

PILLARS - Pathways to Inclusive Labour Markets The impact of emerging digital automation technologies on employment

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Timeline of major digital innovations over the past 30 years (Jaccoud et al, 2023)





What we do (I)





Two Key Outputs today

- Emerging Digital Technologies (EDT) are not "AI" and are not (yet) a General Purpose Technology
 - Identification of 9 families of EDT
 - Going (very) granular on EDT and screening of thousands of technical and engineering literature records
 - Can we derive insights on the extent to which specific industries are exposed to specific EDT at higher level of granularity compared to the received literature in economics?

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 Heterogeneity of effects on occupations and industries measured via exposure to families of EDTs



Common thread but different contributions

- What is the value of going granular?
 - Can EDT (as identified in this study) potentially substitute, complement, and/or reconfigure specific technical tasks within occupations within sectors, that are executed by humans?
 - Can we infer trends and dynamics on future of work from EDT characterized by complex interdependency and the pervasive presence of artificial intelligence (AI)?
 - **Granularity** is essential to pick up exposure, adoption, task replacement/complementarity, and other dimensions (knowledge codification, innovation, interactions with human, symbols, or tangible assets)



What we do (I)

"Assessing the **potential** for the EDT, and whether this time it will be different, begins with a careful assessment of the **emergence of new capabilities in the cyber-physical systems** that are the current subjects of **research, development and initial deployment**." (Ciarli et al., 2022)

Summary in <u>Savona, M.et al (2022) The Design of Digital</u> <u>Technologies: Implications for the Future of Work CESifo Econpol</u> <u>Forum, 23(5) 2022</u>



Families of Emerging Digital Technologies

- Technology family A Robots (Articulated, Cylindrical, Cartesian, Dual Arm) Definition: Technologies that sense and (autonomously) act based on data
- **Technology family B Physical Data Acquisition Technologies** *Definition: technologies that harvest and record information*
- **Technology family C Software-based data management** *Definition: Technologies for storing, protecting, managing/handling and acquiring data*
- **Technology family D Computing** *Definition: Technologies used to compute/calculate*
- Technology family E AI (not directly as a cloud service) & Intelligent Information System, Definition: Technologies using algorithms and advanced methods to make sense out of the data
- Technology family F Additive manufacturing (using any material), Definition: Technologies that produce bottom-up goods based on digital models
- **Technology family G Networking,** *Definition: Technologies for communicating between machines* (data transmission) or connecting machines
- Technology family H User interface, Definition: Technologies for human interaction with machines or data



Examples of EDTs (I)

Robots (Primarily stationary)

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| Machine vision and real-time monitoring |
|---|
| SCARA |
| Articulated |
| Cartesian |
| Dual Arm |
| Co-bots |
| Swarm robotics |
| Cylindrical |
| Service robotics |
| Data Acquisition Technologies |
| IoT (including Radio-frequency identification (RFID |
| systems) |
| Scanners |
| Sensors |
| Remote Sensing |
| GPS |
| CCTV |
| Scientific and engineering instruments |
| Healthcare instruments (including Personal health |
| instrumentation) |
| |

| В | Robots (Primarily mobile) |
|---|------------------------------------|
| 1 | Co-bots (mobile) |
| 2 | Semi-autonomous (e.g. bricklaying) |
| 3 | Automated platforms/vehicles |
| 4 | Tunnel boring and mining robots |
| 5 | Submersible robots |
| 6 | Drones |
| 7 | Space vehicles and rovers |
| 8 | Service robotics |

Cloud, PC and Smartphone Computing and

| D | Services |
|---|--|
| 1 | Big data analytics |
| 2 | Gaming |
| 3 | Streaming services |
| 4 | Automated storage and retrieval systems |
| 5 | Database systems |
| 6 | Relational databases [API might go here] |
| | Computer architectures (e.g. quantum |
| 7 | computing) |
| 8 | Cryptography and security |



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Examples of EDTs (II)

| E | AI (not directly as a cloud service) | | |
|---|--|---|--------------------------------------|
| 1 | Simulation | | Additive manufacturing (using any |
| 2 | Machine learning (predictive systems)/DL | F | material – so e.g. powder metallurgy |
| 3 | NIP | | as well as bioplastic filament) |
| 1 | Machine vision (Image receptition) | 1 | Prototyping (including CAD) |
| 4 | Machine vision (image recognition) | 2 | Tools production |
| 5 | Expert systems | 3 | Production at scale |
| 6 | Speech recognition and production | 5 | |
| 7 | Text recognition and production | | |
| | | | |

| G | User interface | Н | | | | | | |
|---|---|----------|--|--|--|--|--|--|
| | Conventional input devices (e.g. keyboard, mice, pens, | 1 | | | | | | |
| 1 | webcams) | | | | | | | |
| 2 | Display devices (conventional) | | | | | | | |
| 3 | Augmented reality | | | | | | | |
| | Haptics and Tele-haptics (including all tele-operations of physical machinery by human operator requiring | | | | | | | |
| 4 | feedback, e.g. tele-dildonics) | | | | | | | |
| 5 | Virtual Reality (including 3D Visualisation) | | | | | | | |
| 6 | Touchscreens/kiosks for customer interface | | | | | | | |
| 7 | Sound technologies (e.g. noise cancellation) | | | | | | | |
| 8 | Neuroscanning | | | | | | | |
| | | SS)L | | | | | | |

