



How to monitor the AI ecosystem ?

The EC AI Watch and the techno-economic segments (TES) approach applied to the AI landscape

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EC JRC – Digital Economy Unit

**Jornada Informativa sobre Inteligencia Artificial aplicada a las
Políticas Públicas de Ciencia, Innovación y Emprendimiento**

How to monitor the AI ecosystem?

- The EC JRC and the Digital Transformation
- The EC AI Watch
- Mapping the AI Ecosystem (the TES approach)

The EC JRC



European Commission's **science and knowledge service**

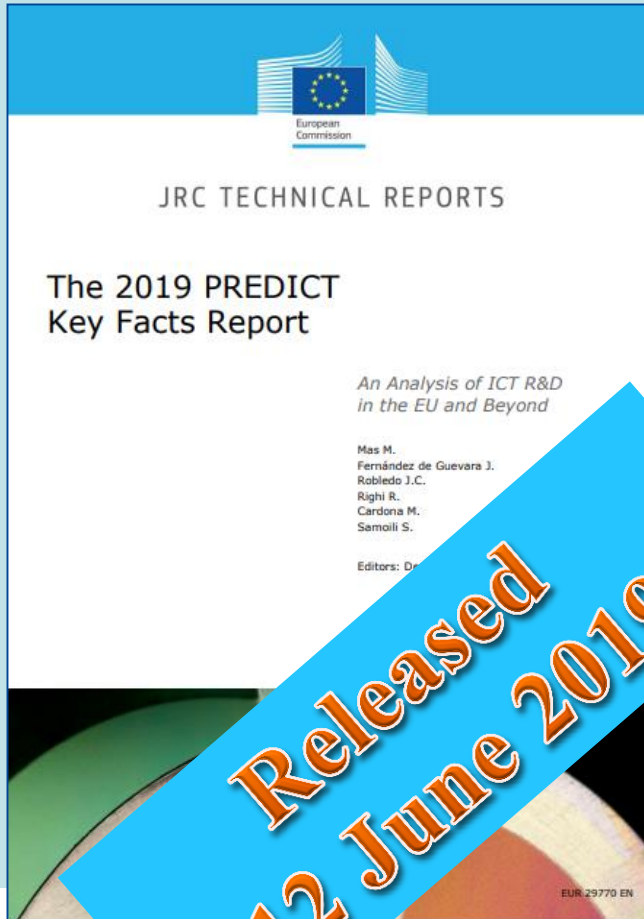
- advice to supports EU policies
- with independent scientific evidence
- throughout the whole policy cycle

Spain: Growth and Innovation Directorate

- Focusing among others priorities on the Digital Single Market
- Strong multi-disciplinarity
- 10 years' experience in monitoring evolution of ICT..



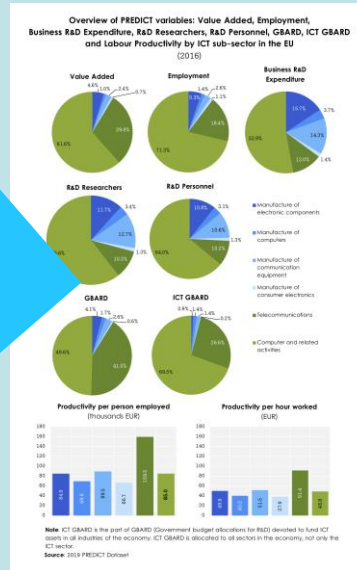
PREDICT - Prospective Insights on ICT R&D



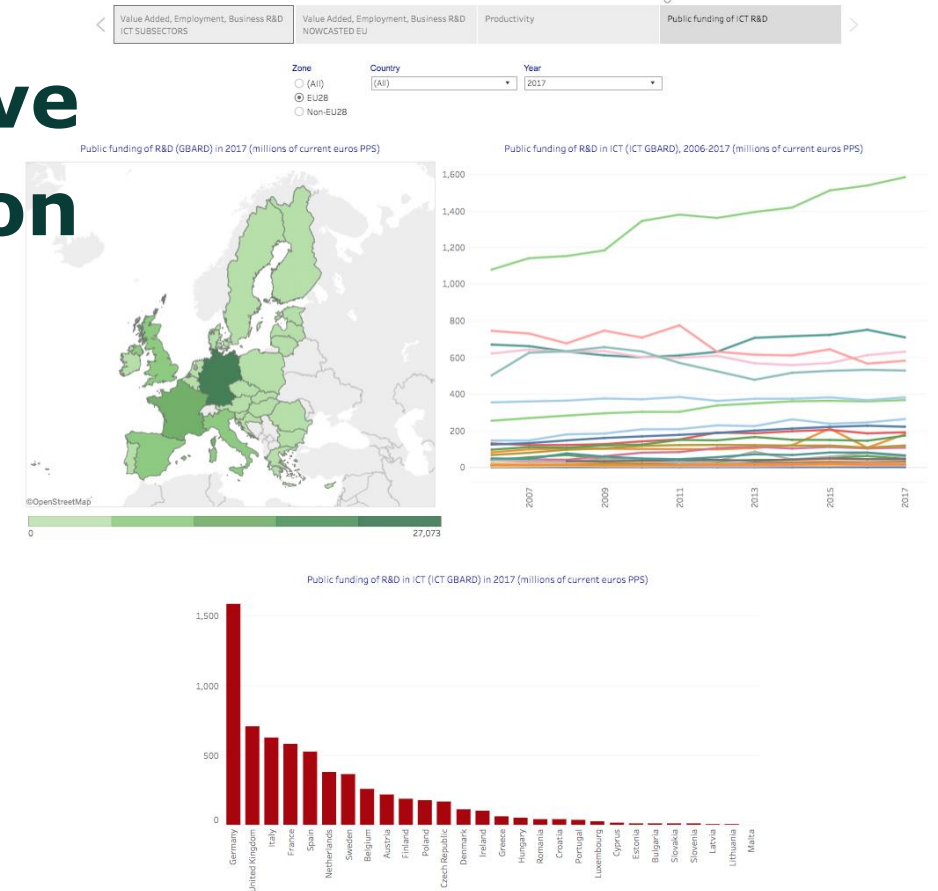
Interactive Visualisation



Created by Brandon Shields from Noun Project



PREDICT - Prospective Insights in ICT R&D 2019



<https://ec.europa.eu/jrc/en/predict>

PREDICT - Prospective Insights on ICT R&D

Joint Project of EC JRC & DG CNECT

2008

**ICT
sector
& ICT
R&D**

- Yearly PREDICT datasets
- DAE, DESI



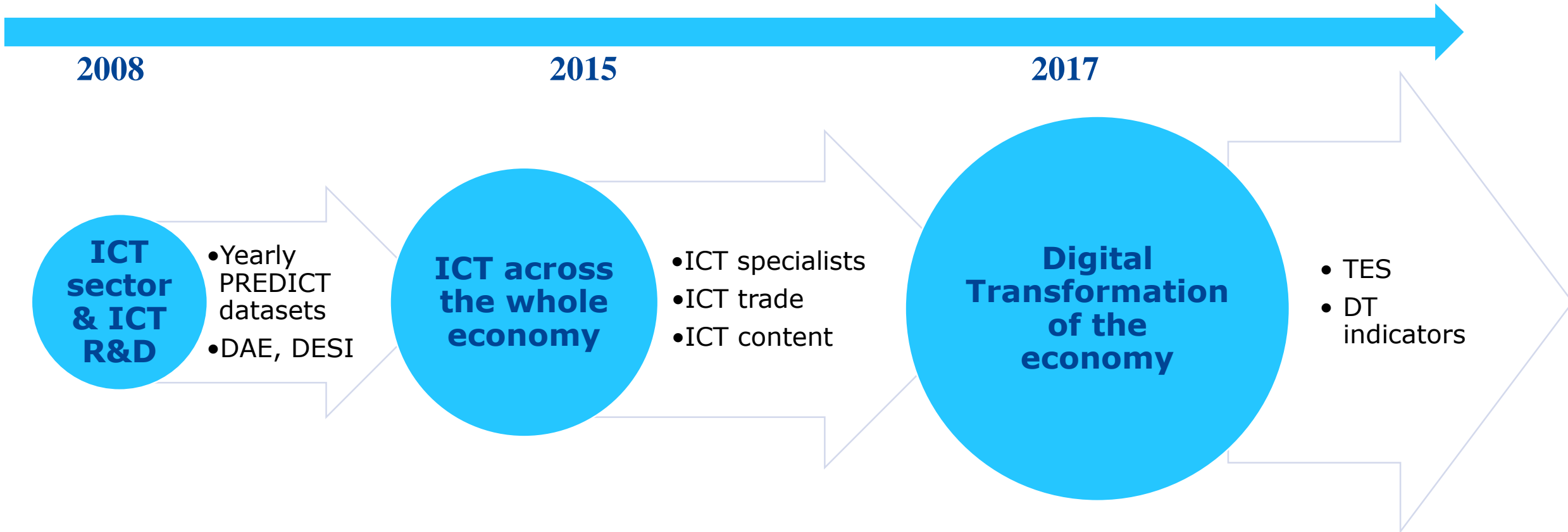
- A unique source of information
 - Comparable data on ICT sector & sub-sectors
 - 28 EU MS + 12 non-EU countries
 - Based on official statistics
 - 1995 – 2018
 - Macroeconomic variables



- Policy relevance
 - Digital Economy and Society Index (DESI)
 - Digital Agenda for Europe (DAE)

