SIDEBAR

Artificial Intelligence Publication Output and International Collaboration

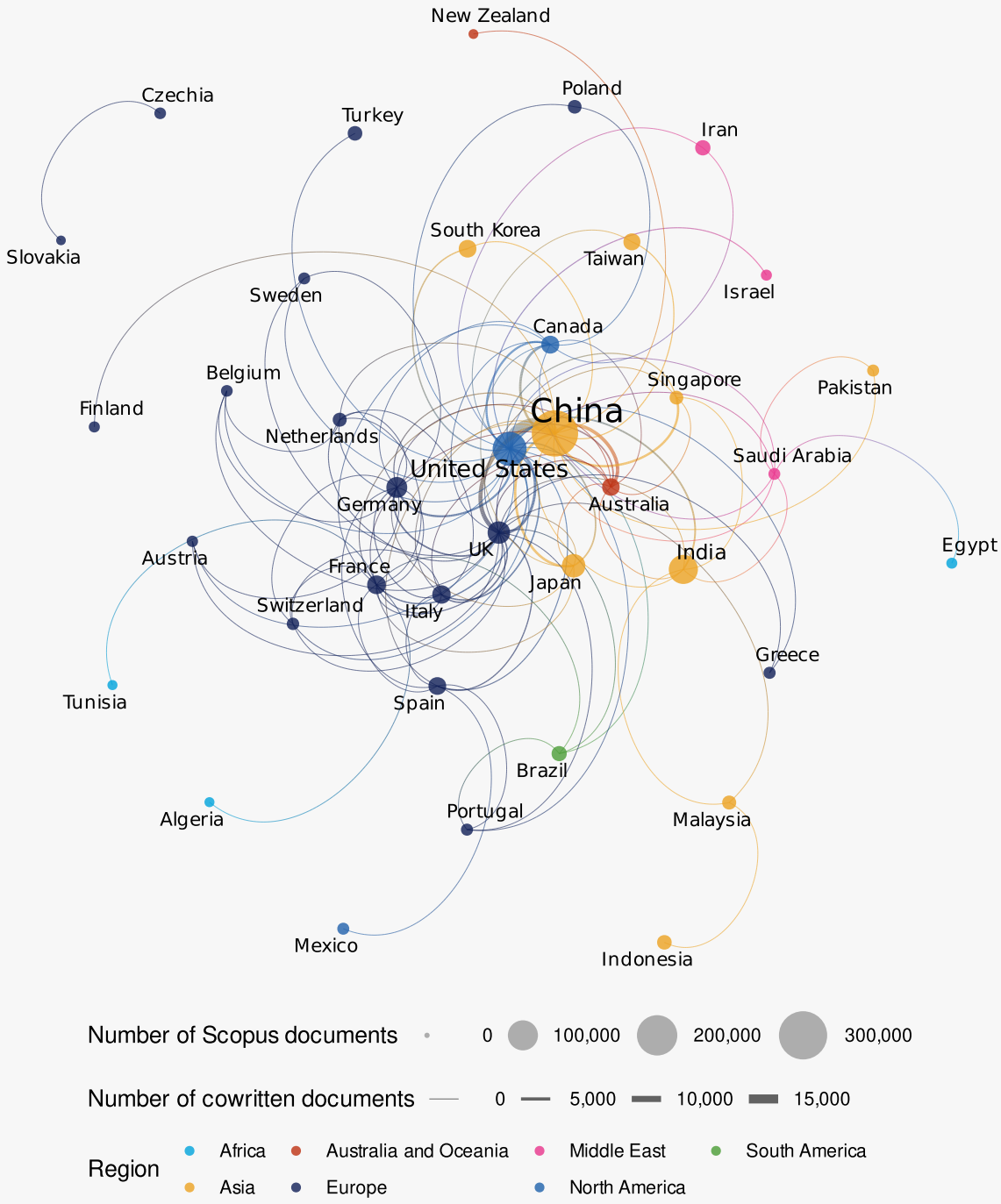
The National Science Board (NSB) highlighted the importance of international collaboration and work in technology-intensive industries in its *Vision 2030* report (NSB 2020). This work became important because of the increasing globalization of science and engineering and the significance of research in fields such as artificial intelligence (AI) playing a large role "to empower U.S. business and entrepreneurs to succeed globally" (NSB 2020). The National Artificial Intelligence Research Resource Task Force (NAIRRTF) has also drawn special attention to the researchers behind AI during the field's rapid growth through a strategic plan to increase access to resources and training for diverse AI researchers (NAIRRTF 2023). Research in the field of AI is an important technology-intensive area that has grown rapidly in recent years and in which international collaborations are crucial (Liu, Shapira, and Yue 2021). The nature of international partnerships between top-producing regions, countries, or economies, such as the United States and China, and other smaller, yet relatively important partnerships, such as Slovakia and Czechia, is an important influence on the AI advancements and priority topics of study.

