Innovation and business dynamics in the era of artificial intelligence and robotization

INNOVA MEASURE III Expert Workshop

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The evolution of AI

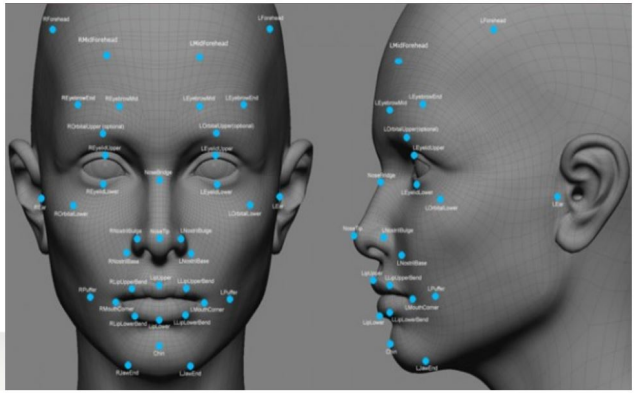
- "Second Machine Age" driven by rapid advances in Artificial Intelligence
  - ✓ "*[M]ake machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves*" (McCarthy, Minsky, Rochester, and Shannon, 1956)
  - ✓ "*An intelligent agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors*" (Russell and Norvig, 2009)
  - ✓ "*[T]hat activity devoted to making machines intelligent, and intelligence is that quality that enables an entity to function appropriately and with foresight in its environment*" (Nilsson, 2009)
- Most definitions of AI revolve around "simulation of intelligent behavior by machines"

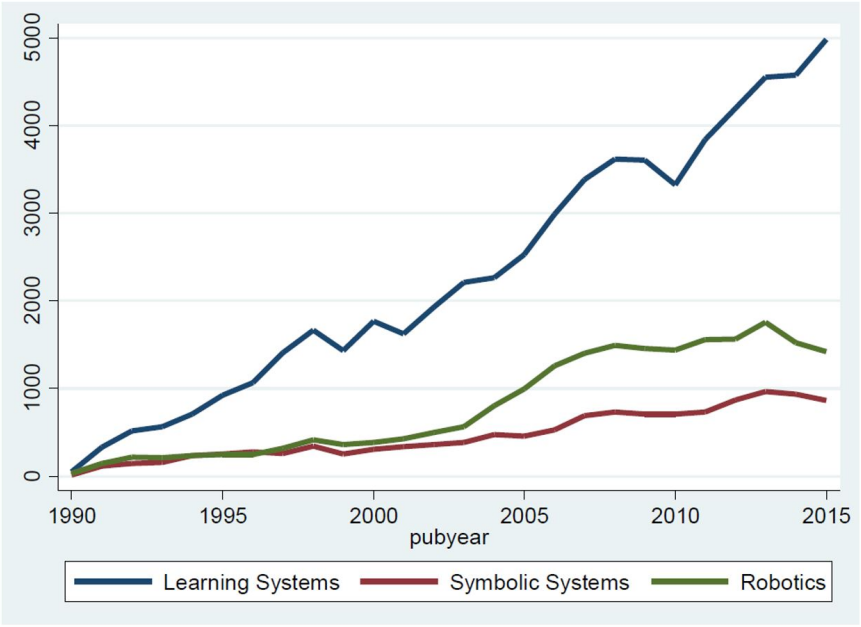
The evolution of AI

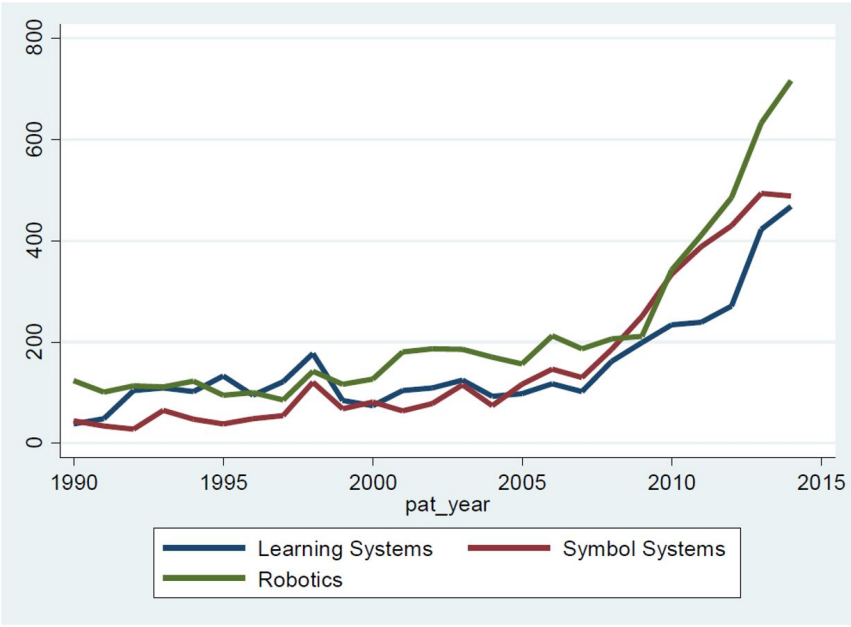
- AI brings together a number of distinct subfields such as machine learning, computer vision, natural language processing, symbolic reasoning, knowledge representation, and robotics

