In-Demand Skills: A Shield Against Automation - Evidence from Online Job Vacancies

Tomáš Oleš[1]

[1] Faculty of Economics and Finance, University of Economics in Bratislava, Slovakia.

Tasks and technology

The age of uncertainty is ahead of us because:

- traditional technology (robots, computers) may substitute only routine tasks (Autor et al., 2003).
- new technology (AI) may substitute also non-routine tasks (Acemoglu et al., 2022; Brynjolfsson et al., 2021; Webb, 2019).

I deliberately focus on skills (tasks) rather than occupations because:

- skills and their combination are central how technological change affects wages and inequalities (Acemoglu and Restrepo, 2022; Bennett et al., 2022).
- occupations are just complex bundles of skills (that changes over time) (Arntz et al., 2016; Deming and Kahn, 2018; Autor et al., 2024)

... in order to explore the skills-earnings association along with the skills-exposure to automation association in the Slovak online labor market.

Data

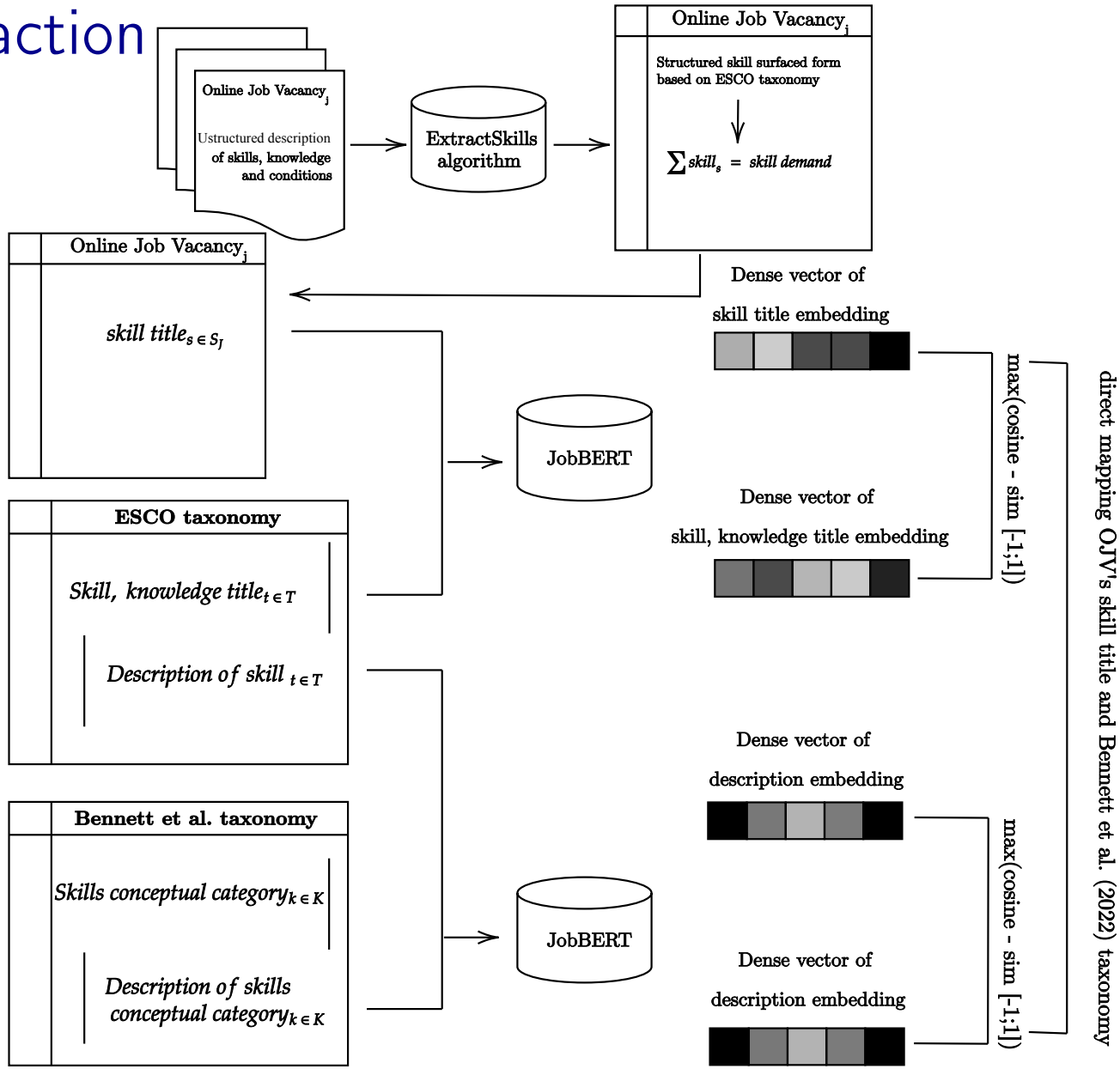
Online job vacancies (OJV) sourced from Profesia (2022)

- 350,000 online OJVs
- posted between January 1, 2022, and December 31, 2022
- approximately 21,000 distinct firms

Data are available for

- the description of job posting
- offered wage (and range)
- occupation code (4-digit level)
- industry (1-digit level)
- education requirements, region, benefits, type of contract, workplace etc.