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| Н | Other |
|---|---------------|
| 1 | Machine Tools |
| 2 | |

Relevant dimension to codify selected papers

| Adoption/Rate | Development (function-design)/Stage | Geographical area | | | |
|-------------------------------------|--|--|--|--|--|
| Level of adoption of the technology | Stage of development of the technology | UN M49 classification. Classification per geog | | | |
| Low | Conceptual | 015 Northern Africa | | | |
| Medium | Experimental | 202 Sub-Saharan Africa | | | |
| High | Product/type | 419 Latin America and the Caribbean | | | |
| | Ready-to-deploy | 021 Northern America | | | |
| | Mature | 010 Antarctica | | | |
| | | 143 Central Asia | | | |
| | | 030 Eastern Asia | | | |
| | | 035 South-eastern Asia | | | |
| | | 034 Southern Asia | | | |
| | | 145 Western Asia | | | |
| | | 151 Eastern Europe | | | |
| | | 154 Northern Europe | | | |
| | | 039 Southern Europe | | | |
| | | 155 Western Europe | | | |
| | | 009 Oceania | | | |

| Tasks/Routinisaiton | Tasks/Knowledge codification | Works with |
|--|---|---|
| Ability to perform a task without any human intervention | Able to make all the instructions explicit with no use of tacit knowledge | Target integration of the technology |
| Yes | Yes | People: "in-person" services (requires high soft skills) |
| No | No | Things: routine production services (does not require soft skills) |
| | | Symbols: "symbolic- analytic" services (does not require soft skills) |
| | | |

| Employment/Compensation/Skills | Employment/Compensation/Substitute/Complement | Employment/Compensation/Product/process Improvement |
|--------------------------------|---|---|
| | Whether the technology is meant to complement or substitute the human workers | Improvements on quality (product) and/or process (quantity, i.e. time saving) |
| Low | Complement | Process |
| Medium | Substitute | Product |
| High | | |
| | | |





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Relevant dimension of job impact to codify selected papers

| Sectors | Actors | Actors/Size | Tasks/Task |
|---|----------|-----------------------------------|---|
| 3-digit ISIC for manufacturing and 2-digit for other sectors | Actors i | Size based on number of employees | ONET aggregate work activities |
| A1 - Crop and animal production, hunting and related service activities | | Micro<10 | Getting Information |
| A2 - Forestry and logging | | Small<50 | Monitor Processes, Materials, or Surroundings |
| A3 - Fishing and aquaculture | | Medium<500 | Identifying Objects, Actions, and Events |
| B5 - Mining of coal and lignite | | Large | Inspecting Equipment, Structures, or Material |
| B6 - Extraction of crude petroleum and natural gas | | N/A | Estimating the Quantifiable Characteristics of Products, Events, or Information |
| B7 - Mining of metal ores | | | Judging the Qualities of Things, Services, or People |
| B8 - Other mining and quarrying | | | Processing Information |
| B9 - Mining support service activities | | | Evaluating Information to Determine Compliance with Standards |
| D35 - Electricity, gas, steam and air conditioning supply | | | Analyzing Data or Information |
| E36 - Water collection, treatment and supply | | | Making Decisions and Solving Problems |
| E37 - Sewerage | | | Thinking Creatively |
| E38 - Waste collection, treatment and disposal activities; materials recovery | | | Updating and Using Relevant Knowledge |
| E39 - Remediation activities and other waste management services | | | Developing Objectives and Strategies |
| F41 - Construction of buildings | | | Scheduling Work and Activities |
| F42 - Civil engineering | | | Organizing, Planning, and Prioritizing Work |
| F43 - Specialized construction activities | | | Performing General Physical Activities |
| G45 - Wholesale and retail trade and repair of motor vehicles and motorcycles | | | Handling and Moving Objects |
| G46 - Wholesale trade, except of motor vehicles and motorcycles | | | Controlling Machines and Processes |
| G47 - Retail trade, except of motor vehicles and motorcycles | | | Operating Vehicles, Mechanized Devices, or Equipment |
| H49 - Land transport and transport via pipelines | | | Interacting With Computers |
| H50 - Water transport | | | Repairing and Maintaining Mechanical Equipment |
| H51 - Air transport | | | Documenting/Recording Information |
| H52 - Warehousing and support activities for transportation | | | Interpreting the Meaning of Information for Others |
| H53 - Postal and courier activities | | | Communicating with Supervisors, Peers, or Subordinates |
| I55 - Accommodation | | | Communicating with Persons Outside Organization |
| I56 - Food and beverage service activities | | | Establishing and Maintaining Interpersonal Relationships |
| J58 - Publishing activities | | | Assisting and Caring for Others |
| J59 - Motion picture, video and television programme production, sound recordin | ng and m | usic publishing activities | Selling or Influencing Others |
| J60 - Programming and broadcasting activities | | | Resolving Conflicts and Negotiating with Others |
| J61 - Telecommunications | | | Performing for or Working Directly with the Public |
| J62 - Computer programming, consultancy and related activities | | | Training and Teaching Others |
| J63 - Information service activities | | | Guiding, Directing, and Motivating Subordinates |
| K64 - Financial service activities, except insurance and pension funding | | | Coaching and Developing Others |
| K65 - Insurance, reinsurance and pension funding, except compulsory social see | curity | | Provide Consultation and Advice to Others |
| K66 - Activities auxiliary to financial service and insurance activities | | | Performing Administrative Activities |
| L68 - Real estate activities | | | Staffing Organizational Units |
| M69 - Legal and accounting activities | | | Monitoring and Controlling Resources |
| M70 - Activities of head offices; management consultancy activities | | | |
| M71 - Architectural and engineering activities: technical testing and analysis | | | |