- Three interrelated but separate areas of research:
  - ✓ Symbolic systems attempt to replicate flow of human decision making through processing symbols (e.g., board games)
  - ✓ Robotics develop machines that can perform human tasks (e.g., industrial robots programmed to undertake a given task in a highly controlled environment)
  - ✓ Learning systems attempt to create accurate methods for the prediction of particular events in the presence of particular inputs (e.g., neural networks)

- AI is surpassing human performance in a growing number of domains







Source: Cockburn, Henderson, and Stern (2018) backup

AI and the economy

- AI could contribute up to EUR 13.33 trillion to the global economy by 2030, of which 40% would come from productivity gains (EU, 2017)

- The economic impact of AI is mostly driven by:

✓ Productivity gains from automation: companies maximise value by improving input (labour, capital and assets) productivity

✓ Increased consumer demand: personalised AI-enhanced products and services

✓ Knowledge creation and dissemination: lower R&D costs and new possibilities for experimentation

AI and the economy

- AI and the modern productivity paradox (Brynjolfsson, Rock, and Syverson, 2017) backup
- AI has all the characteristics of GPTs (Cockburn, Henderson, and Stern, 2018; Klinger, Mateos-Garcia, and Stathoulopoulos, 2018):
  - ✓ Pervasive
  - ✓ Improves over time
  - ✓ Spans complementary innovations
- Stock must be accumulated to affect aggregates, and the complementary assets need to be invented and installed (Brynjolfsson and McAfee, 2014)

Today's discussion

- AI and labor
- AI adoption and barriers
- Global race for AI dominance
- Ongoing research at BETA

AI and labor

- Do AI and labor complement or substitute each other? No systematic empirical evidence!

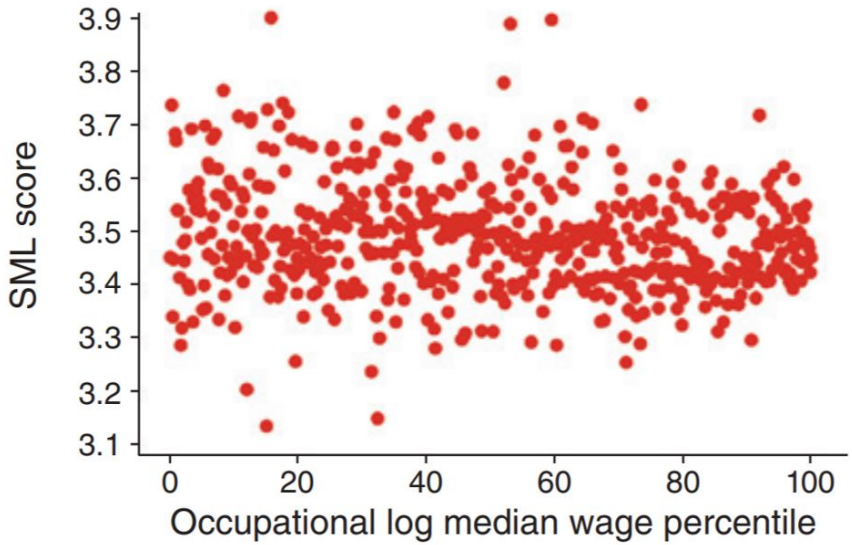
- Some studies on industrial robots:
  - ✓ Overall increase productivity and wages, but decrease in the employment of low-skill workers (Graetz and Michaels, 2015)
  - ✓ Significant decline of employment and wages in commuting zones exposed to intense use of robots; negative but smaller effect at aggregate level (Acemoglu and Restrepo 2017)

AI and labor

- Humans and machines have different strengths
  - ✓ Humans: creativity, improvisation, dexterity, judging, social and leadership abilities, etc.
  - ✓ Machines: speed, accuracy, repetition, prediction capabilities, scalability, etc.
- The unit of analysis is not "the job" or "the occupation" but the "task" (*collection of decisions based on prediction and judgement and informed by data*) (Agrawal, Gans, and Goldfarb, 2018a)
- Some tasks within an occupation may be *suitable for machine learning* (SML) while others may not, hence the overall effects on employment are very complex (Brynjolfsson, Mitchell, and Rock, 2018)

What can machines learn?