Skills extraction



Online Job Vacancy ID: 5368355

In what area will you work? The projects are focused on the issue of heart rhythm disorders and the prevention of heart failure, developed by the leading scientific and technological company CertiCon. We apply the knowledge of experts and develop solutions that improve and simplify the lives of millions of people around the world. The unique added value is our own applied research and cooperation with international institutions.
We are currently working on building infrastructure in Azure DevOps and AWS Amazon Web Services cloud services
We are looking for a new colleague to our team for the position of DevOps Engineer who will help us with the process of migrating our development and production environments to cloud services
What exactly are you going to do? Implementation, deployment and support of Azure DevOps and AWS environments Collaborate with developers to integrate new system components Infrastructure monitoring, analysis of problems and performance characteristics Creating and testing CI CD scripts
What development environment do we use? Azure DevOps AWS Docker Kubernetes Kafka HBase
What technologies we use Azure DevOps AWS Docker Kubernetes Kafka Hbase Requirements for a new team member
MUST HAVE JSON YAML GIT Docker Swarm Kubernetes Knowledge of CI CD automation tools, e.g. Jenkins, Azure DevOps TeamCity Knowledge of a cloud platform such as AWS Azure GCP Knowledge of a scripting language, e.g. SH Bash PowerShell Batch Basics of network connection reverse proxy server client server certificates X 509 standard Also at least at level B with a focus on technical English communication with customers and teams abroad
NICE TO HAVE Knowledge of Linux or Windows operating system Knowledge of SQL language Knowledge of relational databases, eg MS SQL Postgre SQL MySQL Knowledge of virtualization platforms such as VMware OAuth2 OpenID Connect or SAML 2 0 authorization authentication protocols

Extracted ESCO Skills	Mapped Conceptual Category Skills
• Jenkins CI	• Cognitive skills (narrow sense)
• SQL	• Software (specific) skills and technical support
• installing structural masonry materials	• Finger dexterity skills
• DevOps	• Cognitive skills (narrow sense)
• dock operations	• Cognitive skills (narrow sense)
• postgres	• Software (specific) skills and technical support
• SQL	• Software (specific) skills and technical support
• developing solutions	• Cognitive skills (narrow sense)
• migration	• Cognitive skills (narrow sense)
• DevOps	• Cognitive skills (narrow sense)
• cloud technologies	• Machine Learning and AI skills
• technical or academic writing	• Writing skills
• using digital tools for collaboration and productivity	• Cognitive skills (narrow sense)
• monitoring	• Finger dexterity skills
• internal migration	• Cognitive skills (narrow sense)
• cloud technologies	• Machine Learning and AI skills
• operate relational database management system	• Software (specific) skills and technical support
• allocating and controlling physical resources	• Hand-foot-eye coordination skills
• performance analysis techniques	• Cognitive skills (narrow sense)
• technical language	• Cognitive skills (narrow sense)
• software and applications development and analysis	• Cognitive skills (narrow sense)
• cloud computing	• Machine Learning and AI skills
• software and applications development and analysis	• Cognitive skills (narrow sense)

Online Job Vacancy ID: 5367527

You participate in the production of new vehicles in various operations You assemble individual parts into vehicles You work according to the work standard You perform maintenance level 1 minor work within your responsibility You ensure order in your workplace You participate in continuous improvement Primary or secondary education, study certificate, high school diploma, even without previous experience Experience in the production process is an advantage, technical knowledge in the field of cars is welcome Willingness and desire to work on shifts Reliability and flexibility manual dexterity Ability to respond quickly and promptly Motivation and interest in permanent employment at PSA

Extracted ESCO Skills	Mapped Conceptual Category Skills
• motor vehicle	• Finger dexterity skills
• vehicle production process	• Hand-foot-eye coordination skills
• continuous improvement strategies	• Social skills (including agreeableness and extraversion)
• meet commitments	• Character skills (conscientiousness, emotional stability and openness to experience)