The initial step to explore the state of international collaboration in the field of AI is determining the inclusion of articles from scientific journals and conference proceedings relevant for a network analysis of AI international collaboration.[*] Scopus has a series of classification groups that help isolate relevant AI work; this subset of the Scopus data set was used to produce two network figures. The first represents the global collaboration network of AI and displays the number of coauthored articles between regions, countries, or economies to highlight the most prolific collaborations and collaborators. The second network focuses on the relative importance of collaborations by normalizing for overall publication output in AI. This helps highlight smaller, but relatively important, collaborative relationships. Together, the two figures allow for a more complete snapshot of the global collaboration network of AI.[†]

Figure PBS-B shows the network of AI research collaboration. The largest contributors from 2003 to 2022, in terms of total documents produced and the largest collaborative hubs, were China (274,096 total articles as a whole count) and the United States (133,601) (Table SPBS-91). Indeed, this country pairing was responsible for the most coauthored articles of any pair (13,631 articles) (Figure PBS-B). Further, of the top 10 most prolific pairs, all feature the United States or China. The first pairing that does not is the 11th most prolific pair of the United Kingdom and Germany (2,166). Other important contributors in the network include Australia, Japan, Canada, and Singapore. The centrality of the United States and China may follow from their high publication output (see the section Output by Region, Country, or Economy), which enables a greater number of network connections and echoes previously observed patterns of collaboration at the region, country, or economy level (Leydesdorff and Wagner 2008).

Figure PBS-B

AI collaboration network, by region, country, or economy: 2003–2022



AI = artificial intelligence.

Note(s):
This network diagram shows the number of cowritten articles by all pairs of regions, countries, or economies within the top 60 producers of AI-related research based on whole counting for those pairs that cowrote 400 articles or more. AI article counts refer to publications from a selection of conference proceedings and peer-reviewed journals in S&E fields from Scopus that were classified as AI in the All Science Journal Classification. Articles are classified by their year of publication and are assigned to a region, country, or economy on the basis of the institutional address(es) of the author(s) listed in the article. Links are only shown in a single direction, dictated by alphabetical order. The size of the nodes is proportional to the total number of AI-related articles written by each region, country, or economy. The width of the links between nodes is proportional to the quantity of articles both regions, countries, or economies have cowritten. Positioning of nodes is defined using the Kamada-Kawai algorithm. For the list of regions, countries, and economies and their respective geographic regions in this figure, see Table SPBS-91.

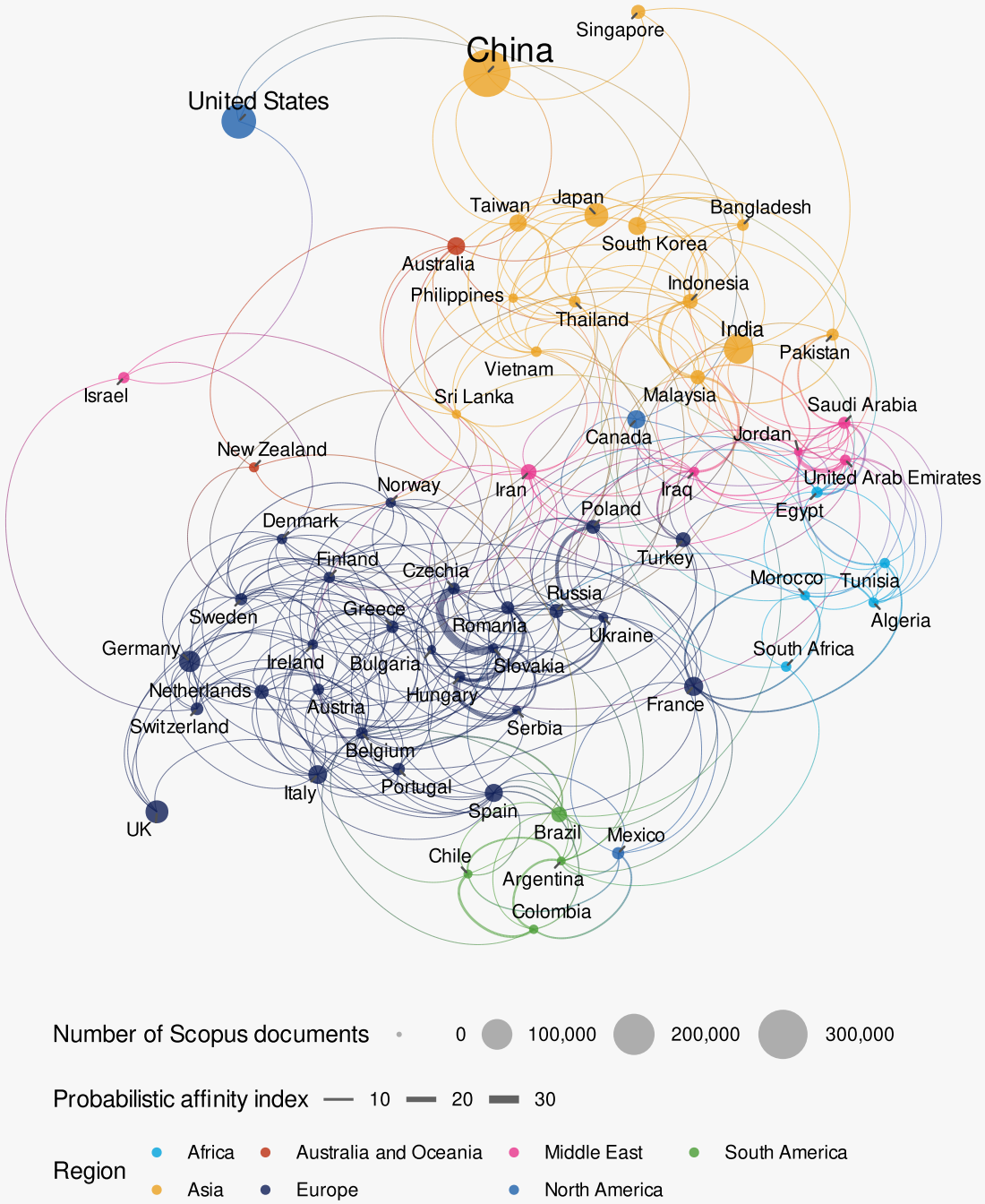
Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; Elsevier, Scopus abstract and citation database, accessed April 2023.