Low SML occupations	SML	High SML occupations	SML
Massage therapists	2.78	Concierges	3.9
Animal scientists	3.09	Mechanical drafters	3.9
Archeologists	3.11	Morticians, undertakers, and funeral directors	3.89
Public address system and other announcers	3.13	Credit authorizers	3.78
Plasterers and stucco masons	3.14	Brokerage clerks	3.78



Source: Brynjolfsson, Mitchell, and Rock (2018)

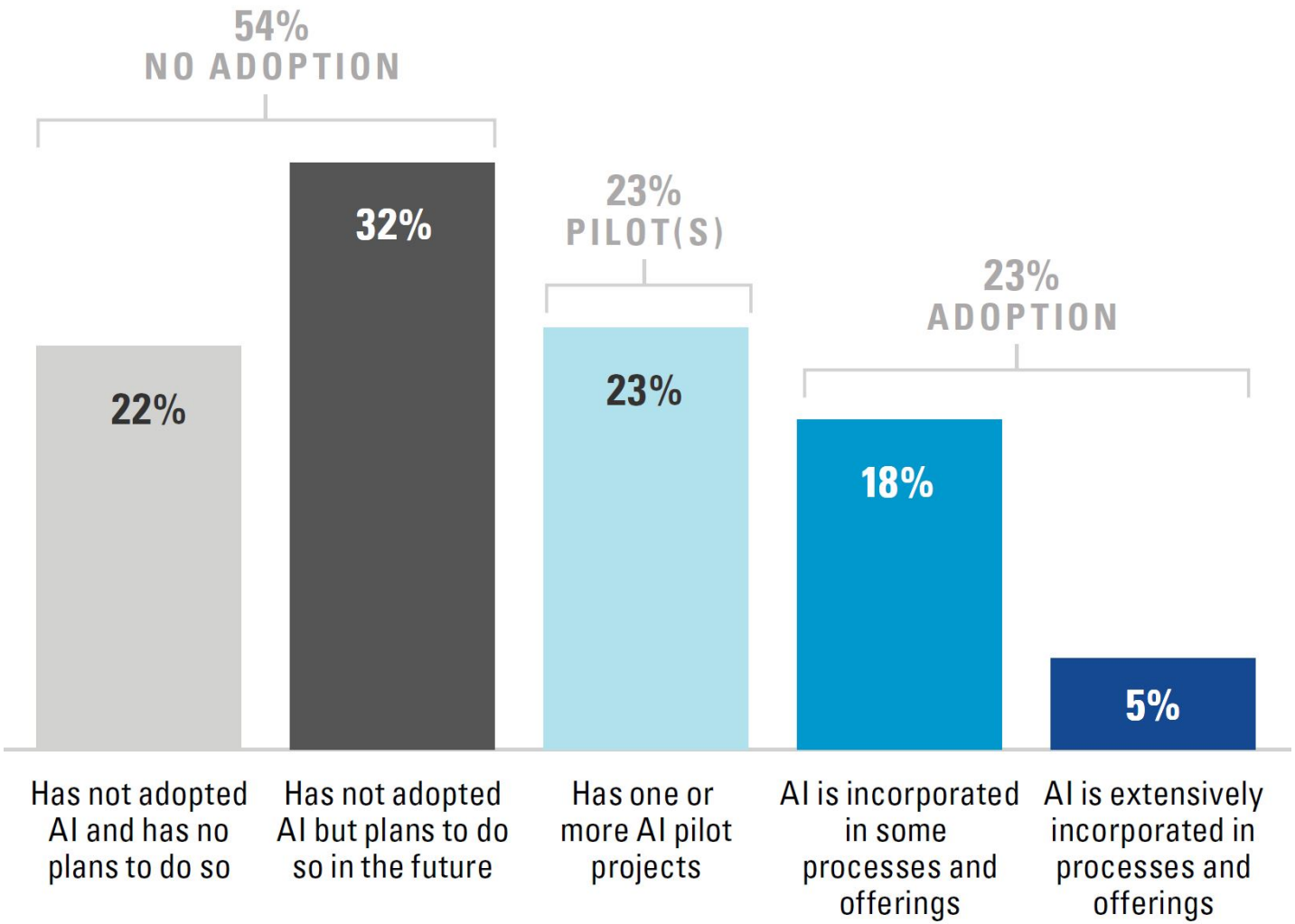
Human + Machine

- AI tools may free up time, creativity and human capital, letting people work more like humans and less like robots (Daugherty and Wilson, 2018)
- There are potential benefits from H+M cooperation as AI can complement and amplify human capabilities
  - ✓ Camelyon Grand Challenge 2016 for metastatic breast cancer detection
  - ✓ Smarter R&D and business innovation with intelligent systems
  - ✓ Unmanned vehicle for mining
- The most important effect on labor is the increasing importance of human *judgement* in decision making (Agrawal et al., 2018b)

