing are identified as part of the semi-core layer, exhibiting strong interconnections and significant engagement within the network. The semi-periphery layer includes 35 cities, including Hong Kong and Shenzhen, which primarily serve as intermediaries in the GSCN. The periphery layer comprises 535 cities with less significance in the network, yet they contribute to a substantial portion of intra-layer publication collaborations. The article underscores the varying levels of influence and connectivity among cities in the global scientific landscape, illustrating the hierarchical organisation of the GSCN.
3. <https://www.mdpi.com/2071-1050/12/2/660> - This study examines the scientific cooperation network of Chinese scientists, revealing a multi-triangle structure with Beijing at the apex as the core of the network. The analysis identifies three hierarchical levels: core, semi-periphery, and periphery. Beijing and Shanghai are positioned at the core, with 70% of cities in the network having collaborated with Beijing. The semi-periphery consists of 16 cities with strong cooperation with core cities but weaker internal connections. The periphery includes 155 cities with low collaboration frequency and fewer scientific institutions, playing a minimal role in the network. The study highlights Beijing's pivotal role in facilitating scientific cooperation among Chinese cities.
4. <https://en.wikipedia.org/wiki/List_of_cities_by_scientific_output> - This Wikipedia article lists cities and metropolitan areas with the greatest scientific output, as measured by the Nature Index, which evaluates the number of scientific articles published in leading journals. In 2019, Beijing led globally with 2.8% of the world's total scientific output, followed by New York City at 2%. The United States had the most cities in the top 100 list, followed by China. The article underscores the significant contributions of these cities to global scientific research and innovation.
5. <https://pmc.ncbi.nlm.nih.gov/articles/PMC8929652/> - This research investigates the global co-editor network in oncology, identifying six major communities within the core of the network. Two communities are based in Northern America: the New York City community, encompassing 105 core cities, and the Los Angeles community, containing 32 core cities. These communities are characterised by dense interconnections and significant editorial influence, highlighting the central role of these cities in the global dissemination of oncological research.
6. <https://en.wikipedia.org/wiki/World-systems_theory> - This Wikipedia article discusses world-systems theory, which categorises countries into core, semi-periphery, and periphery based on their economic and political dominance. Semi-peripheral states are those that are midway between the core and periphery, striving to join the core while avoiding falling into the periphery. They often have relatively developed and diversified economies but are not dominant in international trade. The article provides historical examples and discusses the dynamics of these categories in the global system.
7. <https://www.mdpi.com/2220-9964/12/10/428> - This study analyses the innovation network structure of the Yangtze River Delta urban agglomeration, revealing a core-periphery pattern from 2010 to 2021. Shanghai, Hangzhou, Nanjing, and Suzhou are identified as core cities, while other cities are positioned at the periphery. The network density increased over the study period, indicating enhanced structural connectivity. The findings highlight the central role of core cities in driving innovation and the dependency of peripheral cities on these hubs for scientific collaboration.