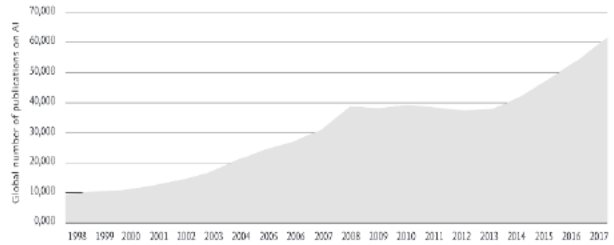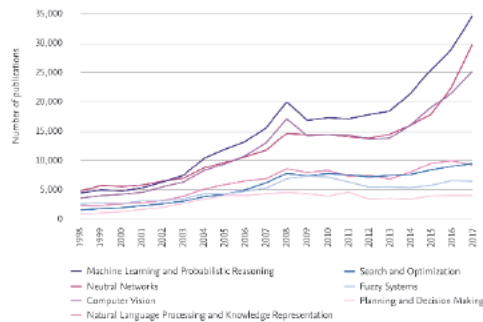# Artificial intelligence: how knowledge is created, transferred, and used

Global AI research output has grown faster than the world average for all research; accelerating in recent years to more than 12% per annum.

*Figure 1. Annual number of AI publications, all document types, 1998-2017. Source: Scopus*

Global output by subfield shows that rapid growth in recent years is largely due to 3 clusters: machine learning and probabilistic reasoning, neural networks, and computer vision.

Figure 2. Annual number of AI publications by keyword co-occurrence (all document types), 1998-2017; sources: Scopus and Elsevier clustering.

The largest contributor to the world's output is the EU – defined as EU44, the countries fully eligible under the Horizon programme – but is also gradually losing share. China shows significant growth, although the 2008-2012 figure is somewhat inflated due to a glut of conferences. The corporate giants and the very large research universities may be in the US and China, but the sum of all the smaller universities in Europe adds up, and European institutions are increasingly working together.

Figure 3. Share of global publication output in AI (all document types) for periods 1998-2002, 2003-2007, 2008-2012, and 2013-2017, per region; source: Scopus
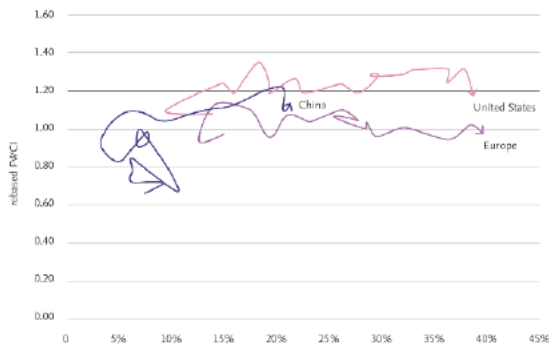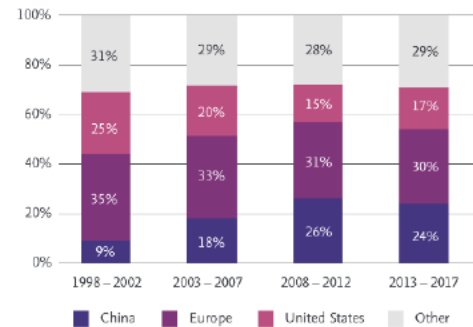

International collaboration share has doubled in 20 years. Further comparing China, the US and the EU by field-weighted citation impact (rebased to 1.0 within the AI corpus) and international collaboration, all regions have doubled their international collaboration share. While citation impact of the US and Europe is largely stable, China has managed a strong increase in FWCI, at the expense of 'rest of world' (i.e.: outside US and EU). Mainstream media pitches the great rivalry. In fact, collaboration is strongly on the rise and is correlated with higher FWCI.

Figure 4. Share of publications from international collaboration (all document types) and their rebased Field-Weighted Citation Impact, 1998-2017; source: Scopus.

The United States AI research is robust. United States researchers increasingly collaborate internationally on AI research. AI in the United States has a strong focus on specific algorithms and separates speech and image recognition into distinct clusters. The corpus shows less diversity in AI research than Europe but more diversity than China, as shown in Figure 10.