<https://ec.europa.eu/jrc/en/predict>

PREDICT - New developments



AI Watch



Artificial Intelligence for Europe COM(2018)237

Boost technological and industrial capacity & AI uptake

Prepare for socio-economic changes

Ensure an appropriate ethical & legal framework

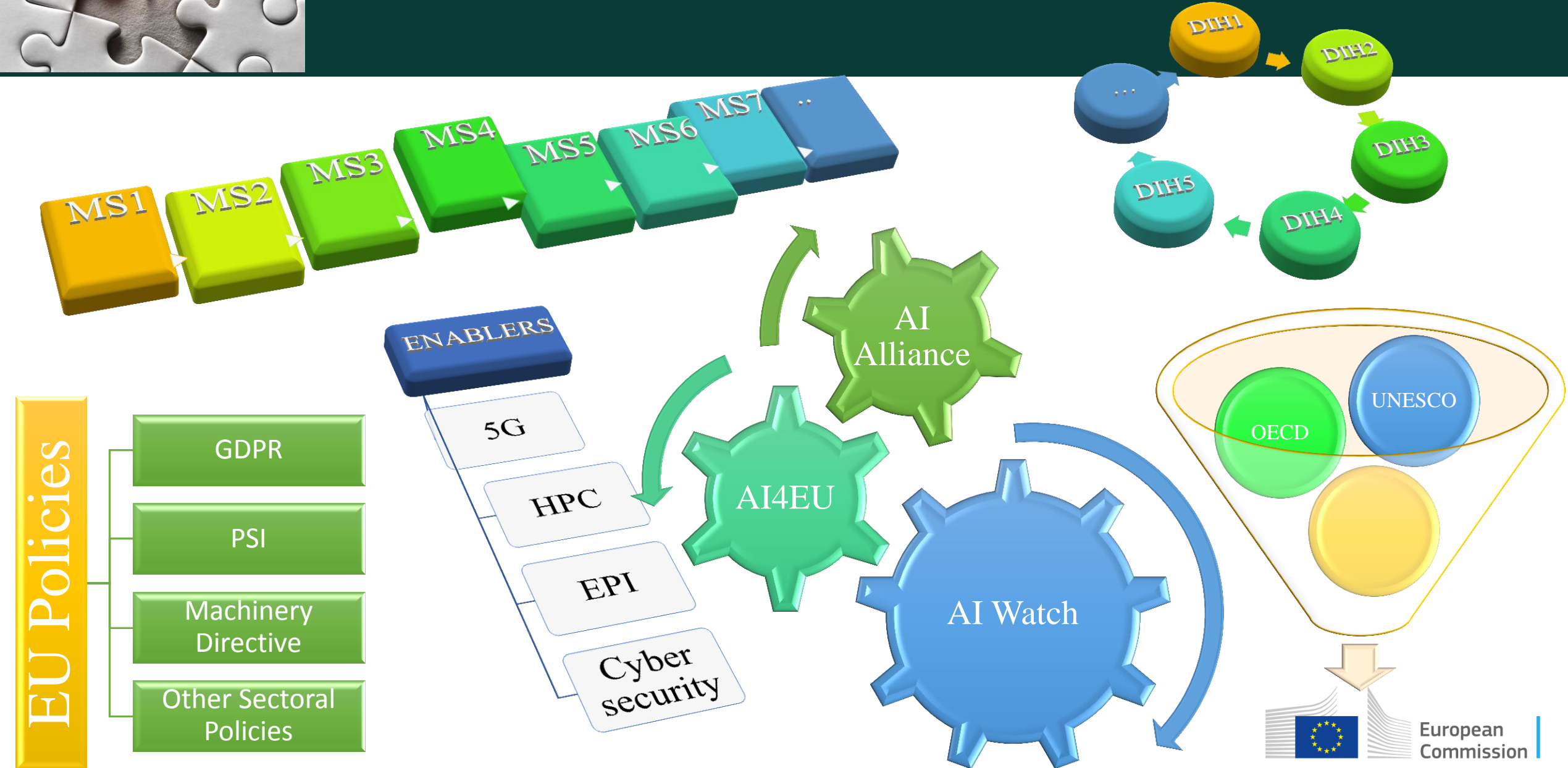
Joining Forces



- **By the end of the year**, the Commission will work, as part of the existing European platform of national initiatives to digitise industry, on a **coordinated plan with Member States** in order to maximise the impact of investments at EU and national levels, exchange on the best way for governments to prepare Europeans for the AI transformation and address legal and ethical considerations. In parallel, the Commission will **systematically monitor AI-related developments**, e.g. policy initiatives in the Member States, AI uptake and its impact on labour markets as well as AI capabilities, including high-level benchmarking, showcasing current capabilities and developing an AI index in order to inform the discussions.
- **By July 2018**, the **European AI Alliance** will be set up. It will involve all relevant stakeholders to gather input, exchange views, develop and implement common measures to encourage the development and use of AI.



.... positioning AI Watch



AI Watch: EC Knowledge Service to monitor Development, Uptake and Impact of AI for Europe

European Commission > Knowledge for policy > AI Watch

Knowledge for policy

AI Watch

Monitor the development, uptake and impact of Artificial Intelligence for Europe

All Online Resource Publication Events News

Topics

AI for the public sector

AI-enabled solutions can deliver shorter and richer feedback loops for all levels of governance, providing an opportunity to speed up, improve the efficiency and effectiveness of service delivery.

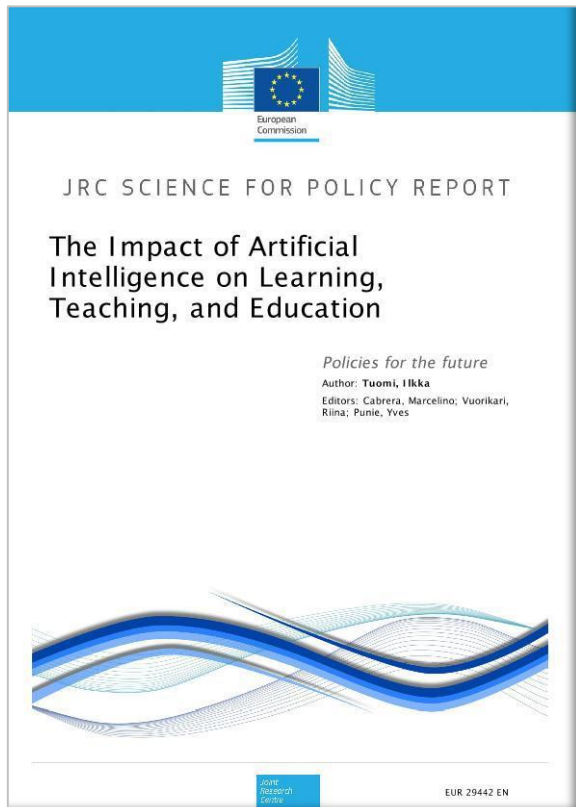
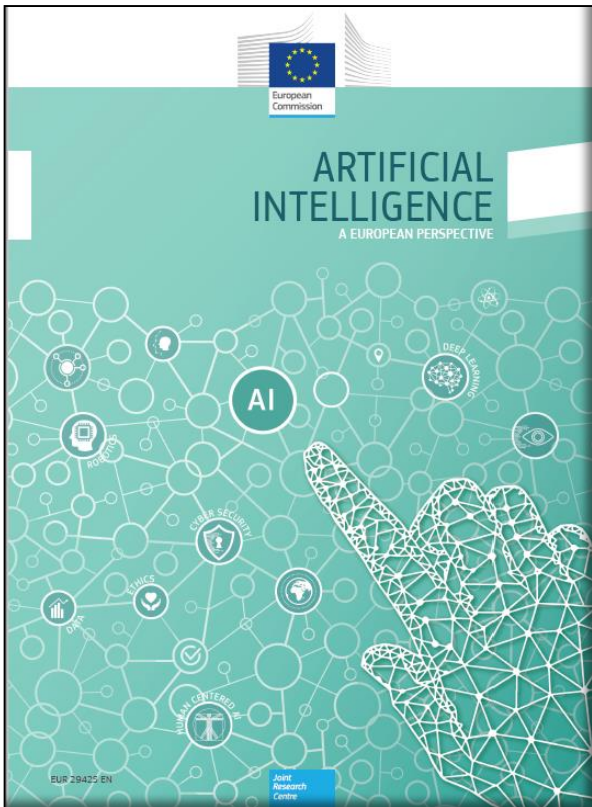
AI Landscape and indicators

AI is experiencing a period of intense progress, due to several key technological enablers: faster processing, increased amounts of data, and better algorithms. Still lacking official statistics, front end methodologies have been applied to analyse the AI ecosystem and track its evolution.

Data: a cornerstone for AI – Toward a Common European Data Space

For an application of artificial intelligence (AI) to be ready for market entry it has to learn on the basis of training data. Additionally, it may need further data sources in order to fulfil its functions. With its actions, the EC seeks to support wider availability of relevant data.

https://ec.europa.eu/knowledge4policy/ai-watch_en



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AI Watch: providing indicators & metrics

1. **AI Landscape** : From Research To Market And Society
2. **Evolution** of AI Technology
3. Evolution of AI **Uptake** across economy (by sectors)
4. Evolution of European Market shares in **Robotics**
5. EU MS **National Initiatives** on AI
6. Use and Impact of AI In **Public Services**
7. AI Index (inc. indicators relevant for policy making)



Landscape of AI in Europe - AI Ecosystem: from research to market and society

To provide a mapping of the AI ecosystem, identifying the main European and non-European stakeholders and the competitive position of Europe with respect to the US and China in major AI subsectors

- Methodology: based on JRC developed techno-economic segment (TES) analytical approach
- Quantitative approach based on variety of data sources & mapping of relations and activities

Mapping the AI ecosystem



Landscape of AI in Europe – TES

Techno-Economic Segment (TES) analytical approach:

Timely representation of an integrated and very dynamic **technological domain** not captured by official statistics or standard classifications, rapidly evolving, expected to play a key role in the digital transformation and gate-keeping further developments, to answer policy needs

→ who is doing what and with whom?

micro-based perspective

*acknowledging the conceptualization of agent-artifacts
space*

**Artificial
intelligence**



Created by Gregor Dresnar
from Noun Project

Photonics



Created by Brandon Gamm
from Noun Project

Geospatial



Created by Line Icons Pro
from Noun Project



Landscape of AI in Europe – TES

→ accounting for the whole ecosystem targeted as a complex system!

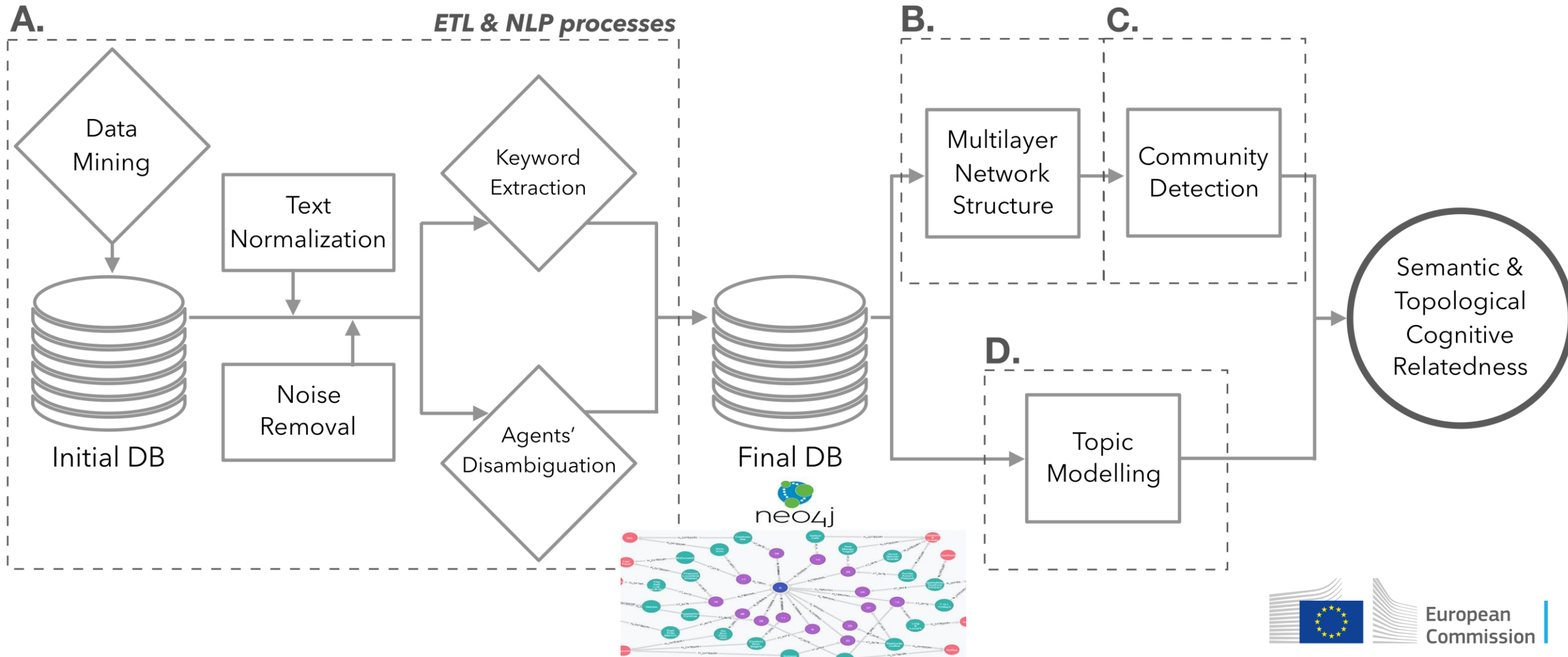
- addressing all the diverse types of players
- their locations
- their activities
- the structure of interactions and underlying relations
- mapping and detecting emergent behaviours/subdomains

→ based on multiple sources

→ applicable to virtually any segment



Landscape of AI in Europe – TES



Landscape of AI in Europe – Definition & Taxonomy

Starting from a Definition of AI to set the boundaries of the technological, and corresponding economic, domain:

- To be sure of what we agree to consider AI
- To frame the landscape
- To perform any activity in the AI Watch!

Validation: the def by the **High Level Expert Group on AI** is a simplified but still comprehensive definition of AI capabilities and research areas to describe summarily the joint understanding of this discipline

Need to provide an operational definition of AI, together with a **classification or taxonomy**, including the most characteristic **terms** belonging to the AI domain

Landscape of AI in Europe – Definition & Taxonomy

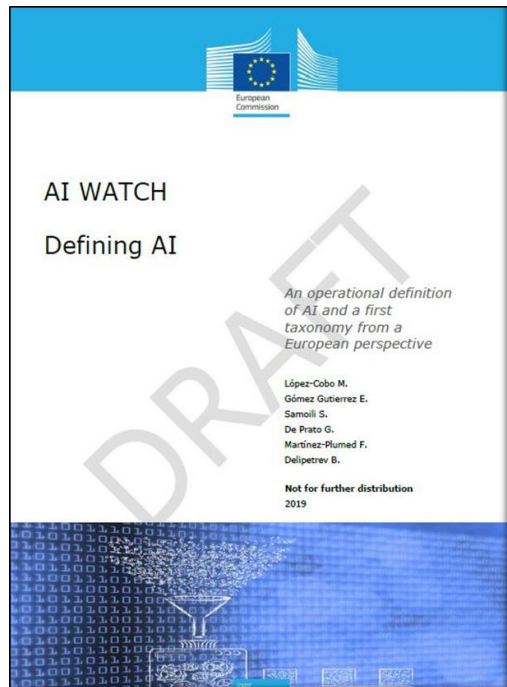
Artificial intelligence (AI) systems are software (and possibly also hardware) systems designed by humans¹ that, given a complex goal, act in the physical or digital dimension by perceiving their environment through data acquisition, interpreting the collected structured or unstructured data, reasoning on the knowledge, or processing the information, derived from this data and deciding the best action(s) to take to achieve the given goal. AI systems can either use symbolic rules or learn a numeric model, and they can also adapt their behaviour by analysing how the environment is affected by their previous actions.