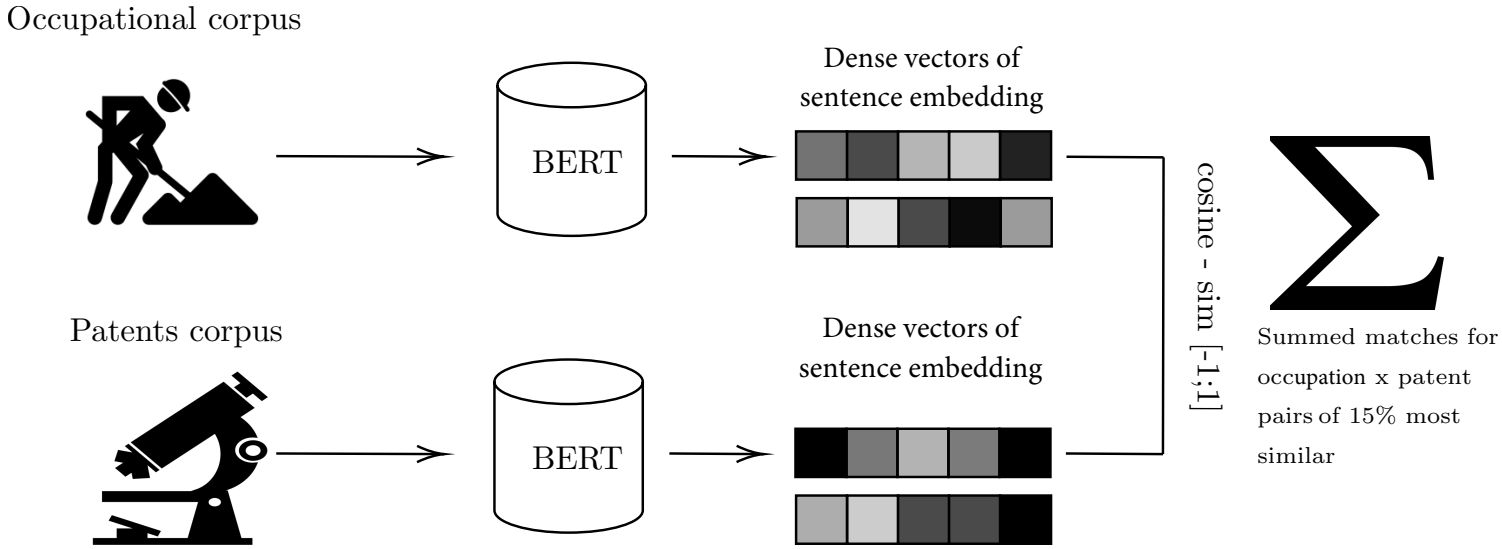
Empirical specification (i)

$$\log(\omega_{ojv,j}) = \beta_0 + \beta_{k \in K} \mathrm{v} + \delta_o + \gamma_i + \omega_t + \varepsilon_{ojv,j}$$

ω_{ojv} monthly wage in online job vacancy j, v is a $1 \times K$ features vector, where K is count intensity in each number of skills conceptual categories; δ_o is fixed effect for each broader occupational group o defined at the 1-digit level; γ_i is fixed effect industry; ω_t is month fixed effect; and ε_{ojv} is the error term.

	Log(Monthly Wage)							
	OLS (1)	WLS (2)	OLS (3)	WLS (4)	OLS (5)	WLS (6)	OLS (7)	WLS (8)
Social skills	0.03**	0.03**	0.02*	0.02*	0.01**	0.01**	0.01**	0.01**
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Cognitive skills (narrow sense)	0.03**	0.03**	0.01**	0.01**	0.01*	0.01**	0.01*	0.01**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Character skills	0.02**	0.02**	0.01**	0.01*	0.01*	0.01*	0.01*	0.01*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Hand-foot-eye coordination skills	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Finger dexterity skills	0.00	-0.00	0.00	0.00	0.01*	0.01*	0.01*	0.01*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Software-specific skills	0.06**	0.05**	0.01+	0.01+	0.01+	0.01+	0.01+	0.01+
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
People management skills	0.05**	0.05**	0.03**	0.03**	0.03**	0.03**	0.03**	0.03**
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Writing skills	0.03+	0.03+	0.02+	0.02+	0.01	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Customer service skills	-0.00	-0.00	0.01	0.01	0.00	0.00	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Physical skills	0.01	0.01	0.01	0.01	-0.00	0.00	-0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Financial skills	0.06**	0.07**	0.04**	0.04**	0.03**	0.03**	0.03**	0.03**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)
Machine Learning and AI skills	0.07*	0.08**	0.04**	0.04**	0.04**	0.04**	0.04**	0.04**
	(0.02)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Project management skills	0.06*	0.06*	0.03+	0.03+	0.02+	0.02+	0.02+	0.02+
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Language skills	0.00	0.01	0.02	0.02	0.00	0.00	0.00	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Computer general skills	-0.05+	-0.05+	-0.02	-0.02	-0.03+	-0.03+	-0.03+	-0.03+
	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Constant	6.96**	6.95**	7.03**	7.02**	7.03**	7.03**	7.03**	7.03**
	(0.05)	(0.04)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Broad occupational groups FE			✓	✓	✓	✓	✓	✓
Industries FE			✓	✓	✓	✓	✓	✓
Other controls					✓	✓	✓	✓
Month FE							✓	✓
N	337895	337895	336822	336822	326553	326553	326553	326553
Adj. R^2	0.25	0.25	0.44	0.44	0.63	0.63	0.63	0.64
R^2 within	0.25	0.25	0.06	0.06	0.05	0.05	0.05	0.05

Exposure to automation



Schematic representation of constructing automation exposure measures inspired by Autor et al. (2024).

$$I^{\tau}_{p,j} = 1 \text{ if } X^{\tau}_{p,j} \geq \lambda^{\tau} \text{ and zero otherwise;} \quad (1)$$

$$Aut^{\tau}_{o} = \sum_{p \in P^{\tau}} \sum_{o \in O} I^{\tau}_{p,o} \quad (2)$$

Empirical specification (ii)