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(Share of papers describing) tasks executed within work activities by technology family

| | Share of Papers By Work Activity | | | | | | | | |
|--|----------------------------------|--------------------------|----------------|-----------|-------|------------------------|------------------|----------------|---------|
| TASKS | | Software Data Management | Data Aquisiton | Computing | AI | Additive Manufacturign | Networking Table | User Interface | GeoMean |
| Processing Information | 2.0% | 29.7% | 21.9% | 19.7% | 15.0% | 7.2% | 10.6% | 15.7% | 12.1% |
| Monitor Processes, Materials, or Surroundings | 3.8% | 4.1% | 28.3% | 8.9% | 6.5% | 16.7% | 22.9% | 13.4% | 10.3% |
| Analyzing Data or Information | 3.1% | 19.7% | 17.0% | 15.4% | 30.9% | 0.5% | 16.3% | 14.9% | 9.3% |
| Identifying Objects, Actions, and Events | 18.4% | 1.6% | 10.3% | 5.5% | 17.9% | 5.4% | 5.8% | 11.9% | 7.6% |
| Getting Information | 7.5% | 15.9% | 13.8% | 4.9% | 2.1% | 1.4% | 16.1% | 10.9% | 6.7% |
| Controlling Machines and Processes | 3.8% | 0.3% | 1.3% | 2.8% | | 16.7% | 4.0% | 4.8% | 2.8% |
| 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% | 2.6% |
| Making Decisions and Solving Probelems | 1.7% | 2.5% | 1.9% | 7.1% | 2.5% | | 5.5% | 0.6% | 2.4% |
| Assisting and Caring for Others | 6.5% | | | | | | | 0.8% | 2.3% |
| Monitoring and Controlling Resources | 0.3% | 1.9% | 3.5% | 11.4% | 0.8% | 5.4% | 3.0% | 0.8% | 2.0% |
| Perfroming General Physcial Activties | 9.9% | 1.3% | | | 0.6% | 9.5% | 0.3% | 1.9% | 1.8% |
| Scheduling Work and Activities | 1.0% | 8.1% | 0.3% | 6.5% | 0.4% | | 4.0% | | 1.7% |
| Handling and Moving Objects | 21.5% | | | 0.3% | | 2.3% | 0.3% | 2.3% | 1.5% |
| Judging the Qualities of Things, Services, or People | 1.0% | 1.6% | 0.6% | 1.5% | 5.6% | 2.7% | 0.5% | 1.7% | 1.5% |
| Inspecting Equipment, Structures, or Material | 6.1% | 0.9% | 5.1% | 0.3% | 1.5% | 7.7% | 0.3% | 0.4% | 1.4% |
| Interacting with Computers | 0.7% | 1.3% | | 3.7% | 0.2% | 1.4% | 1.5% | 6.7% | 1.4% |
| Operating Vehicles, Mechanized Devices, or Equipment | 3.1% | | | 0.3% | | 9.0% | 0.5% | 1.0% | 1.4% |
| Documenting/Recording Information | 1.7% | 5.6% | 2.3% | 0.9% | 0.2% | | 2.5% | 0.8% | 1.3% |
| Updating and Using Relevant Knowledge | | | 1.0% | 0.3% | 0.4% | 1.8% | 2.5% | 2.5% | 1.0% |
| Developing Objectives and Strategies | 1.4% | | | 1.8% | | 0.5% | 1.0% | 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% | 0.9% |
| Training and Teaching Others | 1.0% | | | | 0.4% | | | 2.1% | 0.9% |
| Organizing, Planning, and Prioritizing | 1.0% | 1.9% | | 1.5% | | | | 0.2% | 0.9% |
| Interpreting the Meaning of Information | 1.4% | 0.9% | | 0.3% | 0.6% | | | 0.2% | 0.5% |
| Communicating with Supervisors, Peers, or Subordinates | 0.7% | 0.3% | | | | | | | 0.5% |
| Establishing Information to Determine | 0.3% | | | | | | | | 0.3% |
| Performing for or Working Directly with the Public | 0.3% | | 0.3% | | | | | | 0.3% |
| Performing Administative Activites | 0.3% | 0.6% | | | 0.2% | | 0.3% | | 0.3% |
| Staffing Organizational Units | | 0.3% | | 1 | | | | | 0.3% |
| Communicating with Persons Outside the Organisation | | | | 0.3% | | | | | 0.3% |
| Coaching and Developing Others | 0.3% | | | | 0.2% | | | 0.2% | 0.2% |
| Repairing and Maintaining Mechanical | | | | | | 0.5% | 0.3% | 0.2% | 0.3% |
| Provide Consultation and Advice to Others | 0.3% | 0.3% | | | | | | 0.2% | 0.3% |
| Selling Or Influencing Others | | 0.3% | | | 0.2% | | | 0.2% | 0.2%, |
| | | | | 1 | | | | | |
| Total Observations | 293 | 320 | 311 | 325 | 521 | 221 | 398 | 477 | |
| Total Papers | 154 | 122 | 177 | 162 | 251 | 134 | 156 | 184 | |



