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# Global networks in collaborative programming

Fabian Braesemann <sup>a</sup>, Niklas Stoehr <sup>b</sup> and Mark Graham <sup>a</sup>

## ABSTRACT

To understand the dynamics of the digital knowledge economy, it is crucial to reveal the geography of global flows of knowledge on digital platforms. This article visualizes a key form of knowledge production in the digital economy: mapping the joint collaborations of users from different cities on Stack Overflow, the world's most popular question-and-answer website for programming questions. The network map reveals that users from only a limited number of places are actively taking part in the exchange of programming knowledge. While Stack Overflow access and participation are theoretically unrestricted, contributions are clustered in metropolitan regions in North America, Western Europe, and South Asia.

## ARTICLE HISTORY

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Internet Geography; Knowledge Geographies; Digital Economy; Global Information Flows; Networks; Collaborative Programming; Stack Overflow

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Knowledge creation and flows of digital information are central in today's globalized economy (Zook, 2018). While increased internet availability has allowed people to use digital platforms to connect to, create and use digital content from almost anywhere on the planet, it remains that digital information tends to cluster geographically (Graham, De Sabbata, & Zook, 2015; Zook, 2018). Presuming that knowledge has increasing returns to scale (Feldman & Storper, 2018), it should then aggregate in places that are already central hubs of knowledge creation. As a consequence, we would still expect large cities to remain as central nodes in the global networks of information flows (Clark, Feldman, Gertler, & Wójcik, 2018), despite more widespread internet accessibility (Graham, Straumann, & Hogan, 2015).

This paper visualizes a key form of knowledge creation in the digital economy: mapping joint collaborations of users from different cities on 'Stack Overflow', the world's most popular question-and-answer website for programming questions. The platform has global coverage, and in its 10-year history has accumulated more than 19 million geolocated contributions from more

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**Figure 1.** Network connections on Stack Overflow, 2009 and 2017 (1% random sample).

Note: Each dot represents a city from which users made contributions to the platform. Two cities A and B are connected by a blue line if there was at least one collaboration on a programming question between users from these cities in 2009 (a user from A posing a question, a user from B replying, or vice versa). Two cities are connected by a red line, if there was a collaboration in 2017. The shifting geographies from 2009 to 2017 indicate the rising importance of South Asia in the digital economy. (inset) Complementary cumulative distribution functions (CCDF) of degree centrality in the network, 2009–17. The distribution became more skewed over time. For example, the share of cities with  $\geq 100$  connections decreased from 32% in 2009 to 12% in 2017.

than 2 million users. In other words, it is a proxy for where people know about, and want to know about, knowledge related to programming.

We collected all contributions of users who make their location information accessible.<sup>1</sup> The user locations were geocoded using the Google Geocoding API. From this data set we constructed a network: similar to scientific collaborations, two cities are connected if users from the cities jointly contribute to a question, either in posing the question or in providing an answer.

The resulting intercity network shows distinct geographies. Figure 1 displays a 1% random sample: each dot represents a participating city, each line a collaboration between two cities in 2009 (blue) and 2017 (red). While Stack Overflow access and participation are theoretically unrestricted, contributions are geographically clustered. Most cities are only sparsely connected to others, but dense flows connect the metropolitan regions in North America, Western Europe and South Asia.

In contrast to 2009, when flows almost entirely connected places in the Global North, Indian cities have become major hubs in the 2017 network. With the exception of Shanghai and Beijing, most other places from the Global South failed to catch up.

Despite the higher participation of Indian cities, overall, a smaller proportion of places have accumulated an increasing number of network connections. This finding is visualized by the inset in Figure 1, which displays the complementary cumulative distribution of the connections per city (degree centrality). Although the distributions have a similar heavy-tailed shape, the inward shift indicates increased skewness. For example, the share of cities with more than 100 connections dropped from 32% in 2009 to 12% in 2017. In other words, programming knowledge is becoming more concentrated.

While platforms such as Stack Overflow make programming knowledge more accessible, the network map reveals that users from only a limited number of places are actively taking part in the exchange of such knowledge. The shifting geographies of digital knowledge creation and

collaboration might help to explain the strong position of certain countries in other domains, such as the leading role of Indian freelancers on online labour platforms. Visualizing such information flows is therefore important to understand the dynamics that shape the geographies of the digital knowledge economy.

## NOTE

<sup>1</sup> All Stack Overflow data are publicly available at <https://archive.org/details/stackexchange>.

## DISCLOSURE STATEMENT

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