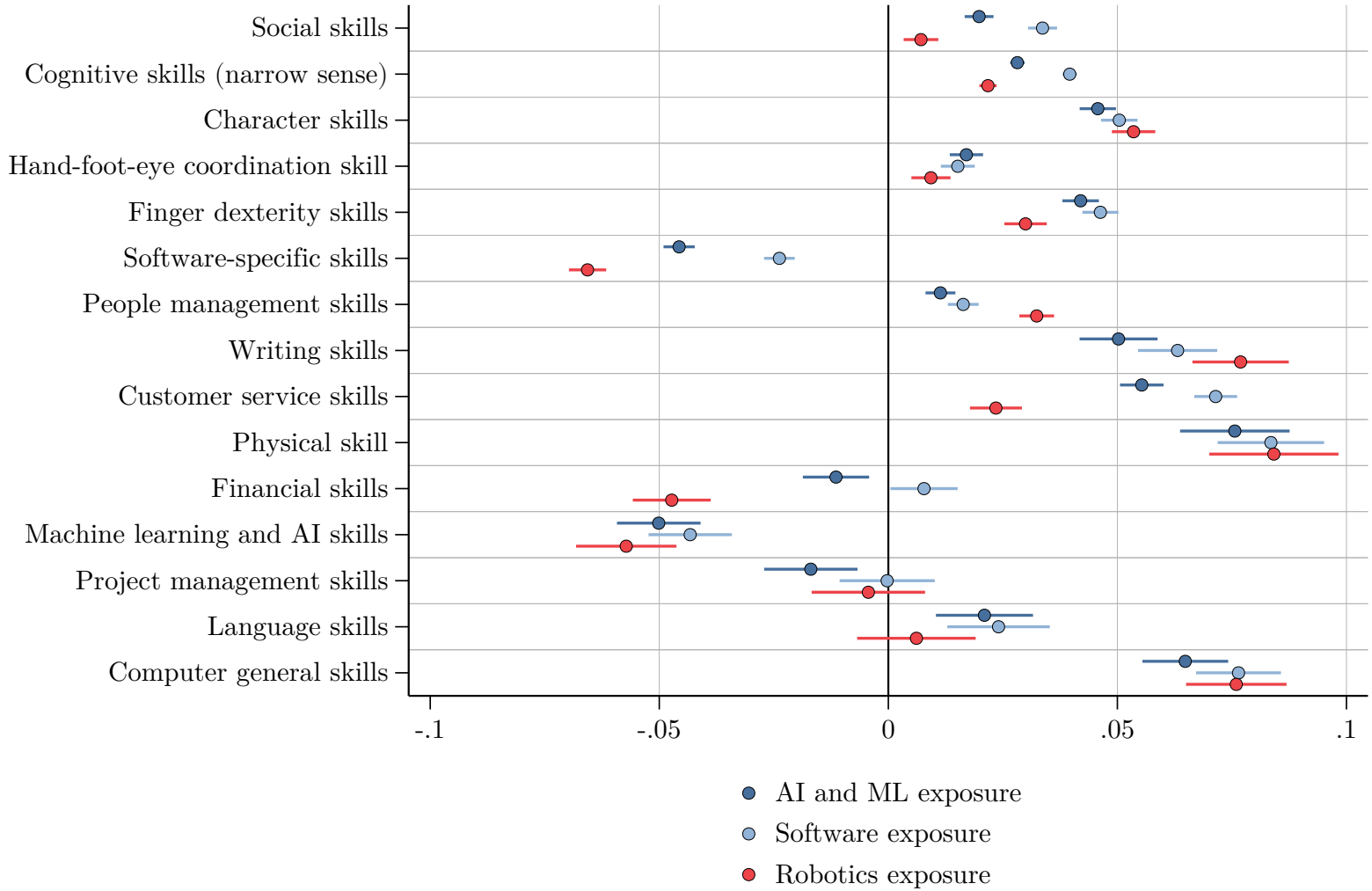
$$Aut^{\tau}_{ojv,j} = \beta_0 + \beta^{\tau}_{k \in K} \mathrm{v} + \delta_o + \gamma_i + \omega_t + \varepsilon_{ojv,j}$$

$$Aut^{\tau}_{ojv,j} = \beta_0 + \beta^{\tau}_{k \in K} \mathrm{v} + \gamma^{\tau}_{k \in K} (\mathrm{v} \cdot \text{Social Skills}) + c\mathrm{Z_j} + \delta_o + \gamma_i + \omega_t + \varepsilon_{ojv,j}$$

$$\text{Skills group}^{k}_{ojv,j} = \beta_0 + \beta_1 \mathcal{F}^{\tau}_{j} + c\mathrm{Z_j} + \delta_o + \gamma_i + \omega_t + \varepsilon_{ojv,j}$$

$Aut^{\tau}_{ojv,j}$ represents the standardized exposure to automation technology τ for ISCO-08 occupation o at the 4-digit level (unit groups). v is a $1 \times K$ features vector, where K is count intensity in each number of skills conceptual categories; δ_o is fixed effect for each broader occupational group o defined at the 1-digit level; γ_i is fixed effect industry; ω_t is month fixed effect; $\mathrm{Z_j}$ is the vector of controls; and ε_{ojv} is the error term.