AI adoption

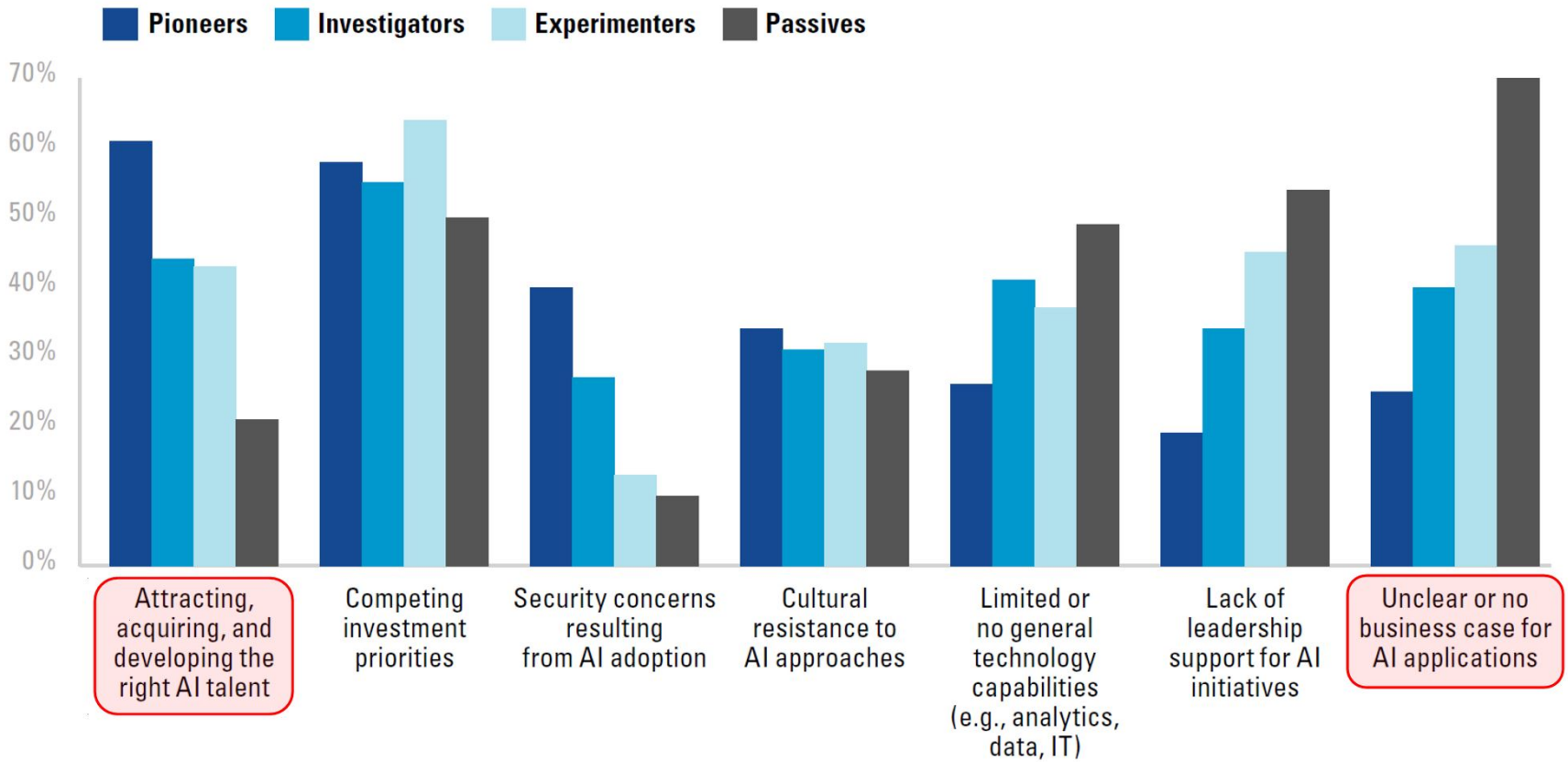
- Despite high expectations, business adoption of AI technologies is still at an embryonic stage
- AI has scale economies (e.g., data-scale advantage) and first-mover advantages may have long-lasting consequences
- Companies are adopting AI mostly to obtain and sustain competitive advantages and move into other markets backup
  - ✓ Few large companies are investing heavily and competing aggressively to acquire key AI assets
  - ✓ Several start-ups are deploying AI-fuelled products and services (backed by massive venture capital)

AI adoption



Source: Ransbotham, Kiron, Gerbert, and Reeves (2017)

Barriers to AI adoption



Source: Ransbotham, Kiron, Gerbert, and Reeves (2017)