Figure 5. Annual publications per cluster for the US (all document types), 1998-2017; sources: Scopus and Elsevier clustering.
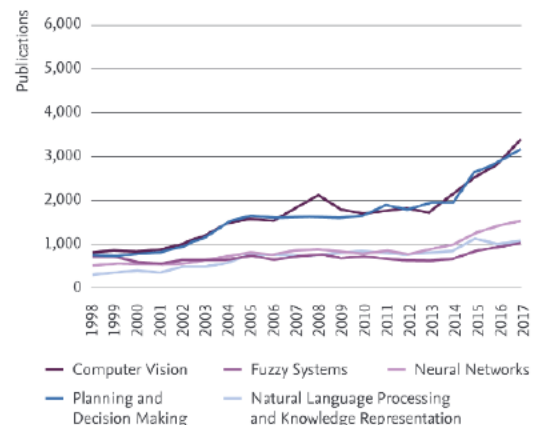
Artificial intelligence: how knowledge is created, transferred, and used
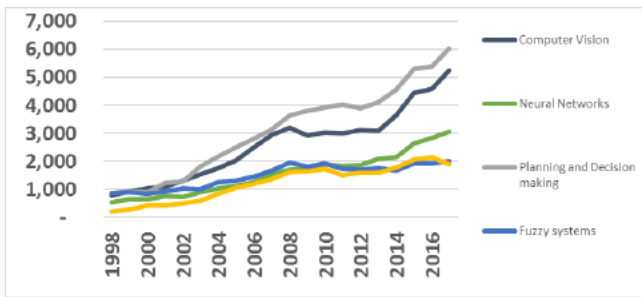
United States
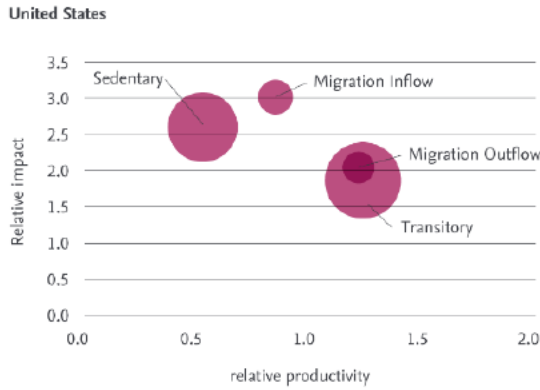
The mobility profile in the US is exceptional: sedentary researchers, while less productive than their mobile peers, show very high citation impact. This suggests that the US academic sector itself is both highly competitive, and able to retain top researchers.

Figure 6. Relative productivity and relative citation impact per mobility class for the US, 1998-2017; bubble size represents the percentage of researchers in each mobility class. Source: Scopus


Figure 7a. AI and interconnection between disciplines: study for the Dutch Ministry of Economic Affairs

Europe is the largest region in AI scholarly output, with high and rising levels of international collaborations outside of Europe. The broad spectrum of AI research in Europe reflects the diversity of European countries, each with their own agenda and specialties. Focus areas of European AI research include genetic programming for pattern recognition, fuzzy systems, and speech and face recognition. Deep learning research in Europe appears less connected to other subfields than it is in other regions, and AI robotics in Europe appear to be embedded in the machine learning cluster.

Figure 7. Annual publications per cluster for Europe (all document types), 1998 2017; sources: Scopus and Elsevier clustering.
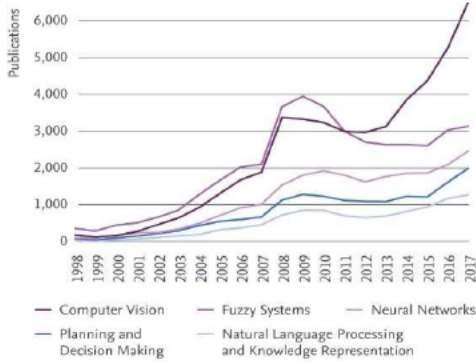
China aspires to lead globally in AI and is supported by ambitious national policies. China's AI focuses on computer vision. It shows robust growth of its research and education ecosystems, with a rapid rise in scholarly output and similar research usage as other regions. China's AI research has a rapidly increasing yet still comparatively low citation impact which could be a symptom of regional, rather than global, reach.

Figure 8. Annual publications per cluster for China (all document types), 1998-2017; source Scopus

Analysis of mobility in China shows while the share of transitory and inflow of AI researchers is modest, they do have comparatively high citation impact and productivity.
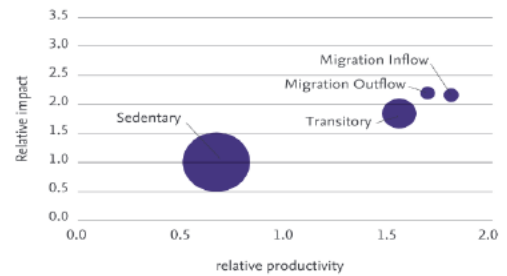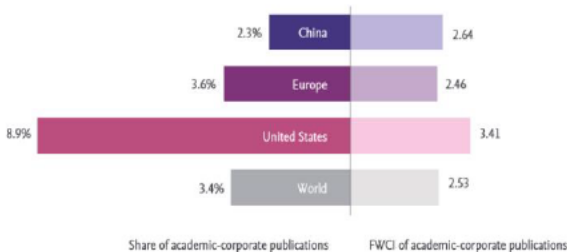
Figure 9. Relative productivity and relative citation impact per mobility class for China, 1998-2017; bubble size represents the percentage of researchers in each mobility class. Source: Scopus

Academic-corporate collaboration receives higher citation rates globally and in all sectors. Such cross-sector collaborations are particularly prominent in the United States, accounting for nearly 9% of their output in the field with a citation impact of more than thrice the world average. China is below the 3% global average share of academic-corporate publications, and Europe slightly above it, with both regions reaping similar citation impact benefits these collaborations.

Figure 10. Academic-corporate share of publications (left-hand side, dark color) and their Field Weighted Citation Impact, FWCI (right-hand side, light color) (all document types), 1998-2017; source: Scopus.