Automation and skills



	Exposure to AI and ML		Exposure to software		Exposure to robotics	
	OLS	WLS	OLS	WLS	OLS	WLS
	(1)	(2)	(3)	(4)	(5)	(6)
Social skills	0.00	0.01	0.01	0.01	0.00	0.01
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
Cognitive skills (narrow sense)	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Character skills	0.01	0.00	0.01	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Hand-foot-eye coordination skills	-0.01	-0.01	-0.01*	-0.01*	-0.01	-0.01^{+}
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Finger dexterity skills	0.01	0.01	0.01	0.01	0.01	0.02
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Software-specific skills	-0.01	-0.01	-0.01	-0.01	-0.02**	-0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
People management skills	-0.01	-0.00	-0.01	-0.00	-0.01	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Writing skills	0.01	0.00	0.02	0.01	0.03	0.03
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
Customer service skills	0.02	0.02	0.02	0.03*	0.01	0.02
	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.02)
Physical skill	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
Financial skills	-0.04^{+}	-0.04^{+}	-0.04^{+}	-0.04*	-0.05	-0.05^{+}
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
Machine Learning and AI skills	-0.05*	-0.06**	-0.03	-0.05*	-0.09*	-0.11**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
Project management skills	-0.01	-0.02	-0.00	-0.00	-0.01	-0.01
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Language skills	0.04^{+}	0.04*	0.04*	0.04^{+}	0.05^{+}	0.05*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Computer general skills	0.01	0.01	-0.00	0.00	0.02	0.02
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.02)
Cognitive skills (narrow sense) × Social skills	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Character skills × Social skills	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Hand-foot-eye coordination skills × Social skills	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Finger dexterity skills × Social skills	-0.00	-0.00	-0.00	-0.01	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Software technic × Social skills	0.00	0.00	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
People management skills × Social skills	0.00	0.00	0.00	-0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Writing skills × Social skills	-0.01	-0.01	-0.01	-0.01	-0.02^{+}	-0.01^{+}
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Customer service skills × Social skills	-0.01	-0.01^{+}	-0.01	-0.01^{+}	-0.01	-0.01
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Physical skills × Social skills	0.02**	0.02**	0.02**	0.02**	0.02	0.02^{+}
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
Financial skills × Social skills	0.02**	0.02**	0.02**	0.02**	0.02**	0.02**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Machine Learning and AI skills × Social skills	0.00	0.01^{+}	0.00	0.01^{+}	0.01*	0.02**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Project management skills × Social skills	0.00	0.01	0.00	0.00	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Language skills × Social skills	-0.00	-0.00	-0.00	0.00	-0.01	-0.01
	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
Computer general skills × Social skills	-0.00	-0.00	0.00	0.00	-0.00	-0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Constant	0.28**	0.36**	0.35**	0.40**	0.20**	0.29**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Broad occupational groups, Industries, Month FE and Other controls	✓	✓	✓	✓	✓	✓
N	324246	324246	324246	324246	324246	324246
Adj. R^2	0.55	0.50	0.48	0.45	0.49	0.44