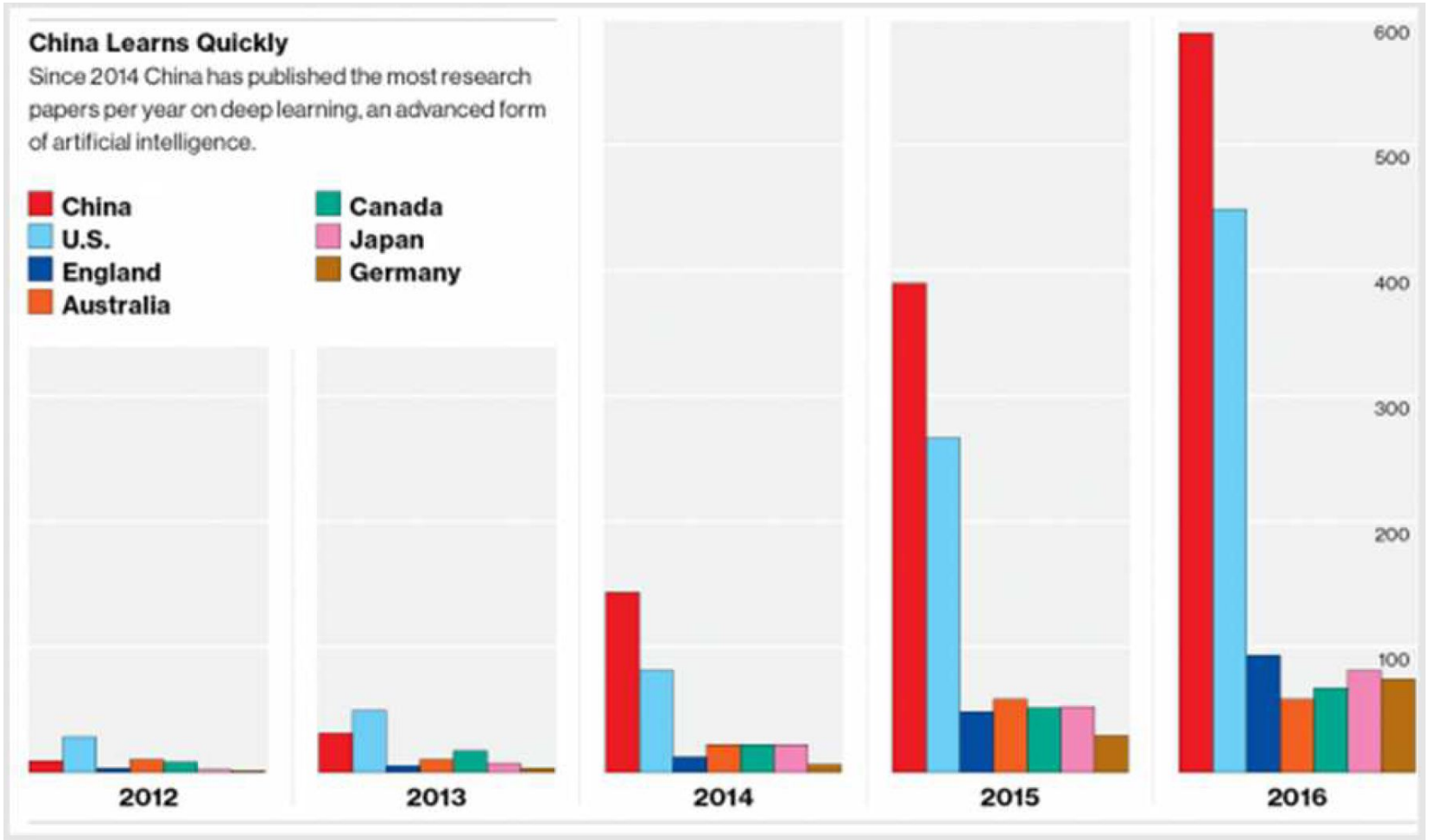
Race for AI leadership

- Early AI adopters will be the next global leader
- Countries can change their regulatory environment and direct public spending to foster the development of AI
  - ✓ Make long-term investments in AI research
  - ✓ Stimulate AI adoption in public and private sector
  - ✓ Improve humans' skills to partner with machines
  - ✓ Educate to understand the opportunities offered by AI
  - ✓ Address the ethical and legal implications of AI deployment

Race for AI leadership

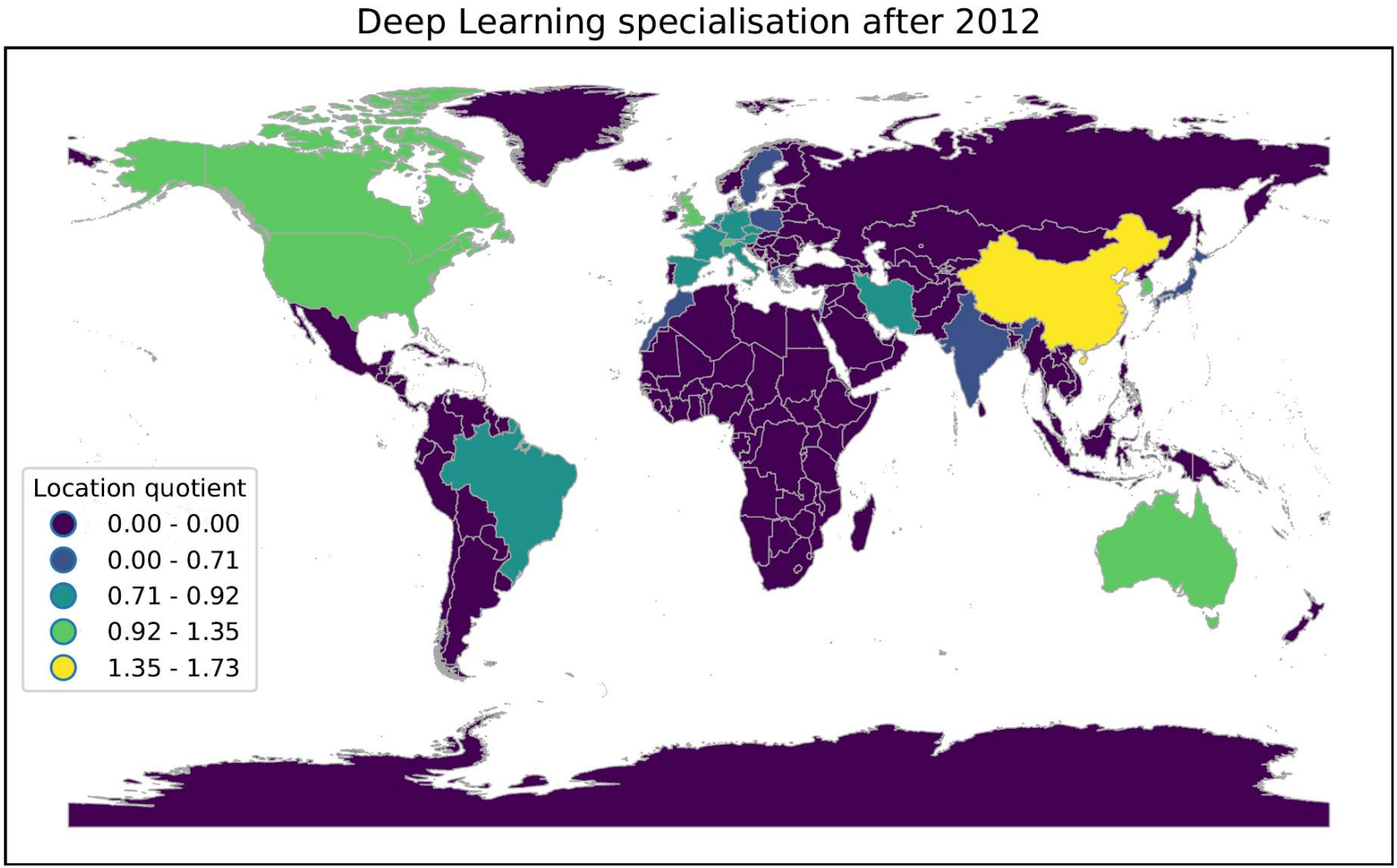
- Some countries are developing strategic plans for AI supremacy
  - ✓ US: The American National AI R&D Strategic Plan (May 2016)
  - ✓ China: Next Generation AI Development Plan (July 2017)
  - ✓ Europe: No strategic plan at EU level, although some plans at country level (e.g., #FranceIA)
- Three reasons why China may become the world leader in AI
  - ✓ Large scale R&D investments, including basic research
  - ✓ Scale advantage (more people, more data, more predictions)
  - ✓ Easy data access (lack of privacy protection)

