Science, Innovation, Markets – **and AI**: research insights and an agenda

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Outline

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Introduction

Do we need new economic theory(ies) to study **current** Artificial Intelligence (AI)?

- **current** AI: a variety of dedicated virtual machines (algorithms) performing statistical learning, using data from different modalities and types (e.g. images, voice, text) and relying on dedicated computing capacity (Vannuccini and Prytkova 2022) $\Rightarrow$ a family of software technologies

we face a situation similar to the early economics of ICT:

- *"recent literature that aims to understand the economics of information technology is firmly grounded in the traditional literature. As with technology itself, the innovation comes not in the basic building blocks, but rather **in the ways in which they are combined**."* (Varian 2005)

Introduction

AI is essentially a new wave of ICT technologies; to study AI building blocks and “the ways in which they are combined”, we rather need:

1. a new angle of analysis
2. the identification of the fundamental mechanisms characterising AI, and their impact

Why? Because this approach can suggest research directions, and show forces and processes at work that are comparable across diverse domains

Outline

A new angle of analysis

Key idea: AI is a system/infrastructural technology, rather than a 'singleton' one. Its elements:

- **technology**: algorithms + computation + data + domain structure
- **broader technology systems** in which AI is integrated (i.e. cyber–physical systems)
- **actors** (ecosystem of users and producers — see i.e. Jacobides et al. (2021) for a typology)
- **uses/impacts** (industries/markets/products)
- **policy**: i.e. towards factor dependencies

in Vannuccini and Prytkova (2022), we suggest the framework of Large Technical Systems as a guide for studies, as it captures AI features as a technology…

- …with limited penetration in production but wide final users reach
- …in superposition on other technology systems (i.e. the Internet)
- …with a technological trajectory shaped by actors' power, reverse salients, and momentum

AI in context

Impact of AI wrt other automation technologies — Savona et al. 2022

Share of Papers By Work Activity

TASKS	Robots	Software Data Management	Data Aquisiton	Computing	AI	Additive Manufacturing	Networking	User Interface
Processing Information	2.0%	29.7%	21.9%	19.7%	15.0%	7.2%	10.6%	15.7%
Monitor Processes, Materials, or Surroundings	3.8%	4.1%	28.3%	8.9%	6.5%	16.7%	22.9%	13.4%
Analyzing Data or Information	3.1%	19.7%	17.0%	15.4%	30.9%	0.5%	16.3%	14.9%
Identifying Objects, Actions, and Events	18.4%	1.6%	10.3%	5.5%	17.9%	5.4%	5.8%	11.9%
Getting Information	7.5%	15.9%	13.8%	4.9%	2.1%	1.4%	16.1%	10.9%
Controlling Machines and Processes	3.8%	0.3%	1.3%	2.8%		16.7%	4.0%	4.8%
Estimating the Quantifiable Character of Products, Events or Information	0.3%	0.3%	7.1%	5.5%	12.9%	11.3%	1.3%	3.1%
Making Decisions and Solving Probelems	1.7%	2.5%	1.9%	7.1%	2.5%		5.5%	0.6%
Assisting and Caring for Others	6.5%							0.8%
Monitoring and Controlling Resources	0.3%	1.9%	3.5%	11.4%	0.8%	5.4%	3.0%	0.8%
Perfoming General Physcial Activties	9.9%	1.3%			0.6%	9.5%	0.3%	1.9%
Scheduling Work and Activities	1.0%	8.1%	0.3%	6.5%	0.4%		4.0%	
Handling and Moving Objects	21.5%			0.3%		2.3%	0.3%	2.3%
Judging the Qualities of Things, Services, or People	1.0%	1.6%	0.6%	1.5%	5.6%	2.7%	0.5%	1.7%
Inspecting Equipment, Structures, or Material	6.1%	0.9%	5.1%	0.3%	1.5%	7.7%	0.3%	0.4%
Interacting with Computers	0.7%	1.3%		3.7%	0.1%	1.4%	1.5%	6.7%
Operating Vehicles, Mechanized Devices, or Equipment	3.1%			0.3%		9.0%	0.5%	1.0%
Documenting/Recording Information	1.7%	5.6%	2.3%	0.9%	0.2%		2.5%	0.8%
Updating and Using Relevant Knowledge			1.0%	0.3%	0.4%	1.8%	2.5%	2.5%
Developing Objectives and Strategies	1.4%			1.8%		0.5%	1.0%	1.0%
Evaluating Information to Determine Compliance with Standards	0.3%	0.6%	1.9%	1.2%	1.2%	1.4%	0.8%	1.0%
Training and Teaching Others	1.0%				0.4%			2.1%
Organizing, Planning, and Prioritizing	1.0%	1.9%		1.5%				0.2%
Interpreting the Meaning of Information	1.4%	0.9%		0.3%	0.6%			0.2%
Communicating with Supervisors, Peers, or Subordinates	0.7%	0.3%						
Establishing Information to Determine…	0.3%							
Performing for or Working Directly with the Public	0.3%		0.3%					
Performing Administrative Activites	0.3%	0.6%			0.2%		0.3%	
Staffing Organizational Units		0.3%						
Communicating with Persons Outside the Organisation				0.3%				
Coaching and Developing Others	0.3%				0.2%			0.2%
Repairing and Maintaining Mechanical						0.5%	0.3%	0.2%
Provide Consultation and Advice to Others	0.3%	0.3%						0.2%
Selling Or Influencing Others		0.3%			0.2%			0.2%
Total Observations	293	320	311	325	521	221	398	477
Total Papers	154	122	177	162	251	134	156	184