	Skills demand														
	Social skills	Cognitive skills	Character skills	Hand-foot-eye coordination skills	Finger dexterity skills	Software-specific skills	People management skills	Writing skills	Customer service skills	Physical skills	Financial skills	Machine learning and AI skills	Project management skills	Language skills	Computer general skills
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Panel A - 50th percentile															
AI and ML exposed firms	-0.019**	0.165**	0.027**	0.039**	0.037**	0.045**	0.032**	0.005**	-0.002	0.007**	0.000	0.008**	0.008**	0.006**	0.017**
	(0.004)	(0.008)	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)	(0.001)	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.630**	1.669**	0.409**	0.508**	0.366**	0.380**	0.514**	0.073**	0.259**	0.041**	0.117**	0.043**	0.063**	0.028**	0.061**
	(0.003)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.243	0.444	0.179	0.131	0.143	0.345	0.251	0.095	0.174	0.053	0.155	0.163	0.098	0.087	0.126
Software exposed firms	0.034**	0.188**	0.059**	0.020**	0.047**	0.055**	0.062**	0.004**	0.032**	0.005**	0.002	0.001	0.012**	0.011**	0.015**
	(0.004)	(0.008)	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)	(0.001)	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
	(0.005)	(0.010)	(0.004)	(0.004)	(0.003)	(0.004)	(0.005)	(0.001)	(0.003)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Constant	0.604**	1.657**	0.394**	0.517**	0.361**	0.375**	0.499**	0.073**	0.242**	0.042**	0.117**	0.046**	0.061**	0.026**	0.062**
	(0.003)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.243	0.444	0.180	0.131	0.144	0.345	0.251	0.095	0.175	0.052	0.155	0.163	0.098	0.087	0.126
Robotics exposed firms	0.062**	0.220**	0.058**	0.069**	0.049**	0.043**	0.061**	0.005**	0.015**	0.006**	0.006**	0.003*	0.014**	0.012**	0.022**
	(0.004)	(0.008)	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)	(0.001)	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.591**	1.641**	0.394**	0.493**	0.360**	0.381**	0.500**	0.073**	0.250**	0.042**	0.114**	0.045**	0.060**	0.026**	0.058**
	(0.003)	(0.005)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R^2	0.243	0.444	0.180	0.132	0.144	0.345	0.251	0.095	0.174	0.052	0.155	0.163	0.098	0.088	0.127
Panel B - 90th percentile															
AI and ML exposed firms	-0.088**	-0.184**	-0.099**	-0.086**	-0.069**	-0.051**	-0.108**	-0.030**	-0.003	-0.013**	-0.015**	-0.008**	-0.005**	-0.006**	-0.007**
	(0.005)	(0.010)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)	(0.001)	(0.004)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Constant	0.631**	1.771**	0.434**	0.537**	0.392**	0.408**	0.542**	0.078**	0.258**	0.046**	0.119**	0.047**	0.068**	0.032**	0.070**
	(0.002)	(0.004)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)
R^2	0.243	0.444	0.179	0.131	0.144	0.345	0.251	0.095	0.174	0.052	0.155	0.163	0.098	0.087	0.126
Software exposed firms	-0.017**	0.057**	-0.021**	-0.050**	-0.042**	-0.033**	-0.040**	-0.021**	0.026**	-0.005**	0.002	0.002	0.002	-0.007**	-0.015**
	(0.006)	(0.015)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)	(0.002)	(0.004)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)
Constant	0.623**	1.744**	0.425**	0.533**	0.389**	0.406**	0.535**	0.077**	0.255**	0.045**	0.117**	0.046**	0.067**	0.032**	0.071**
	(0.002)	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)
R^2	0.243	0.443	0.179	0.131	0.143	0.345	0.251	0.096	0.174	0.052	0.155	0.163	0.098	0.087	0.126
Robotics exposed firms	-0.088**	-0.240**	-0.097**	-0.079**	-0.075**	-0.058**	-0.135**	-0.026**	0.000	-0.014**	-0.014**	-0.010**	-0.007**	-0.006**	-0.004**
	(0.005)	(0.010)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)	(0.002)	(0.004)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)
Constant	0.631**	1.777**	0.434**	0.536**	0.393**	0.408**	0.545**	0.078**	0.258**	0.046**	0.119**	0.048**	0.068**	0.032**	0.069**
	(0.002)	(0.004)	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)
Broad occupational groups, Industries, Month FE and Other controls	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
R^2	0.243	0.444	0.180	0.131	0.144	0.345	0.252	0.096	0.174	0.053	0.155	0.163	0.098	0.087	0.126
N	344141	344141	344141	344141	344141	344141	344141	344141	344141	344141	344141	344141	344141	344141	344141

Table: Relationship between skill demand (in counts) and mostly exposed firms belonging to the 50th percentile and higher (Panel A) and the 90th percentile and higher (Panel B) of firms labor demand exposure to AI, machine learning, software, and robotics technology. Controls include region of work, workplace type, temporary work agencies, type of contract, and minimum education level. Robust standard errors are in parentheses. Note: ** $p < 0.01$; * $p < 0.05$; + $p < 0.10$.