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From the Technical Literature

- First, automation technologies, including within the same family, are fundamentally different in their design and the tasks they can execute
- **Second**, the number of sectors that attract the development of most automation technologies is still relatively limited, but expanding.
- **Third**, automation related to robotisation is likely to become more and more substitutive of tasks performed by humans
- **Fourth**, the use of codified or tacit knowledge is fairly associated with routinisation, whereby the most routinised tasks performed by these technologies seem to make use of codified more than tacit knowledge.
 - data intensive technologies interact more with symbols, rather than with things or people as robotisation-based automation.



What we do (II)



Summary in Pritkova et al (2024) The Employment Impact of Emerging Digital Technologies CESifo n. <u>10955, 2024</u>



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Combination of machine and human intelligence to study industry and occupation exposure to emerging technologies, and firm adoption

Emerging technologies

- <u>Generative AI</u>: Analyse the text of 1M+ patents and 4M+ scientific publications to identify novel automation technologies and their patterns of emergence
- <u>Experts</u>: asked 600k scientists, 20k inventors, 20k managers and 5k representative of civil society what **technologies** are most likely to be **used in 2030**, by industry

Exposure



- <u>Generative AI</u>: Analyse the text of **40 technologies**, to identify the **industries** (NACE) and **occupations** (ISCO) in in which they can be employed
- <u>Experts</u>: asked experts what **task** the selected technology will be able to perform, by industry



• <u>Generative AI</u>: Analyse the technologies mentioned by **firms** in 4M+ online **job vacancies**



Clerical support workers, Technicians, Professionals, and Managers are becoming increasingly exposed to emerging automation technologies



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Occupation Exposure to Emerging Technologies



Across service industries: IT, Administration, Finance & Insurance, Professional and Scientific Activities, and Utilities



Industry Exposure to Emerging Technologies

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Distribution of 3-digit NACE Industry Exposure across 1-digit NACE Industries



Impact varies by industry: positive for exposed occupations in industries **producing** emerging technologies, negative for industries **using** them



Employment growth rate and occupational exposure to 'all technologies' (2012-2019)



Digitalisation and employment – Main policy challenges

- Monitoring the evolution of technologies and the overall level of (un)employment at certain critical timing (i.e. Generative AI), not only new emerging tasks, but the transition between old and new
- Facilitating citizens and workers' voices and involvement in decisions to support critical technologies (e.g. platform workers) in case effects on working conditions worsen
- Much of ETDs is largely data intensive, and an inclusive governance of data is a major policy challenge, if we consider issues of individual data, digital trade and the narrowing of AI research
- The regulation of the boundaries between human and artificial intellectual property rights is also a major policy challenge, from the perspective of antitrust and value redistribution



Back up slides

Selected references of extant taxonomies





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A summary of methodological steps



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