¹ Humans design AI systems directly, but they may also use AI techniques to optimise their design. (The footnote is in the original).

Landscape of AI in Europe – Definition & Taxonomy

The AI WATCH subdomains of AI

derived from the definition developed
by the High Level Expert Group on AI



other relevant domains

- Reasoning & Decision making
 - *Knowledge representation & reasoning*
 - *Planning & scheduling*
 - *Searching, Optimisation*
- Learning
 - *Machine Learning*
 - Perception
 - *Natural language processing*
 - *Computer Vision*
- *Robotics & Automation*
- *Agents & Multi-agent systems*
- *AI Applications, Platforms, Software services*
- *AI ethics*

Knowledge Representation and Reasoning;**Searching; Optimisation**

bayesian optimization
case-based reasoning
causal inference
causal models
common-sense reasoning
constraint satisfaction
evolutionary algorithm
expert system
fuzzy logic
genetic algorithm
gradient descent
graphical models
inductive programming
information theory
knowledge reasoning
knowledge representation
knowledge representation and reasoning
latent variable models
metaheuristic optimisation
semantic web
stochastic optimization
uncertainty in artificial intelligence

Natural Language Processing

audio processing
chatbot
computational linguistics
conversation model
coreference resolution
information extraction
information retrieval
machine translation
natural language processing
question answering
sentiment analysis
speech processing
text classification
text mining
voice recognition

Machine Learning

active learning
adaptive learning
adversarial machine learning
adversarial network
anomaly detection
artificial neural network
automated machine learning
automatic classification
automatic recognition
bagging
bayesian modelling
boosting
classification
clustering
collaborative filtering
content-based filtering
convolutional neural network
data mining
deep learning
deep neural network
ensemble method
feature extraction
generative adversarial network
generative model
machine learning
multi-task learning
neural network
pattern recognition
probabilistic learning
probabilistic model
recommender system
recurrent neural network
recursive neural network
reinforcement learning
semi-supervised learning
statistical learning
statistical relational learning
supervised learning
support vector machine
transfer learning
unstructured data
unsupervised learning

Computer Vision

action recognition
computer vision
face recognition
gesture recognition
image processing
image retrieval
object recognition
recognition technology
sensor network
visual search

AI Applications, Platforms, Software services

ai applications
ai benchmark
ai competition
ai software toolkits
analytics platform
big data
business intelligence
central processing unit
computational creativity
computational neuroscience
data analytics
decision analytics
decision support
distributed computing
graphics processing unit
intelligence software
intelligent control
intelligent control system
intelligent hardware development
intelligent software development
intelligent user interface
internet of things
machine learning framework
machine learning library
machine learning platform
personal assistant
platform as a service
tensor processing unit
virtual environment
virtual reality

Robotics & Automation

automated vehicle
autonomous driving
autonomous system
autonomous vehicle
cognitive system
control theory
human-ai interaction
industrial robot
robot system
self-driving car
service robot
social robot
unmanned vehicle

AI Ethics

accountability
ai ethics
explainability
fairness
privacy
safety
security
transparency

Agents & Multi-agent systems

agent-based modelling
agreement technologies
computational economics
game theory
intelligent agent
multiagent system
negotiation algorithm
network intelligence
q-learning
swarm intelligence

General

artificial general intelligence
artificial intelligence
narrow artificial intelligence
strong artificial intelligence
weak artificial intelligence

Landscape of AI in Europe – TES

Eco-System's Types of Activities	Number of detected Documents	Number of detected Players
Production and Trade	18'357	16'681
Innovation	29'247	10'873
Frontier Research	4'719	1'856

Final Number of Documents*	Final Number of Players**
52'323	29'049

- ❑ v1: Initially collected 70'671 activities from 46'183 players
- ❑ resulting in 52'323 activities from 29'049

AI Players

Mapping of worldwide stakeholders to analyse relative competitive position of Europe

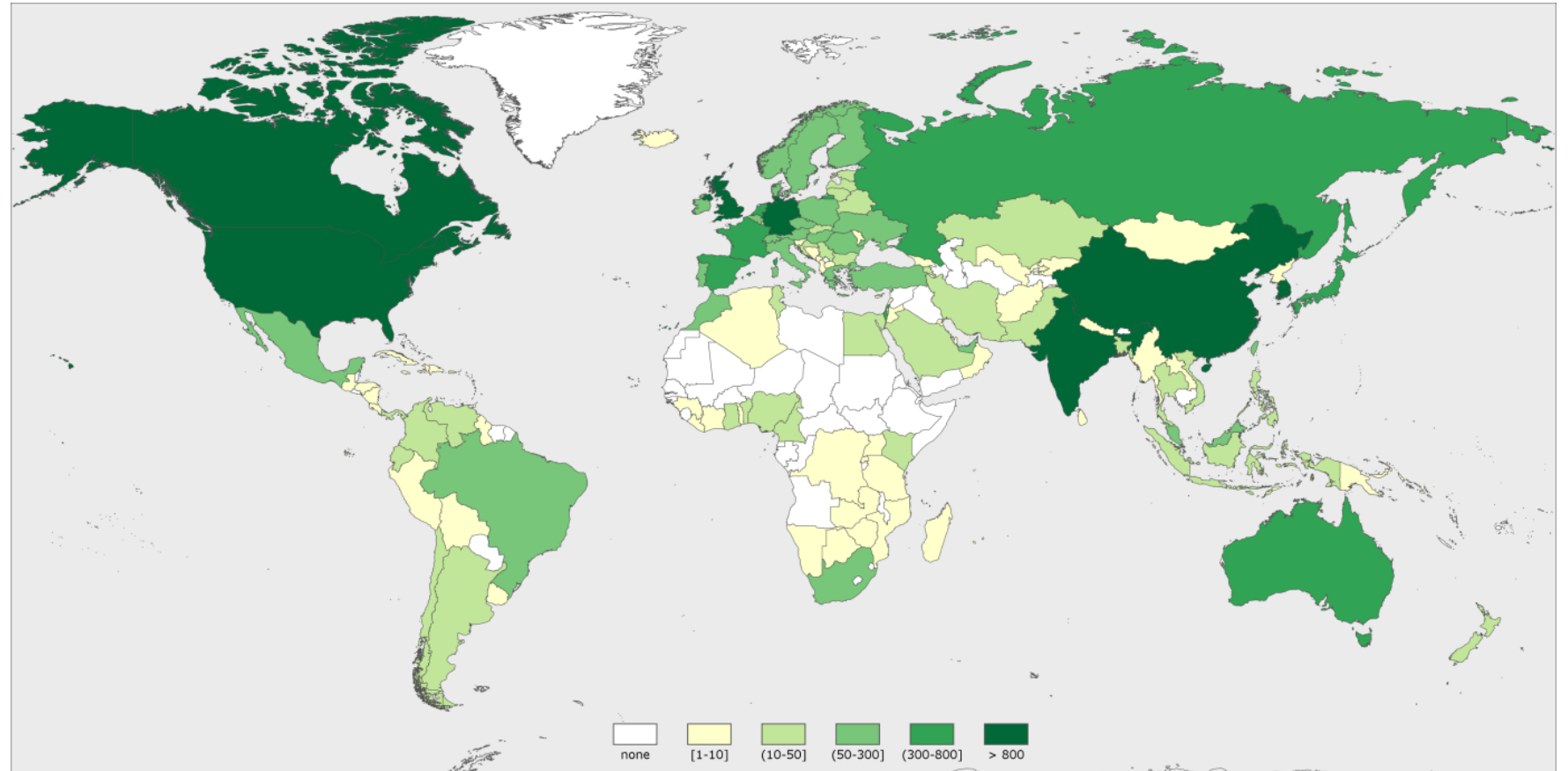
AI players

- Research centres
- Academia
- Companies
- Government

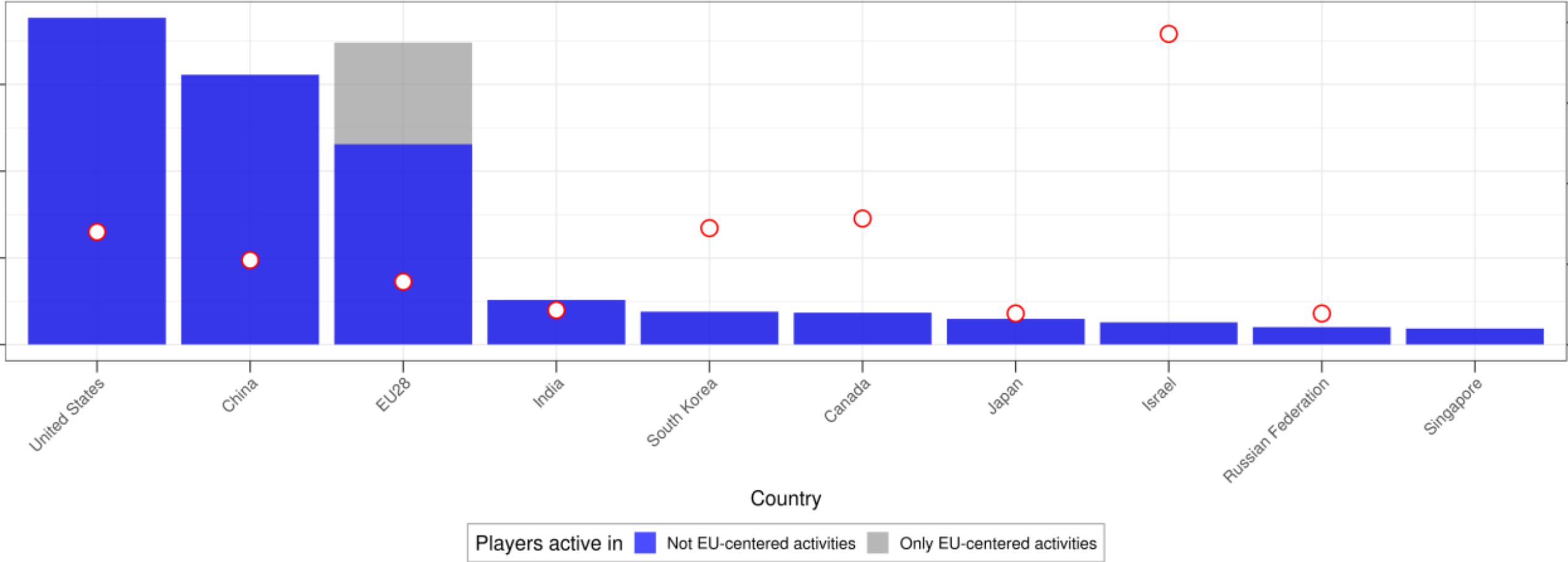
AI related economic activities

- R&D and innovation processes
- Industrial production and marketing
- AI-related services

Worldwide distribution of industrial and research players active in AI, 2000-2018