Identification strategy

$$\text{ATE}_k^\tau = \mathbb{E}[Y_j^\tau(1) - Y_j^\tau(0)]$$

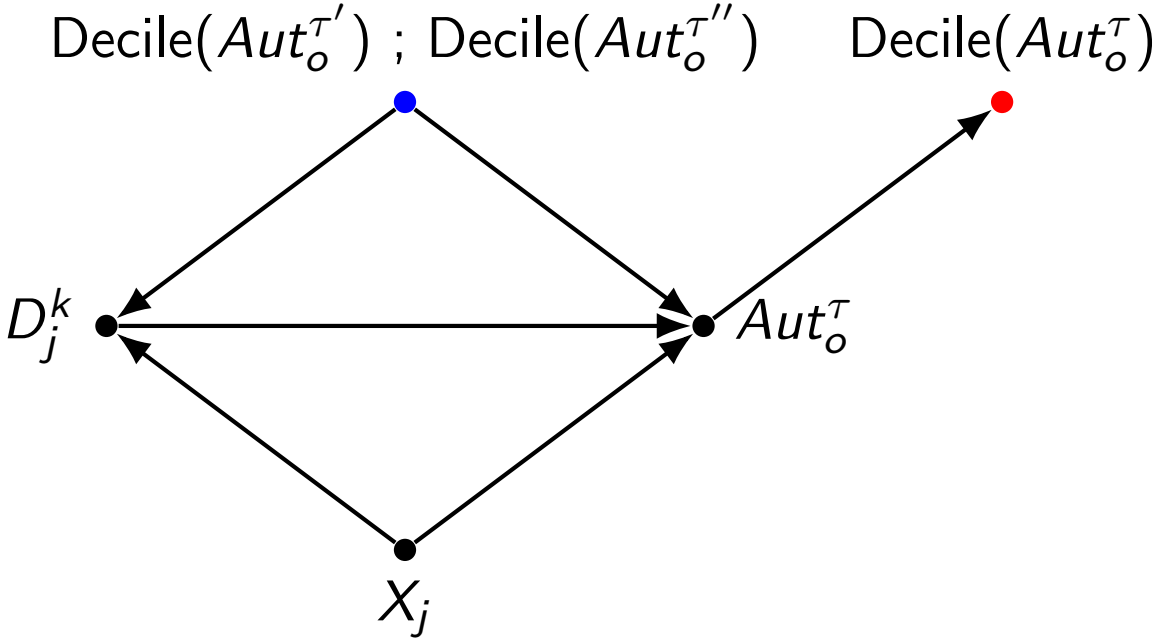


Figure: Directed acyclic graph of the treatment assignment in the identification strategy. The model controls for vacancy characteristics X_j and decile-level exposure to alternative automation technologies—Decile($Aut_o^{\tau'}$) and Decile($Aut_o^{\tau''}$)—while excluding Decile(Aut_o^τ) to avoid bad control bias.

	$ATE^{AI\ and\ ML}$	$ATE^{Software}$	$ATE^{Robotics}$
Social skills	0.018**	0.030**	0.011**
	(0.002)	(0.003)	(0.003)
Cognitive skills (narrow)	0.000	0.008*	-0.021**
	(0.003)	(0.003)	(0.004)
Character skills	0.008**	0.022**	0.017**
	(0.003)	(0.003)	(0.003)
Hand-foot-eye coordination skills	-0.023**	-0.025**	-0.021**
	(0.002)	(0.002)	(0.003)
Finger dexterity skills	0.005+	0.010**	0.011**
	(0.003)	(0.003)	(0.003)
Software-specific skills	-0.046**	-0.030**	-0.070**
	(0.006)	(0.006)	(0.007)
People management skills	-0.018**	0.001	-0.029**
	(0.003)	(0.003)	(0.004)
Writing skills	-0.029*	0.008	-0.003
	(0.014)	(0.015)	(0.016)
Customer service skills	0.030**	0.049**	0.040**
	(0.004)	(0.004)	(0.005)
Physical skills	-0.029+	-0.023	-0.025
	(0.015)	(0.017)	(0.020)
Financial skills	-0.054**	-0.040**	-0.068**
	(0.009)	(0.009)	(0.010)
Machine Learning and AI skills	-0.052	-0.030	-0.042
	(0.033)	(0.031)	(0.041)
Project management skills	-0.023*	0.000	-0.004
	(0.009)	(0.010)	(0.010)
Language skills	-0.029	-0.024	-0.052*
	(0.019)	(0.022)	(0.022)
Computer general skills	-0.003	0.029	0.013
	(0.019)	(0.020)	(0.019)
N	324,377	316,508	316,508

Table: Average Treatment Effects of Skill Presence on Automation Exposure to Technology τ. Firm's labor demand exposure to automation technologies τ' and τ'' decile, broad occupational group (ISCO-1d), industry (NACE-1d), region, and minimal education level included as controls. Robust standard errors are in the parentheses. ** $p<0.01$, * $p<0.05$, + $p<0.1$

Conclusions

- Examined skill groups offering a premium or penalty in the online labor market and their link to automation exposure.
- AI, machine learning, social, and management skills show the highest premium; physical, writing, and customer service skills show none or negative.
- Manual (e.g. hand-eye coordination), abstract (e.g. software use) skills reduce automation exposure; routine (e.g. customer service), social (e.g. teamwork), and character skills (e.g. reliability) are linked to higher exposure.

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Thank you for your attention!

https://tomasoles.github.io/home/

References I

Acemoglu, D., Autor, D., Hazell, J., and Restrepo, P. (2022). Artificial Intelligence and Jobs: Evidence from Online Vacancies. *Journal of Labor Economics*, 40(S1):S293–S340.

Acemoglu, D. and Restrepo, P. (2022). Tasks, Automation, and the Rise in US Wage Inequality. *Econometrica*, 90(5):1973–2016.

Arntz, M., Gregory, T., and Zierahn, U. (2016). The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis. *OECD Working Paper*, pages 1–35.

Autor, D., Chin, C., Salomons, A., and Seegmiller, B. (2024). New frontiers: The origins and content of new work, 1940–2018. *The Quarterly Journal of Economics*, page qjae008.

Autor, D., Levy, F., and Murnane, R. J. (2003). The Skill Content of Recent Technological Change: An Empirical Exploration. *The Quarterly Journal of Economics*, 118(4):1279–1333.

References II

Bennett, F., Escudero, V., Liepmann, H., and Podjanin, A. (2022). Using Online Vacancy and Job Applicants' Data to Study Skills Dynamics. *IZA Discussion Paper*, pages 1–54.

Brynjolfsson, E., Rock, D., and Syverson, C. (2021). The productivity J-curve: How intangibles complement general purpose technologies. *American Economic Journal: Macroeconomics*, 13(1):333–372.

Deming, D. and Kahn, L. (2018). Skill requirements across firms and labor markets: Evidence from job postings for professionals. *Journal of Labor Economics*, 36(S1):S337–S369.

Webb, M. (2019). The Impact of Artificial Intelligence on the Labor Market. *Working paper Available at SSRN 3482150*, pages 1–61.