Outline

AI and economic mechanisms

Not a real mechanism: end of scarcity (e.g. in labour markets) due to rapid advances in AI and super–intelligence

- Braitenberg's (1986) *'law of uphill analysis and downhill intervention'*: humans tend to overestimate the complexity of a mechanism, guessing its internal structure from observation

A real mechanism: reallocation of resources (financial, innovative, organisational, effort) as AI lowers a specific cost — **prediction** (Agrawal et al. 2018)

- prediction–intense activities: adtech, fintech, HR, scientific discovery

Next, I discuss how AI affects three (classic) economic problems: (1) entry; (2) specialisation; and (3) invention/inno incentives. Their commonality is shown across three different fields:

- Science
- Technology/innovation
- Industries/markets/products

(1) Entry and endogenous sunk costs

AI lowers barriers for entry because of easier access to the technology as it evolves; however…
…as with other informational goods, high fixed costs & low replication costs can lead to concentration

- Science
  - development of accessible datasets can increase entry (i.e. AlphaFold Protein Structure Database)
  - need for computing power can produce winner takes all dynamics among labs and universities
- Technology
  - evolution of techniques towards dominant design: DL/RL — Transformers/LLM/multi–modal
  - development of transfer learning techniques increase 'portability' of AI solutions
- Industries/markets/products
  - tech standardisation increases concentration upstream, decreases downstream
  - availability of models repositories (i.e. Huggingface) lowers startup costs
  - ↑ product variety (i.e. generative AI)
  - ↓ competition because AI models are hard to scale and defend from competitors

(2) Integration vs specialisation

AI reshuffles the 'division of labour'

- Science
  - back to large corporate laboratories doing quasi–fundamental research: OpenAI or DeepMind as Bell Labs?
  - emergence of science–as–a–service specialised suppliers: digital rather than physical scientific equipment (i.e. Elicit)
  - changing tasks for scientists & automation of experiments (i.e. Macleod et al. 2022)
- Technology/innovation
  - computation on the cloud vs the edge and integration of the whole stack in different organisation/market forms
  - product design in related industries impacted by AI 'shock' — i.e. semiconductors (see Prytkova and Vannuccini 2022)
- industries/markets/products
  - emergence of AI–as–a–service specialised suppliers
  - (global) specialisation in the AI value chains; heteromation (Tubaro and Casilli 2021)

(2) Integration vs specialisation — a sketch based on Bresnahan and Gambardella (1998)

- N industries; desired production Q_n in industry n requires two activities:
  - one activity is localised in the industry (i.e. manufacturing) with cost $c_n(Q_n)$
  - the other (i.e. AI–driven analytics) is either localised with cost $c_n^{AI}(Q_n)$ …
  - …or assigned to a specialised supplier that can serve different industries, with cost $c^{AI}(\sum_n Q_n)$
  - when a specialised supplier serves many downstream markets, there is a quality mismatch d_n

- integrated industry (I): $C^I = c_n(Q_n) + c_n^{AI}(Q_n)$
- specialised industry (S): downstream: $C^S = c_n(Q_n) + d_n Q_n$ – upstream: $C^S = c^{AI}(\sum_n Q_n)$
- cost–minimising structure in the (part of the) economy using AI is specialised when

$$\sum_n (c_n(Q_n) + dQ_n) + c^{AI}(\sum_n Q_n) < \sum_n (c_n(Q_n) + c_n^{AI}(Q_n))$$

  - difference between lhs & rhs $= \Delta$

- $\frac{\partial \Delta}{\partial Q} > 0$: scale induces integration; $\frac{\partial \Delta}{\partial N} < 0$: variety induces specialisation

(3) Discovery, invention, and innovation

AI helps solving 'needles in a haystack' problems (Agrawal et al. 2019) and can reduce uncertainty

- Science
  - AI as a research tool / invention of a method of inventing (IMI): a new playbook for discovery based on inductive brute–forcing of knowledge spaces (i.e. protein shapes. chemical reactions)
  - but narrowing of AI research (Klinger et al. 2021) as commercialisation opportunities appear
- Technology
  - in Lombardi and Vannuccini (2022) we discuss how AI can enhance decision–making by reducing the gap between informational explosion of the 'cyber–physical universe' and human computational capabilities
  - feedback loops "production of AI by means of AI"? i.e. in chip design
- Industries/markets/products
  - AI induces product/process innovation (Rammer et al. 2022)
  - use of AI can lower experimentation costs in tandem with other digital technologies i.e. digital twins (cheaper/easier exploration of the design space)
  - in Antonioli et al. (2022), we find that this is the opposite for robot technology, suggesting AI plays a qualitatively different role (being software) from robots (being capital goods/hardware)

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Conclusion

Direction for AI research:

- Investigating the ethical, social, and economic implications of AI and developing approaches to ensure that AI is developed and used responsibly
- Studying the ways in which AI can be used to solve real-world problems, such as healthcare, education, and environmental sustainability
- Investigating the fundamental limits of AI and developing a deeper understanding of the capabilities and limitations of intelligent systems.

Not convinced?
You are right: these were created by OpenAI's ChatGPT from the prompt "tell me a few bullet points on possible AI research themes"!

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(Real) Conclusion

- There is a vast research programme on the techno—economic nature and impact of AI to explore
- a (possible) fruitful way to tackle it is adopting a system view of AI, to guide mapping interdependencies and complementarities
- AI developments shape well–known economic problems, which however take a new, unique, AI 'flavour'
- lots to do yet to capture common mechanisms across the domains of science, innovation / technology, and industry!

THANK YOU FOR YOUR ATTENTION!