AI PLayers

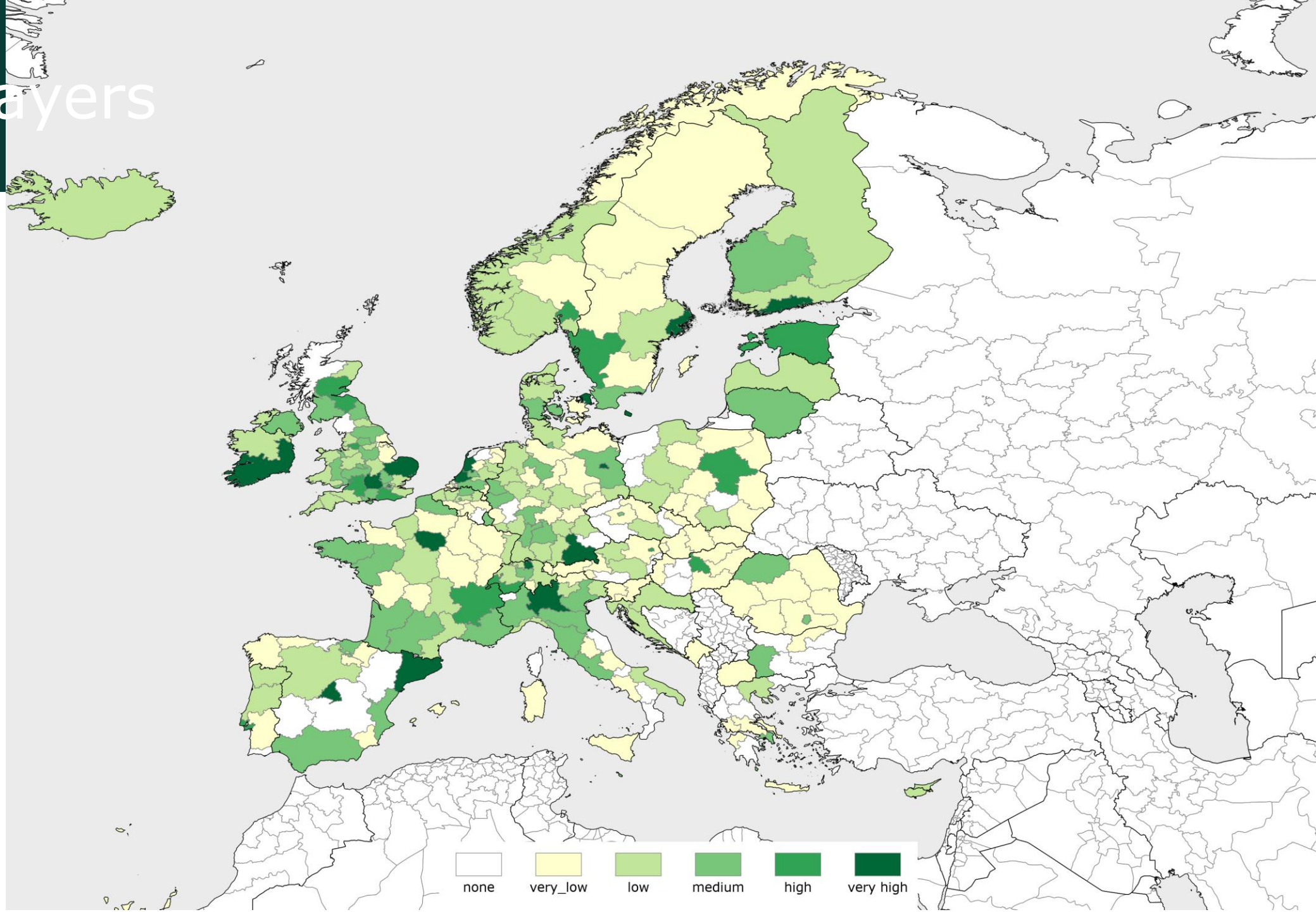


Number of AI players and percentage over GDP (PPS)