Race for AI leadership



Source: MIT Technology Review (2018)

Race for AI leadership



Source: Klinger, Mateos-Garcia, and Stathoulopoulos (2018)

Disillusionment?

- One risk in the current over-hyping of AI is another AI winter, such as the one that devastated the field in the 70s (popularity and funding)
- AI is too brittle, too narrow and too superficial to solve many real-world problems, not to say artificial general intelligence
  - ✓ "*I still dream of Rosie the Robot, a full-service domestic robot that take of my home; but for now, six decades into the history of AI, our bots do little more than play music, sweep floors, and bid on advertisements*" (Markus, 2018)
- Executives and policy-makers need to understand the potential and limits of the current state-of-the-art in AI

Research plans at BETA

- AI and Big Data approaches in R&I policy making [ONGOING]
  - ✓ 7 institutions (coordinated by ZEW)
  - ✓ Deploy AI tools to assist policy decision making
  - ✓ Develop new tools for timely and in-depth information about the performance of R&I system and its links to productivity growth
- AI science base and the economy [ONGOING]
  - ✓ ISI Web of Science (1990-2018) (+ Patstat ?)
  - ✓ Identify AI papers with NLP and supervised learning
  - ✓ Bibliometric indicators and measures of novelty
  - ✓ Country/regional scientific base and industrial activity

Research plans at BETA

- Adoption of AI, robots, and computer-assisted technologies
  - ✓ TIC-TPE + FARE + CIS
  - ✓ Drivers and barriers to adoption
  - ✓ Innovation complementarities
  - ✓ Productivity effects at firm level
- AI and robotisation and the dynamics of wages
  - ✓ Enquête sur la mesure de l'amortissement accéléré pour l'achat de robots industriels + TIC-TPE + DADS + FARE + others...
  - ✓ H+M interactions and labour market dynamics
  - ✓ Skills, age and tasks of persons hired and laid-off