Science and Engineering Indicators

Although whole-counted documents produced by region, country, or economy pairs is an effective way to describe the overall hub-centered structure of collaboration in the field of AI, in Figure PBS-C, the focus on relationships relative to overall output highlights more regional collaboration patterns and partnerships. Instead of line thickness representing the number of coauthored documents, it now shows the *index of collaboration*. This index is best interpreted as the propensity of a region, country, or economy to collaborate with another, given their total collaborations. The baseline of this measure is equal to 1.00, where values greater than 1.00 show a preferential collaborative relationship. This helps highlight important relationships of regions, countries, or economies not significantly featured in Figure PBS-B. Specifically, the values of collaborative pairs Slovakia and Czechia (30.42), Serbia and Hungary (15.79), and the United Arab Emirates and Jordan (15.03) were notably large, given the number of coauthored publications that these countries produced. Unsurprisingly, geography and shared history play significant roles in these relationships, but they help illustrate smaller, and yet important, collaborative relationships in AI.

Figure PBS-C

AI index of collaboration, by region, country, or economy pairs: 2003–2022



AI = artificial intelligence.

Note(s):
The index of collaboration is calculated as follows: *ICxy* = (*Cxy* / *Cx*) / (*Cy* / *Cw*), where *ICxy* = index of collaboration between country *x* and country *y*, *Cxy* = number of publications coauthored between country *x* and country *y* in the relevant field, *Cx* = total number of international coauthorships by country *x* in the relevant field, *Cy* = total number of international coauthorships by country *y* in the relevant field, and *Cw* = total number of international coauthorships in the relevant field overall. This network diagram shows indices of collaboration between all pairs of regions, countries, or economies within the top 60 producers of AI-related research, based on whole counting, for pairs having an index of collaboration higher than 1.00. AI articles refer to publications from a selection of conference proceedings and peer-reviewed journals in S&E fields from Scopus that were classified as AI in the All Science Journal Classification. Articles are classified by their year of publication and are assigned to a region, country, or economy on the basis of the institutional address(es) of the author(s) listed in the article. Links are only shown in a single direction, dictated by alphabetical order. The size of the nodes is proportional to the total number of AI-related articles written by each region, country, or economy. The width of the links between nodes is proportional to the index of collaboration between both regions, countries, or economies. Positioning of nodes is defined using the Fruchterman-Reingold algorithm. For the list of regions, countries, and economies and their respective geographic regions in this figure, see Table SPBS-91.

Source(s):
National Center for Science and Engineering Statistics; Science-Metrix; Elsevier, Scopus abstract and citation database, accessed April 2023.

Science and Engineering Indicators

In conclusion, looking at international collaboration in the field of AI through a network analysis provides some helpful conclusions about the current state of an increasingly important field. Although the United States and China were the most prominent actors in the global collaboration network, looking at relative relationships provides additional perspective for important partnerships like that of Slovakia and Czechia, which would be otherwise obscured. Going forward, AI research will likely remain an influential field affecting multiple facets of society in the coming years. The nature of the networks producing forthcoming research will be just as important in shaping new advancements as the international partnerships that produce them.

* *Network analysis* refers to a broad range of visualization, mathematical, and statistical techniques centered around the conceptualization and depiction of entities and the relationships between them as nodes and edges (linkages between nodes). The analyses here are descriptive.

† Although these figures display work on AI specifically, they also show general trends in international collaboration. For example, the large collaboration between the United States and China is not unique to AI but is true for most subject areas. Further, the relative collaborative relationships and propensity scores are also likely true of other areas as they highlight geographically or culturally close ties where AI research is one part of the larger collaborative relationship. The focus on AI as an important area of study serves as a useful lens to look at these relationships and is not shared with the purpose of distinguishing AI networks from other fields of study.