AI Players

AI players
Europe
NUTS2

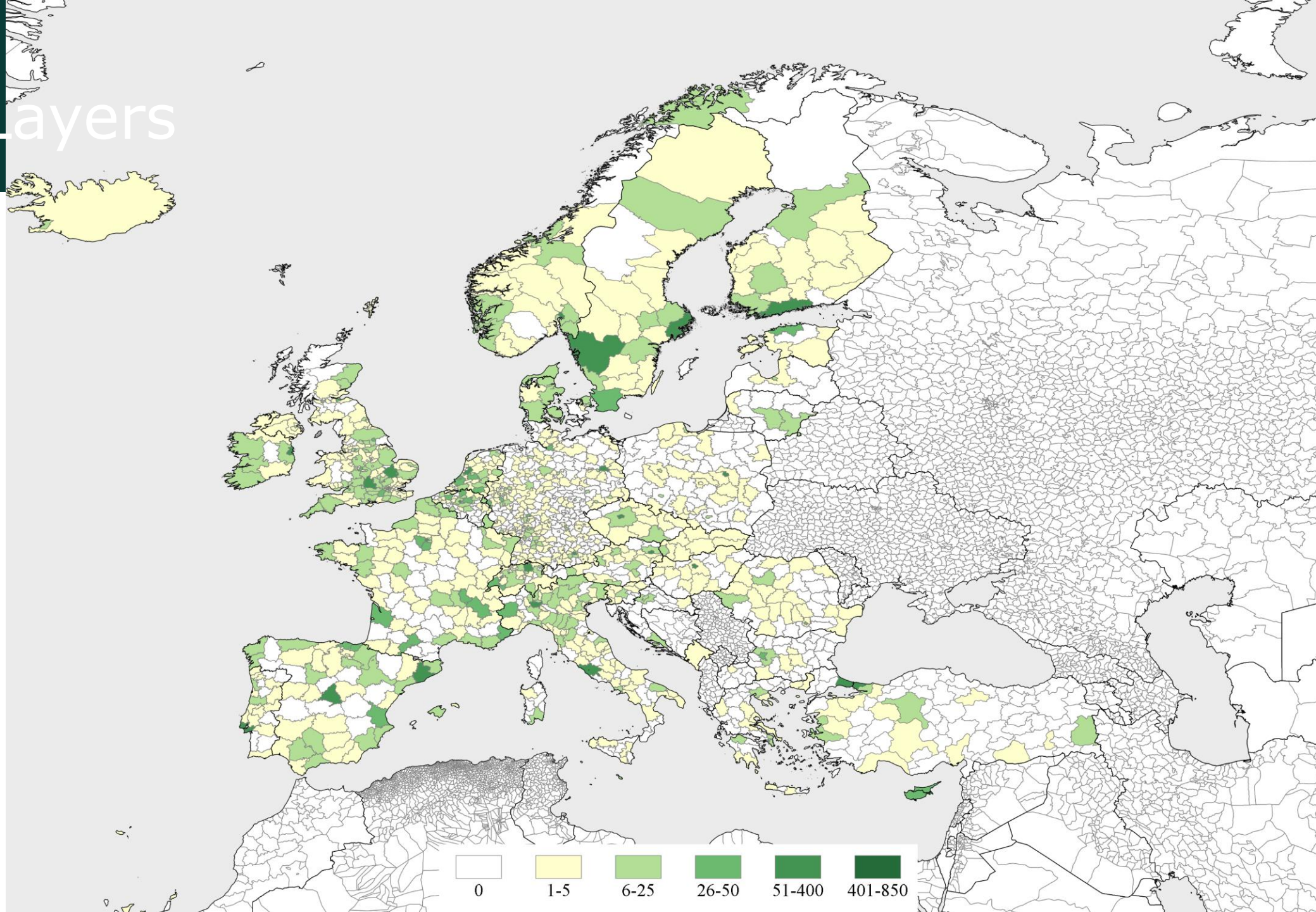
Regional
diversity



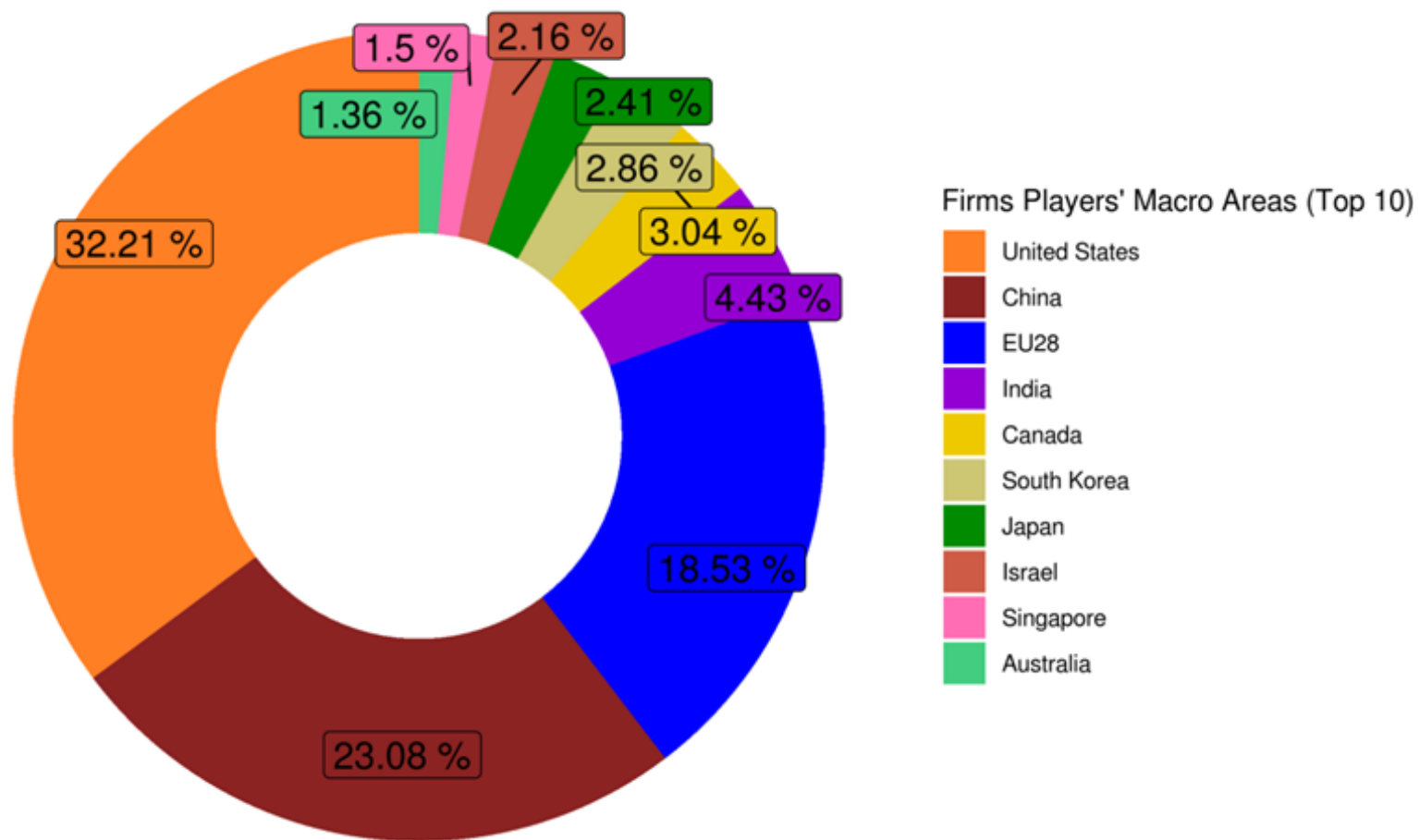
AI PLayers

AI players
Europe
NUTS3

Regional
diversity,
local
dimension



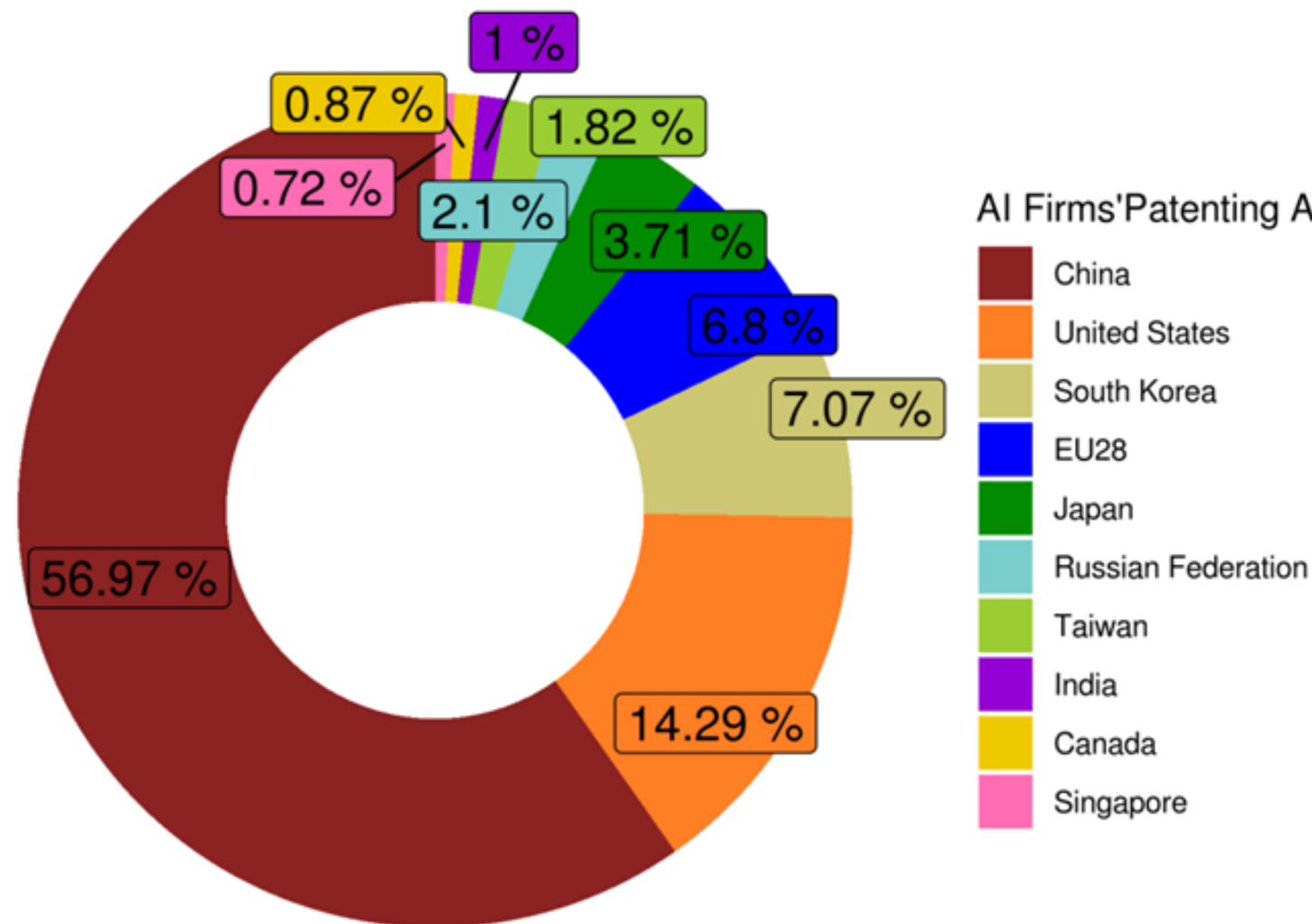
AI Industry landscape: AI firms worldwide



AI players
Only firms

US leads,
then CN

AI firms' patenting applicants worldwide

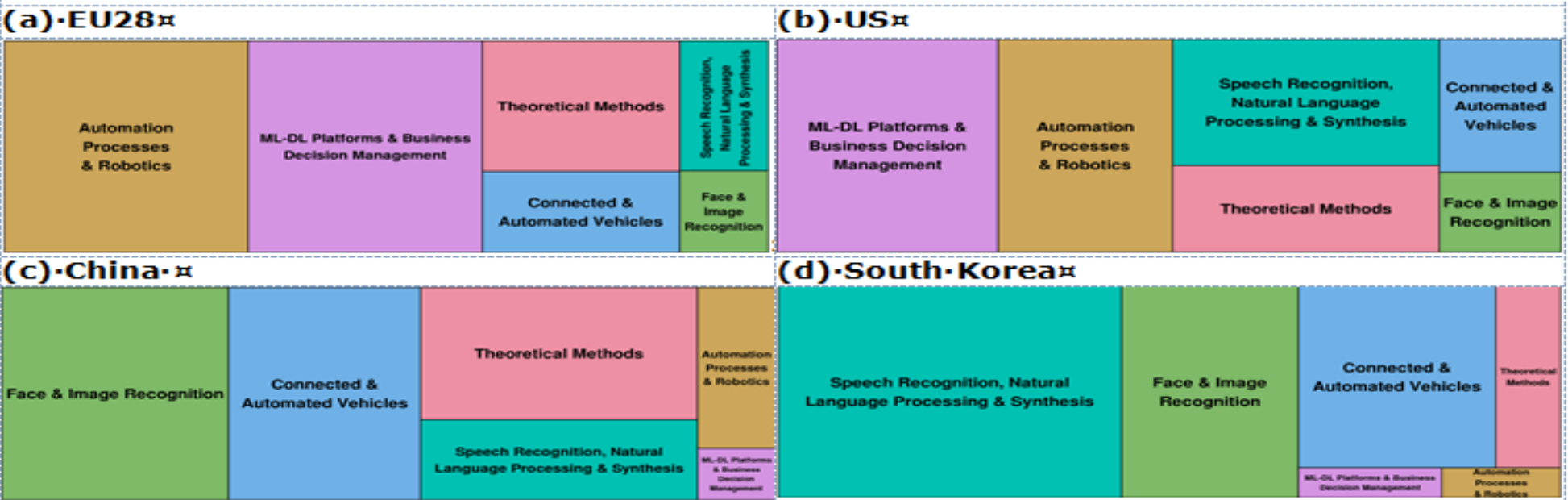
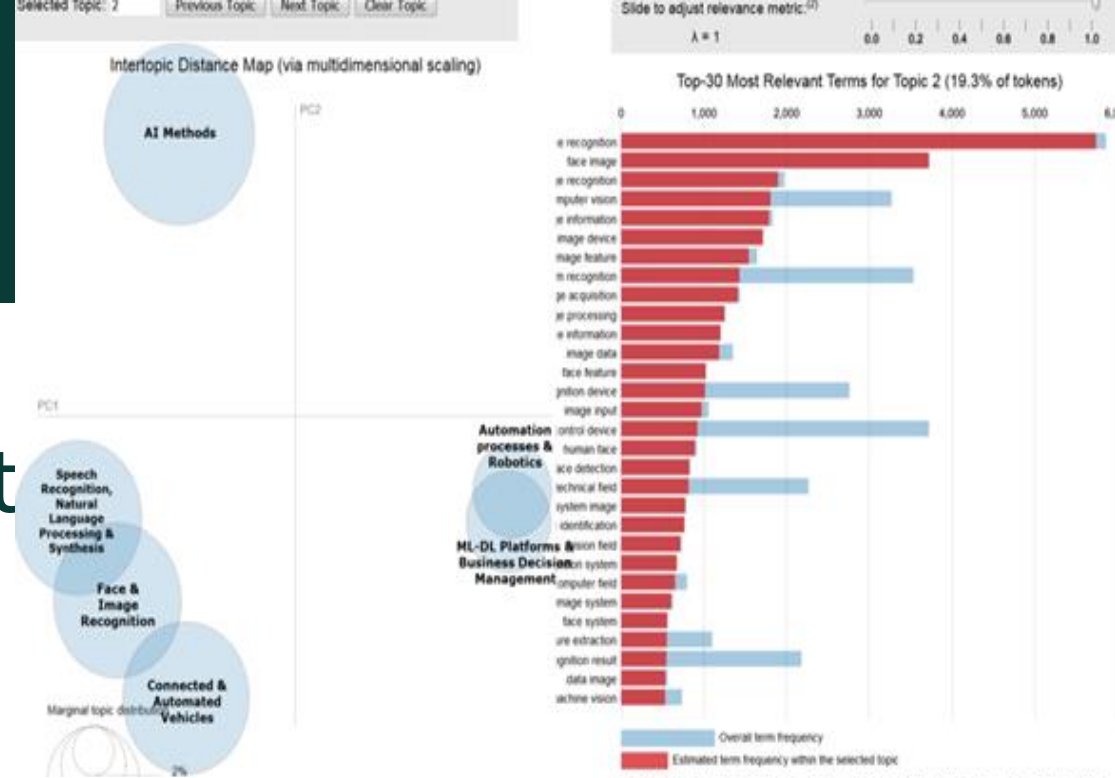


AI players
Patent apps

CN leads,
then US

AI Ecosystem

- mapping of **thematic key areas** of strength and their evolutionary path



1. saliency(term w) = frequency(w) * (sum_j p(j | w)) * log(p(j | w)/p(j)) for topics t , see Chuang et al. (2012)
 2. relevance(term w | topic t) = $\lambda * p(w | t) + (1 - \lambda) * p(w | \text{Doc})$, see Sievert & Shirley (2014)

AI R&D&I Players

Tracking distribution of players' organisational type ("affiliation"):

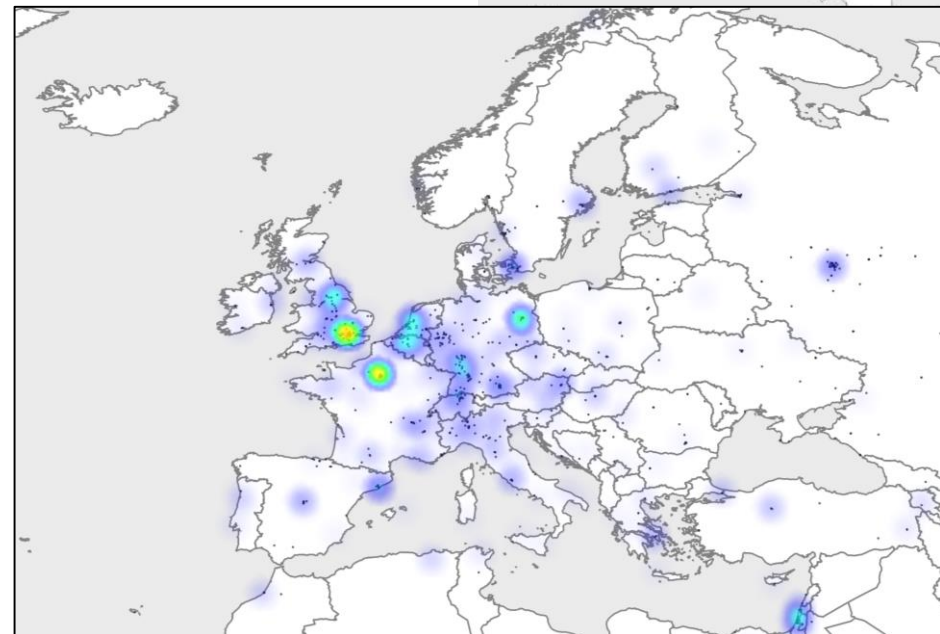
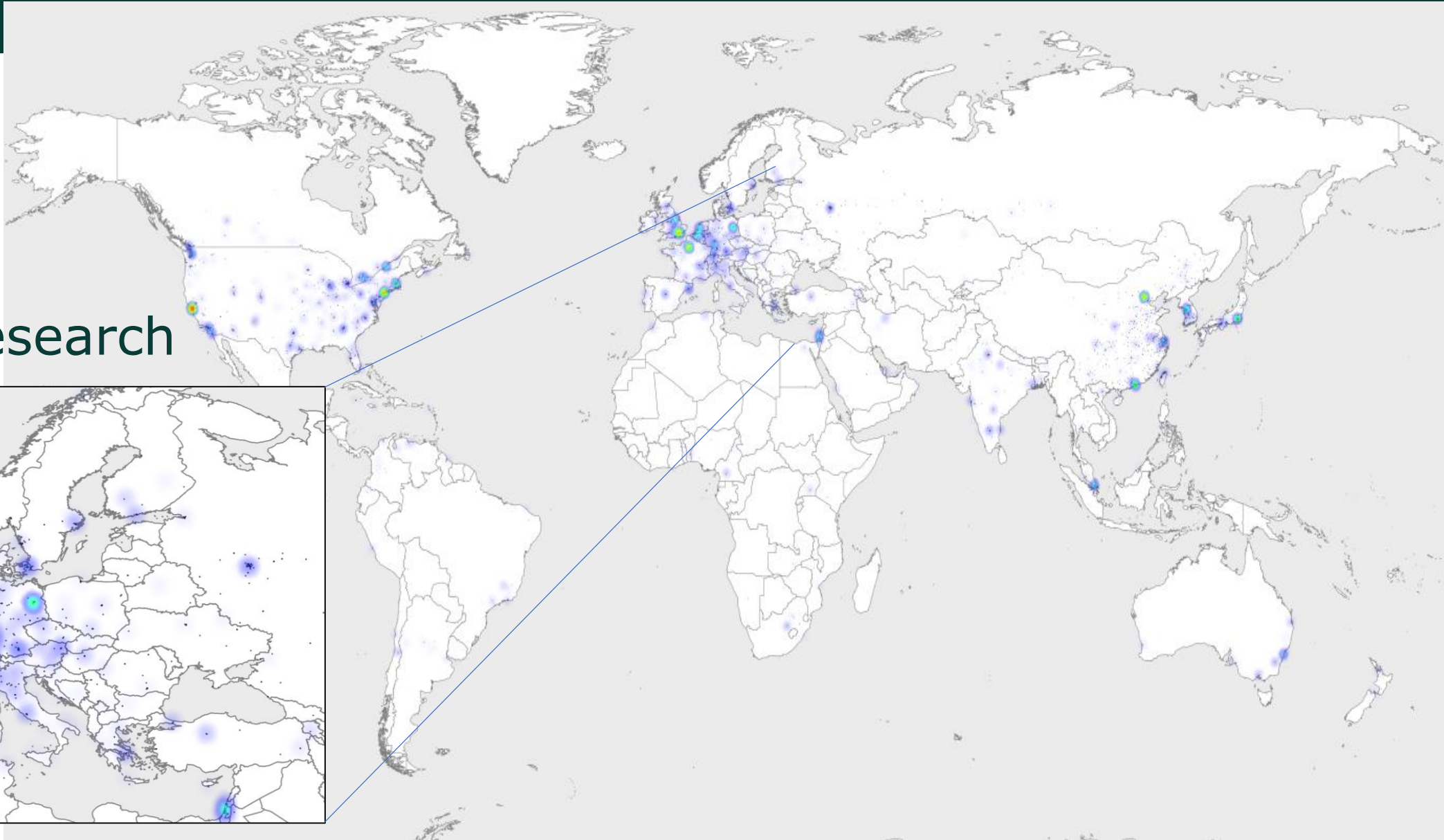
firms, governmental, research institutions