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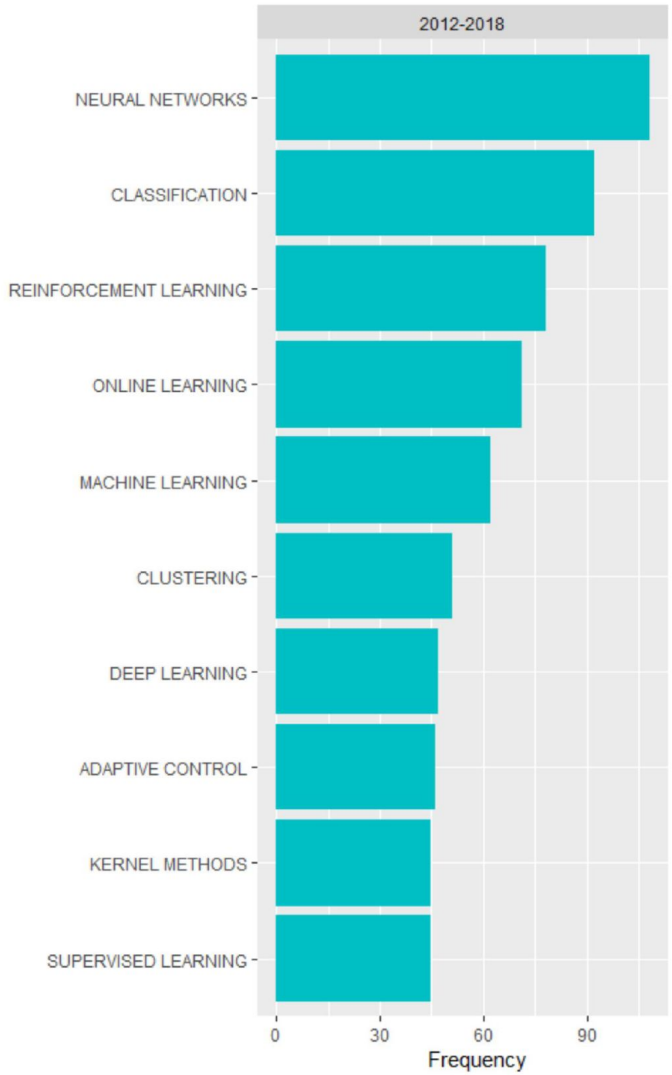
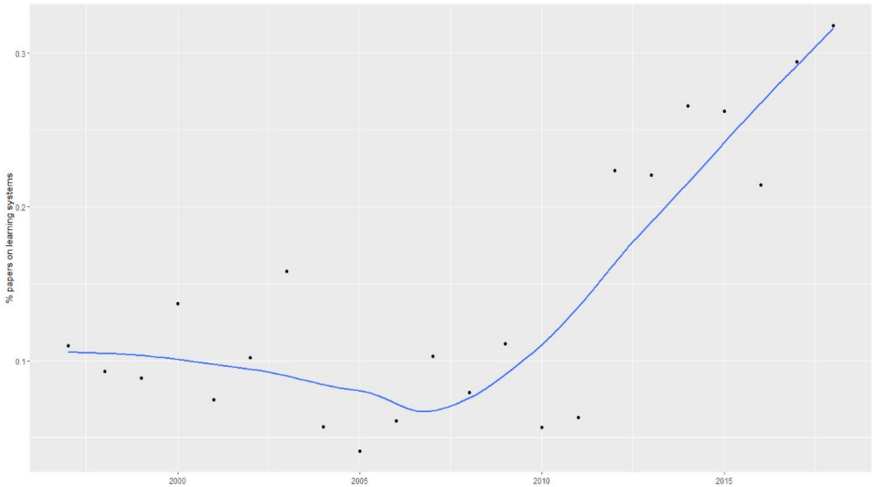
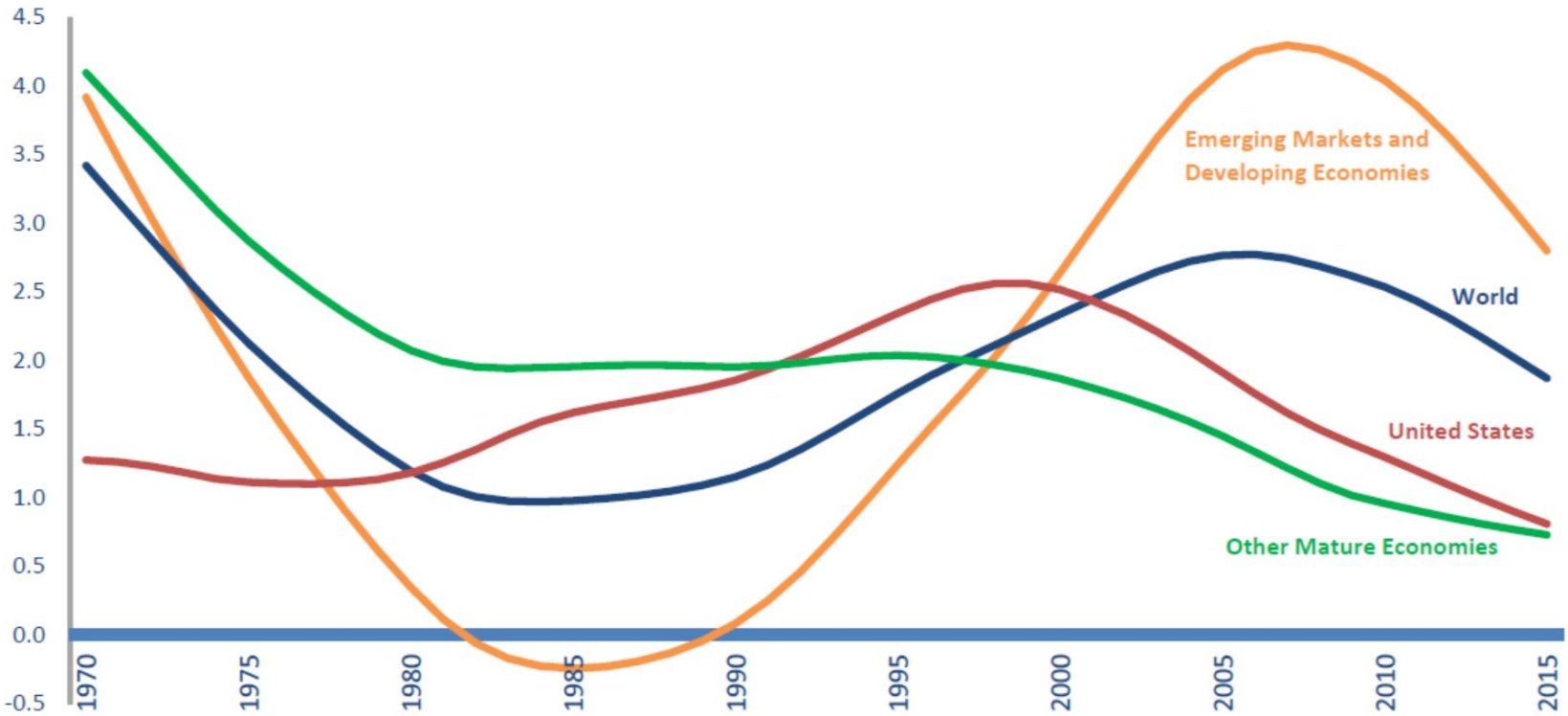