according to literature on Triple-Helix

	Firms	Governmental Institutions	Research Institutions	TOTAL
US	8`364	4	331	8`699
China	6`141	187	1`085	7`413
EU28	4`863	3	557	5`423
India	1`209	2	35	1`246
Other Asian countries	888	3	115	1`006
South Korea	783	2	139	924
Other European countries	739	12	160	911
Canada	796	1	62	859
Japan	582	0	68	650
Middle East	549	0	52	601
Other American countries	528	0	52	580
Oceania	413	0	40	453
Africa	258	1	25	284
TOTAL	26`113	215	2`721	29`049

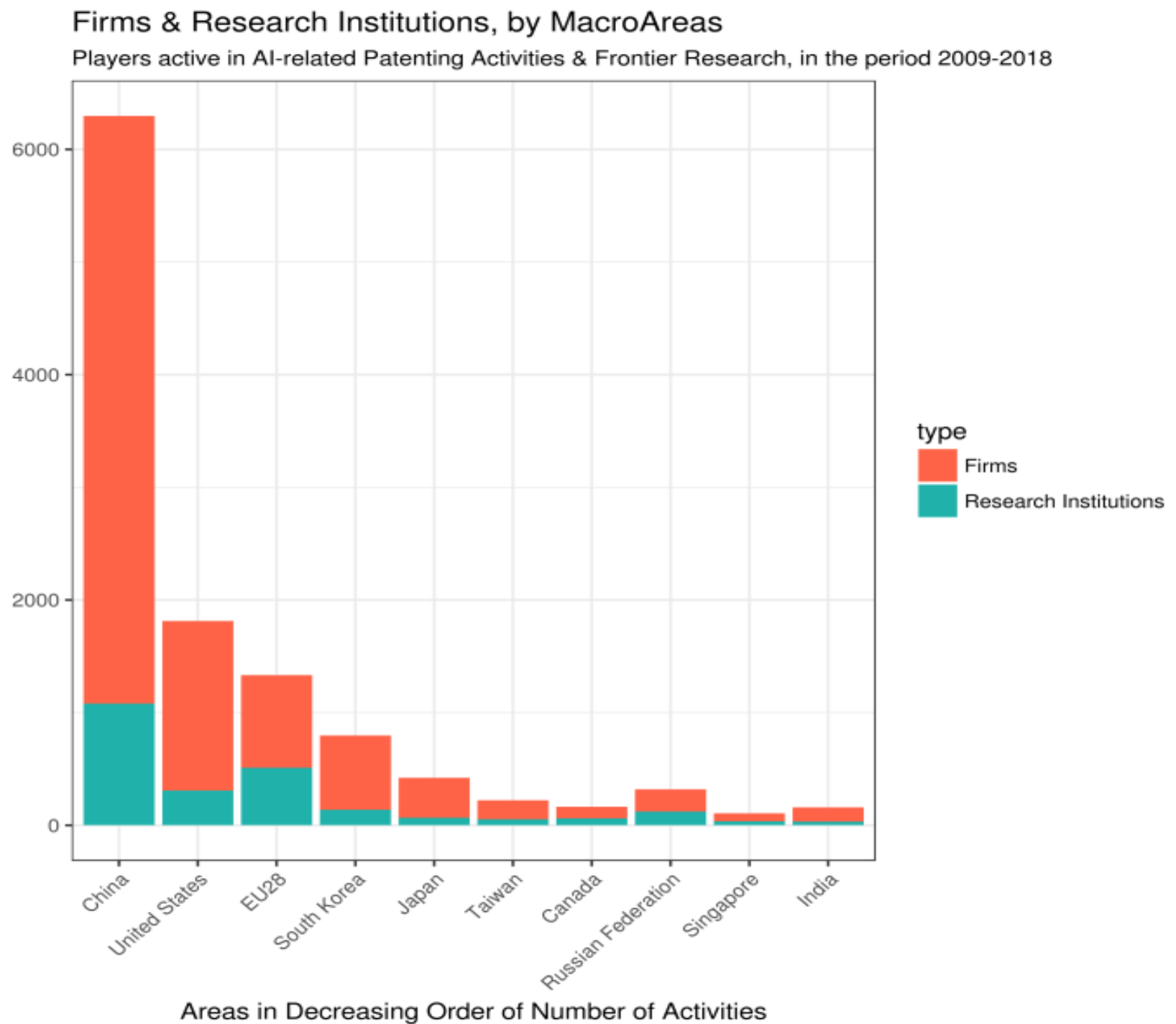
Frontier Research: top 10 AI Conferences

- Number of AI players worldwide active in Frontier Research



Bus Diversity in R&D

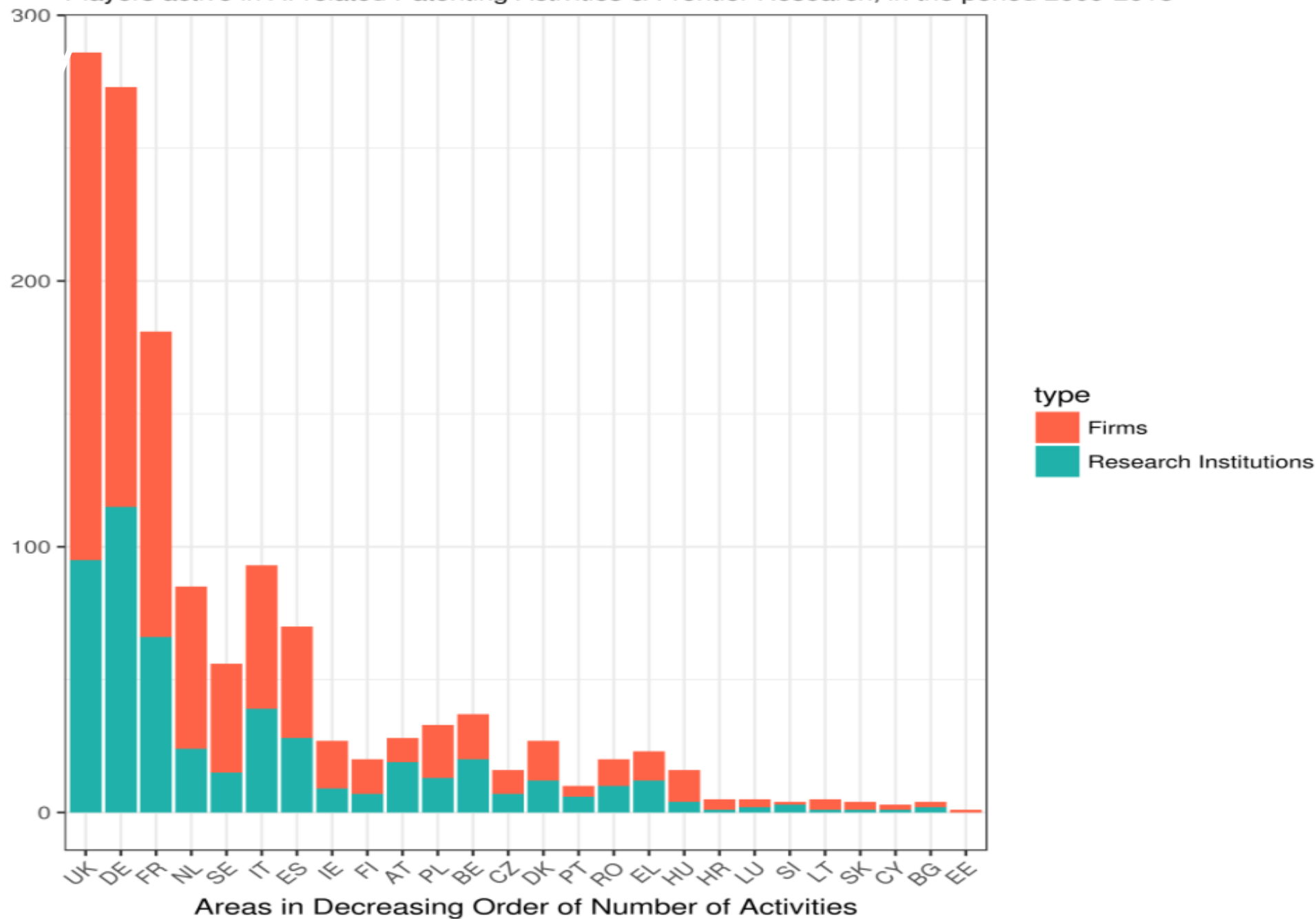
Number of firms and
Research Institutions
in AI patenting
and frontier research
activity



Bus Diver in R&D

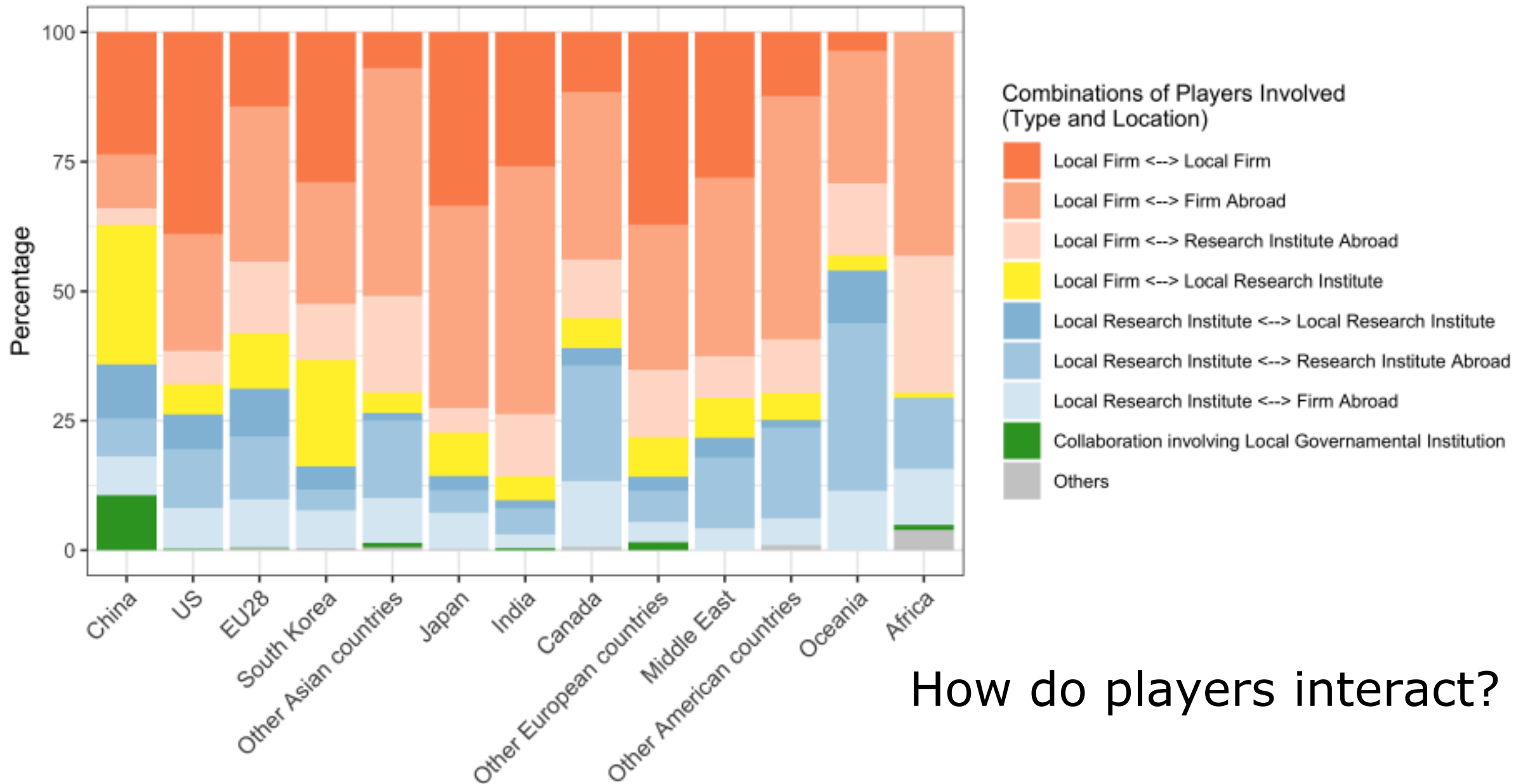
Firms & Research Institutions, by MacroAreas

Players active in AI-related Patenting Activities & Frontier Research, in the period 2009-2018



Collaborations developed by Worldwide Macroareas

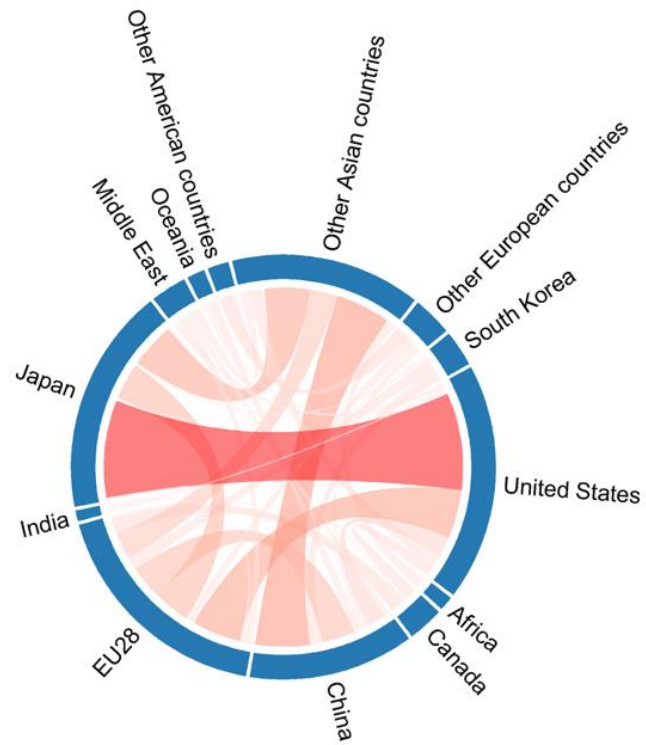
by Combinations of Players Involved



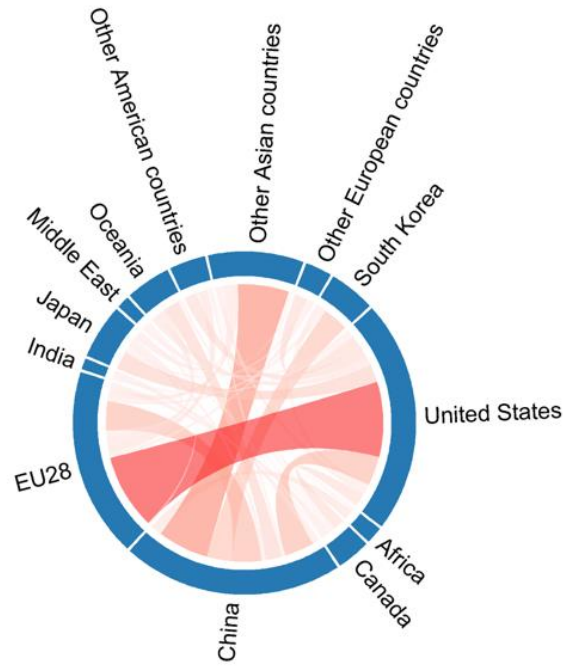
Worldwide Macroareas in Decreasing Order of Number of Activities

How do players interact?

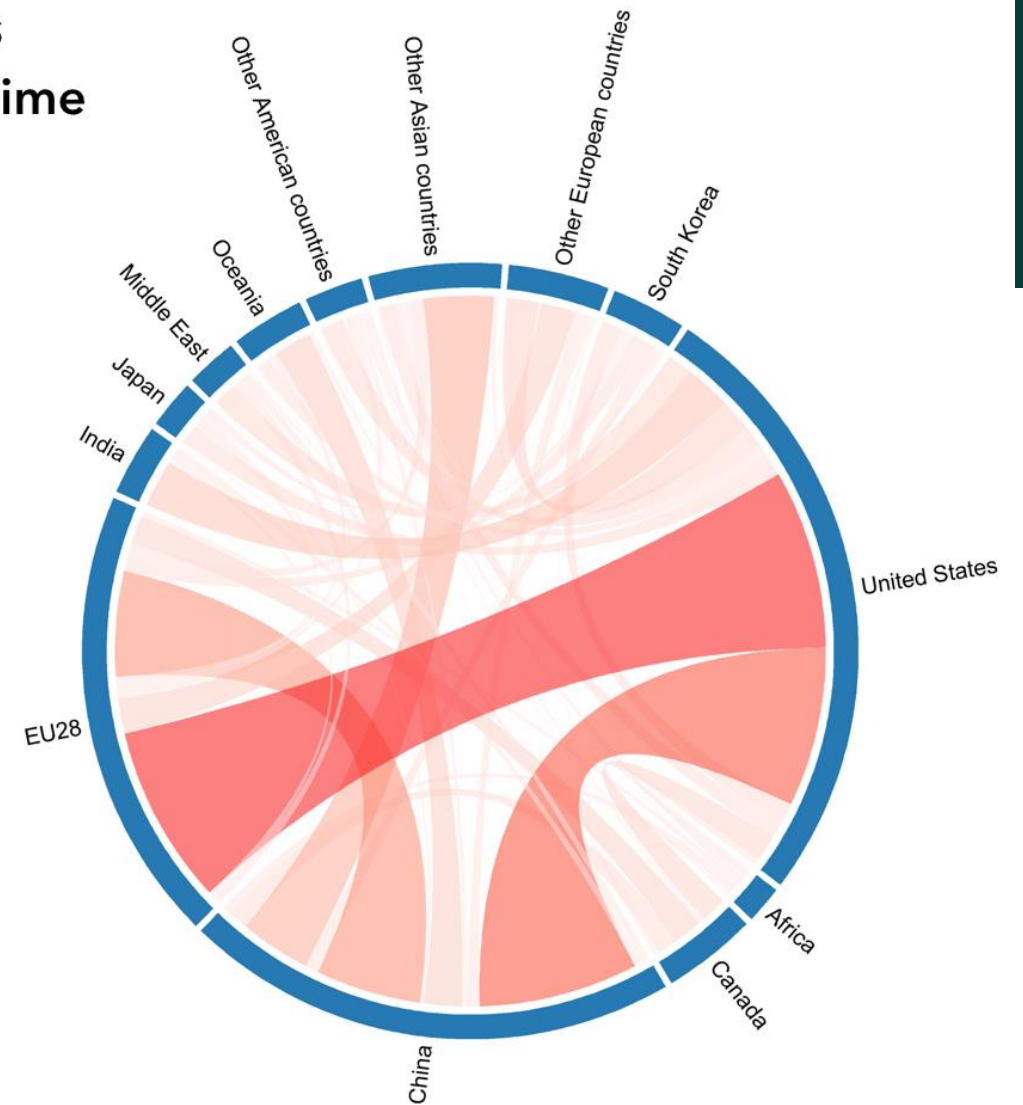
AI Technological Collaborations between Geo-Political Areas, over time



2009-2011



2012-2014



2015-2017

Radius of the diagrams proportional to the amount of external collaborations in the corresponding period of time

AI Ecosystem

- An holistic view to players' **activities** and **interactions**
- Mapping of the networks of **collaborations** at global level
- Diversity of roles in the network

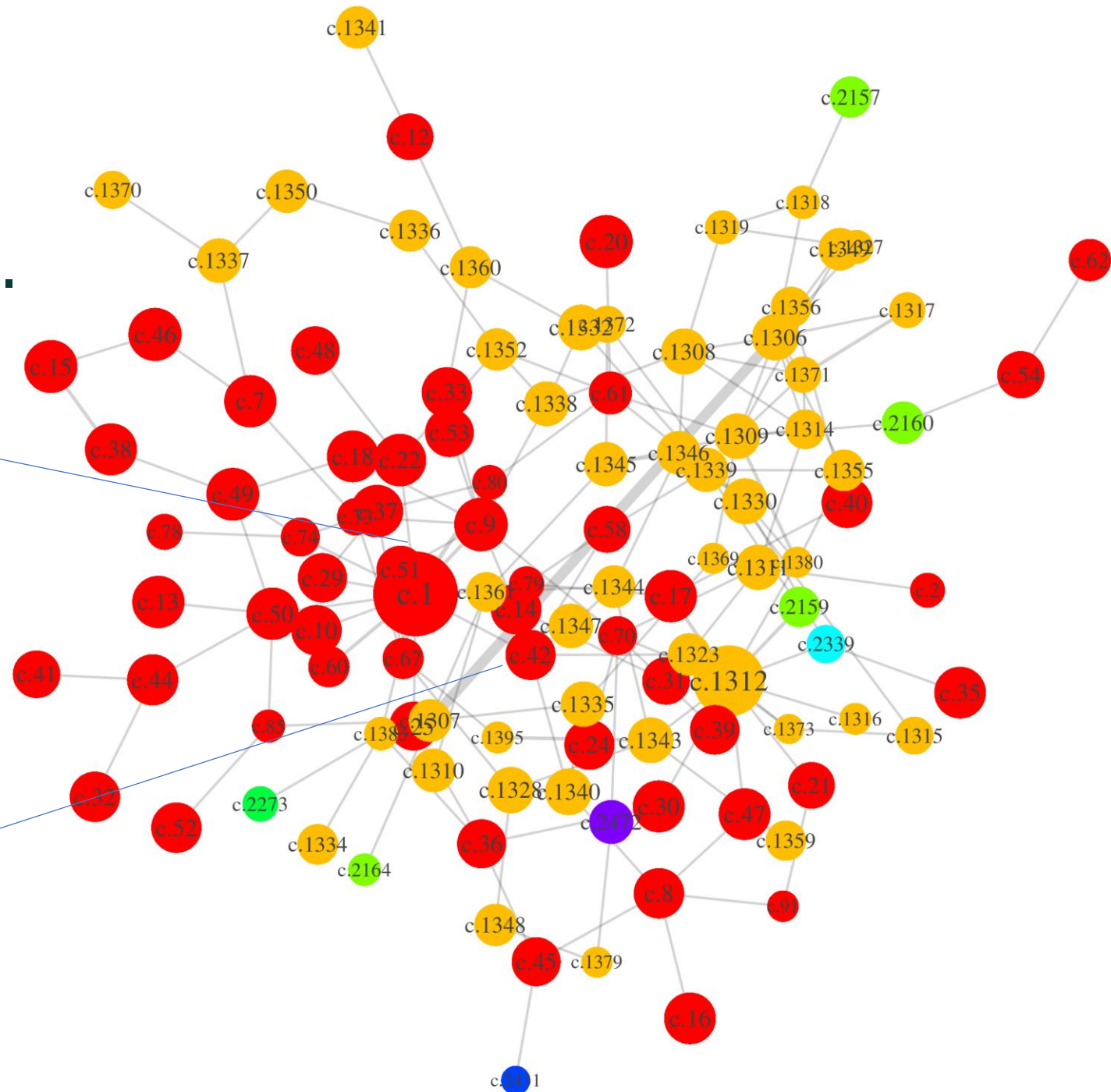
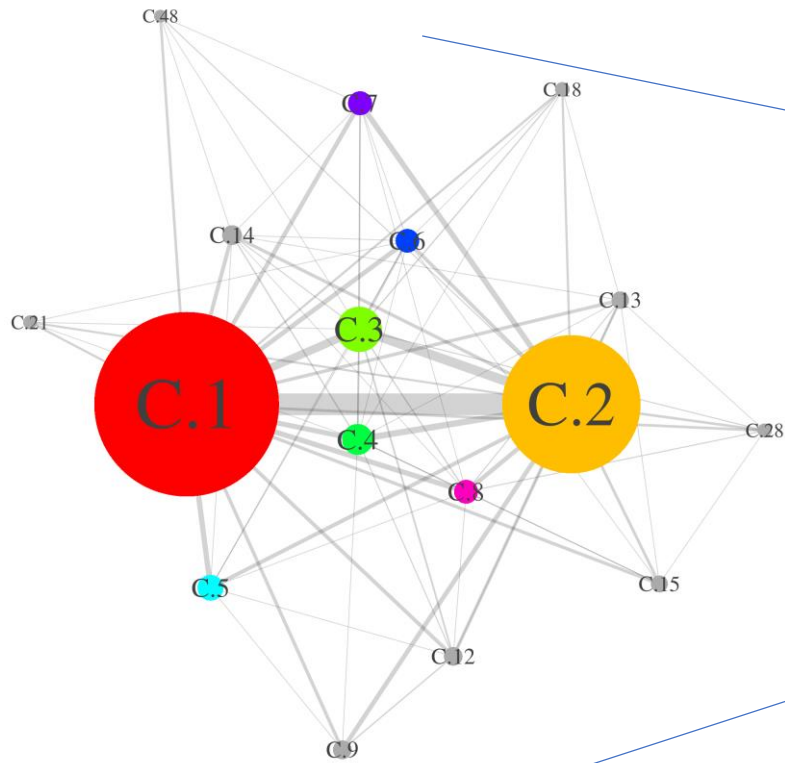
Network of players by shared activities