Left: Recurrent keywords from the abstracts of papers in top 5 Computer Science journals (subfield AI). Right: Share of papers on learning systems main



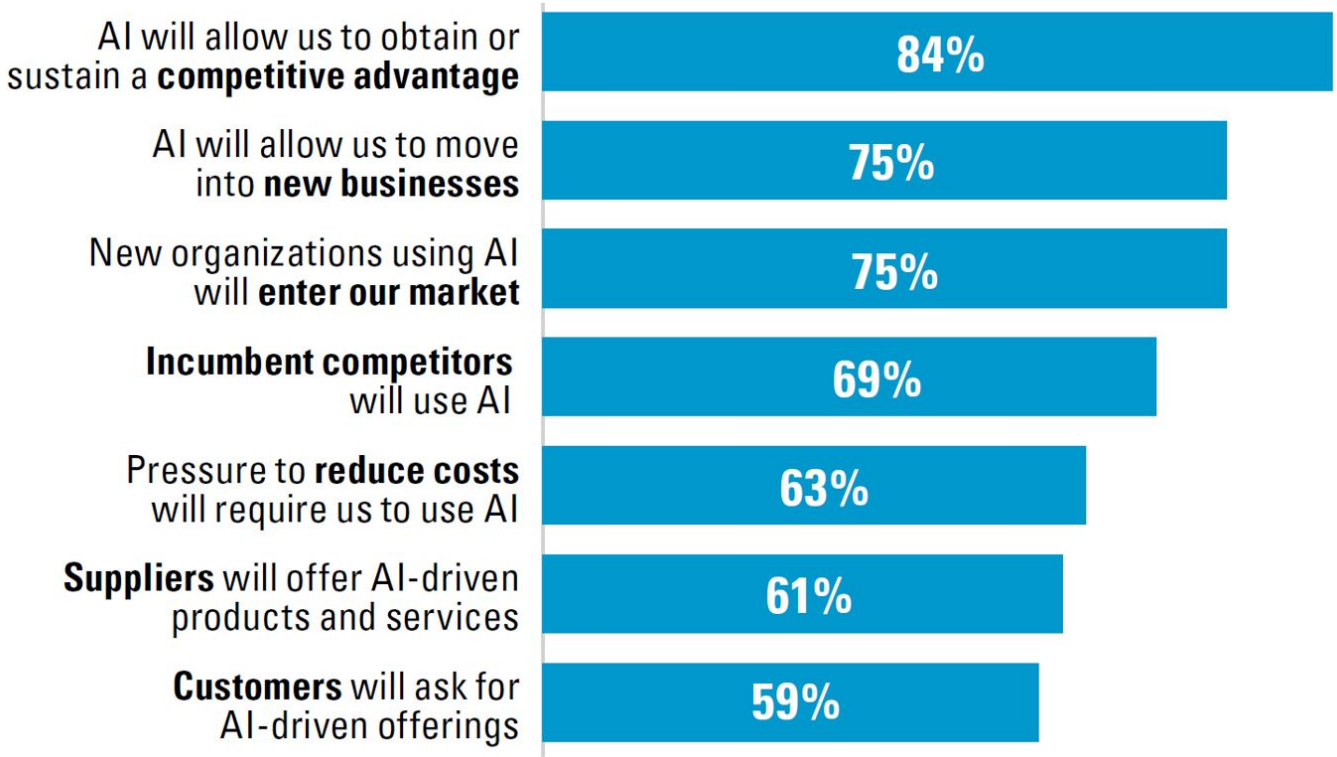
Source: The Conference Board Total Economy Database™ (Adjusted version), November 2016.

Notes: Trend growth rates are obtained using HP filter, assuming a l=100.

main

Reasons for adopting AI

Why is your organization interested in AI?



Source: Ransbotham, Kiron, Gerbert, and Reeves (2017) main