Top 100 active players, labels displayed for top 10 active players



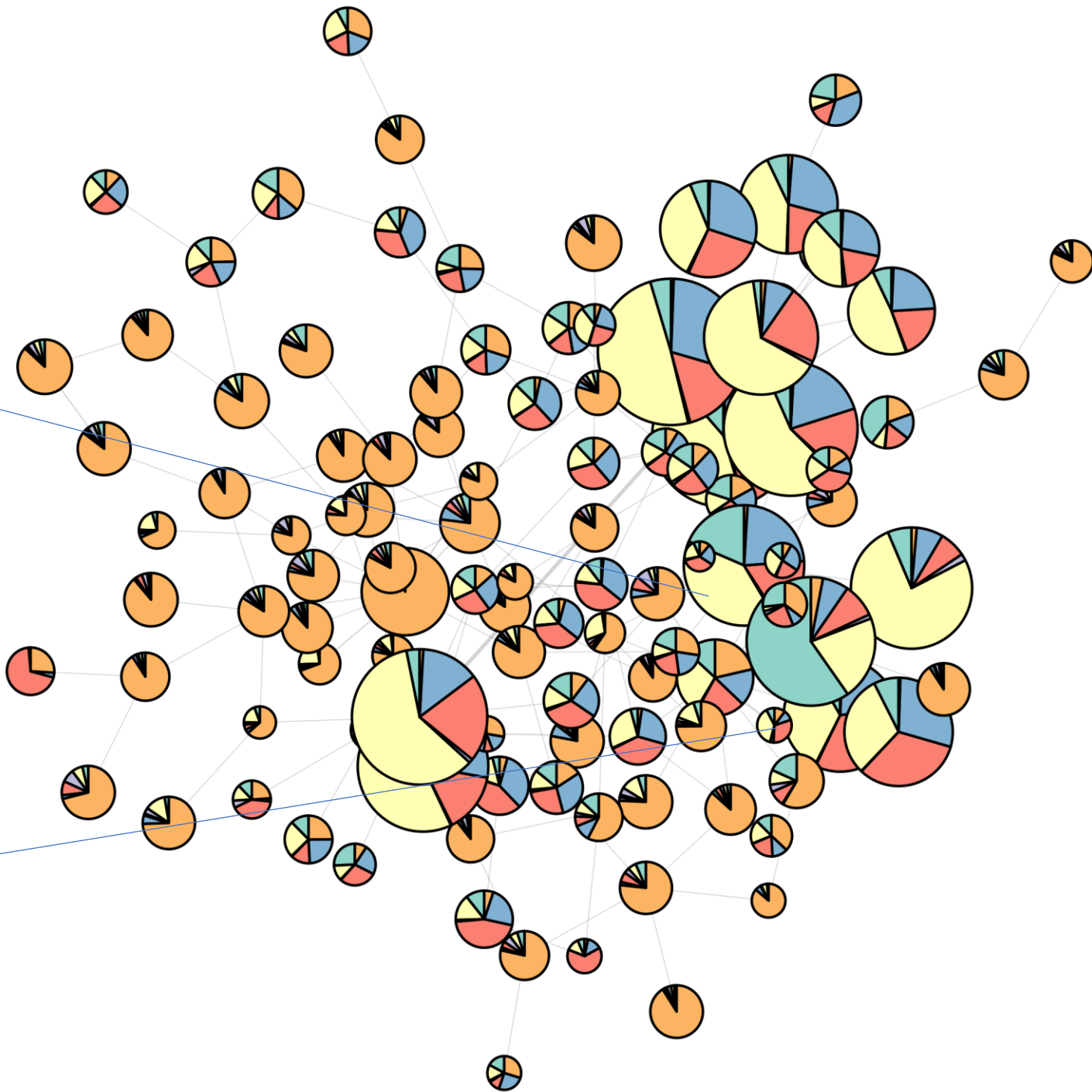
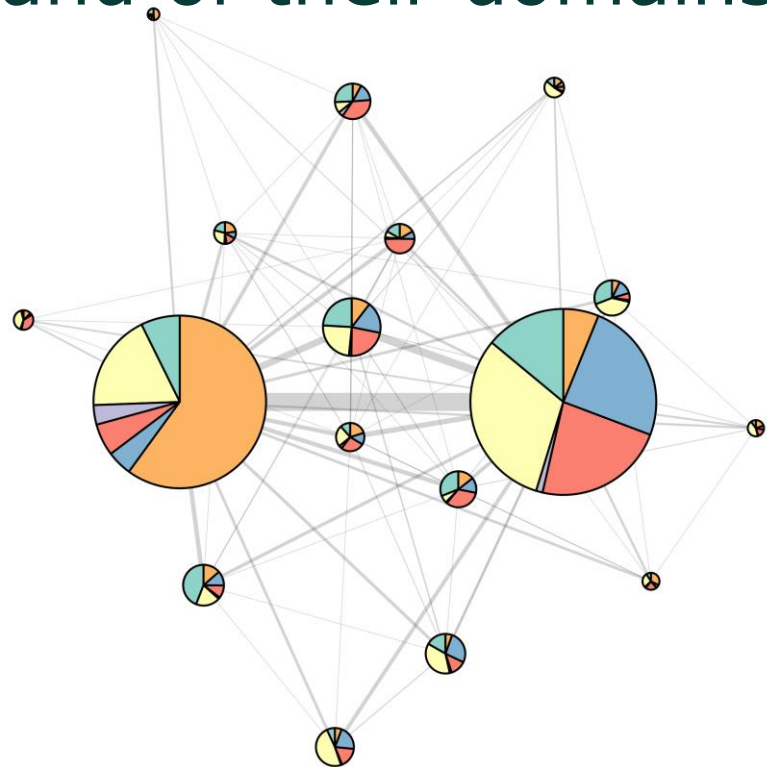
AI Ecosystem

- Detection of communities..



AI Ecosystem

- and of their domains



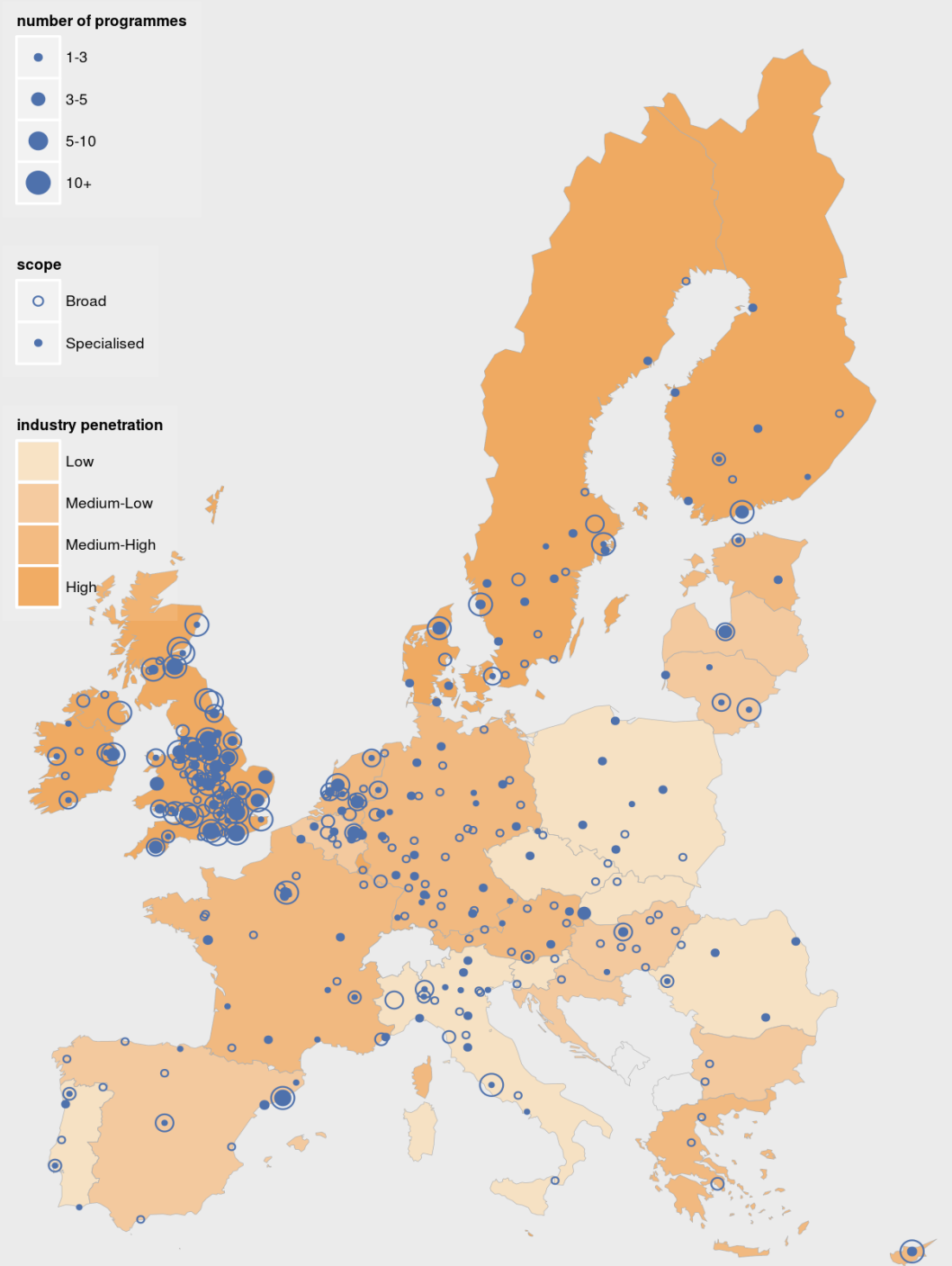
Industry vs Education offer in AI

Industry penetration of AI: The number of AI enterprises over total number of enterprises (Source denom.: Eurostat's SBS)

✓ **Highest penetration rates of AI industry:** MT, UK, DK, IE, FL, Lux, SE

AI academic offer: Total number of programmes (Bachelors & Masters)

✓ **Top 5 European cities by number of specialised programmes on AI** (Bachelors & Masters): London, Southampton, Edinburgh, Barcelona, and Manchester.



Thanks!



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