Appendix

Unstructured skills in OJVs

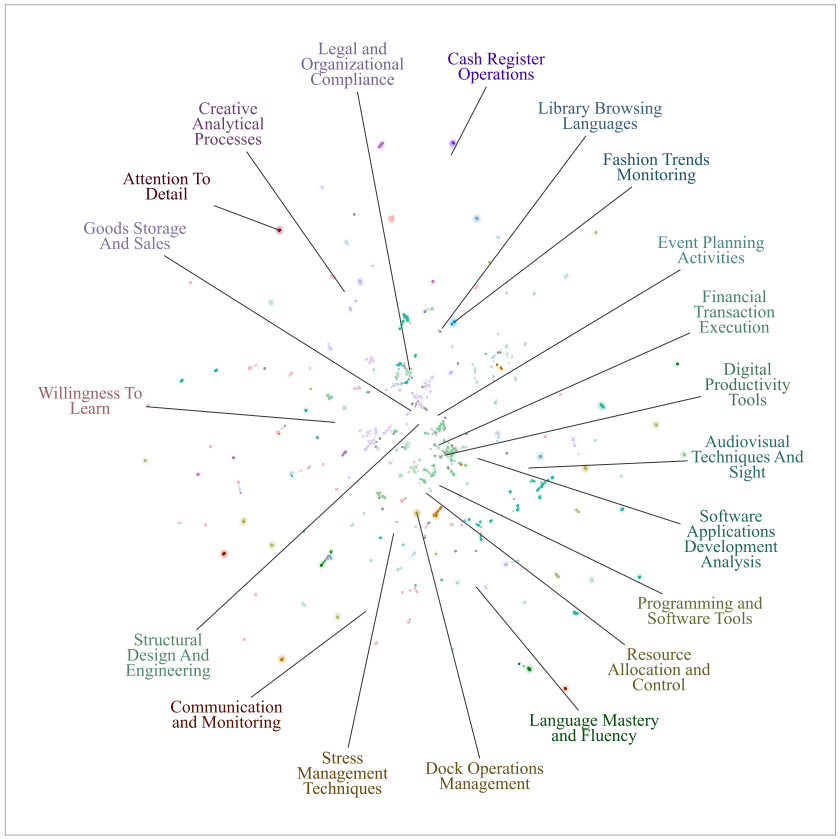
ISCO 2 - Professionals

ISCO 8 - Plant and Machine Operators, and Assemblers

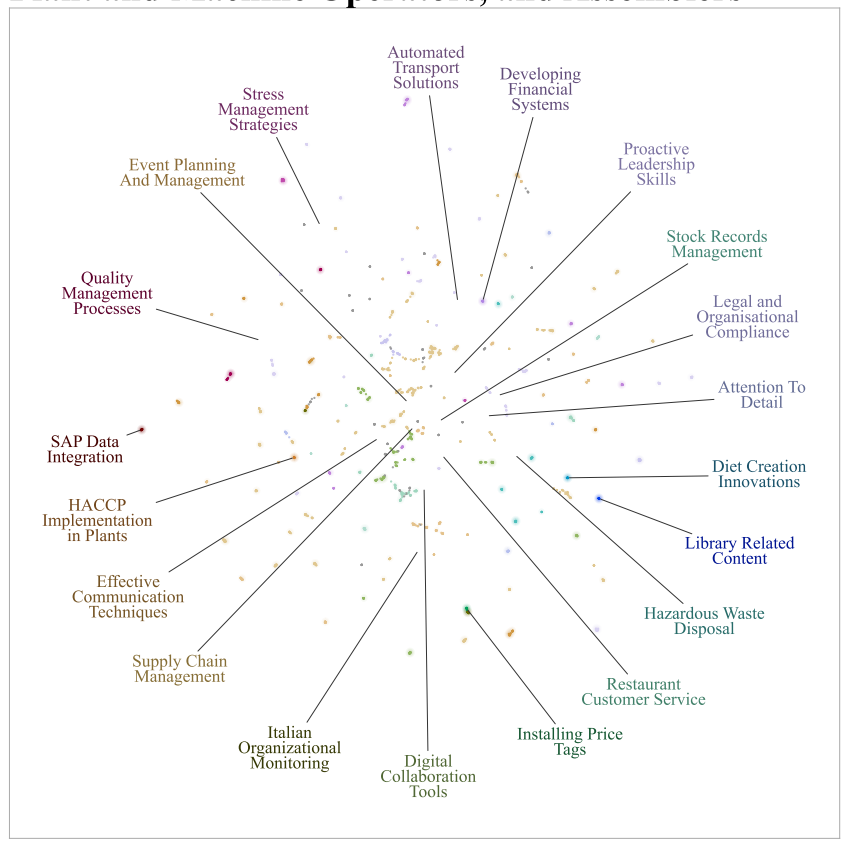
Word clouds by ISCO Major Groups. Figure displays word clouds representing up to 100 skills within each ISCO major occupational group. The size of each skill corresponds to its relative frequency within the group. Skills are in lemmatized form, and stopwords have been removed. Source: Profesia data.

Skill topics in OJVs

Professionals



Plant and Machine Operators, and Assemblers

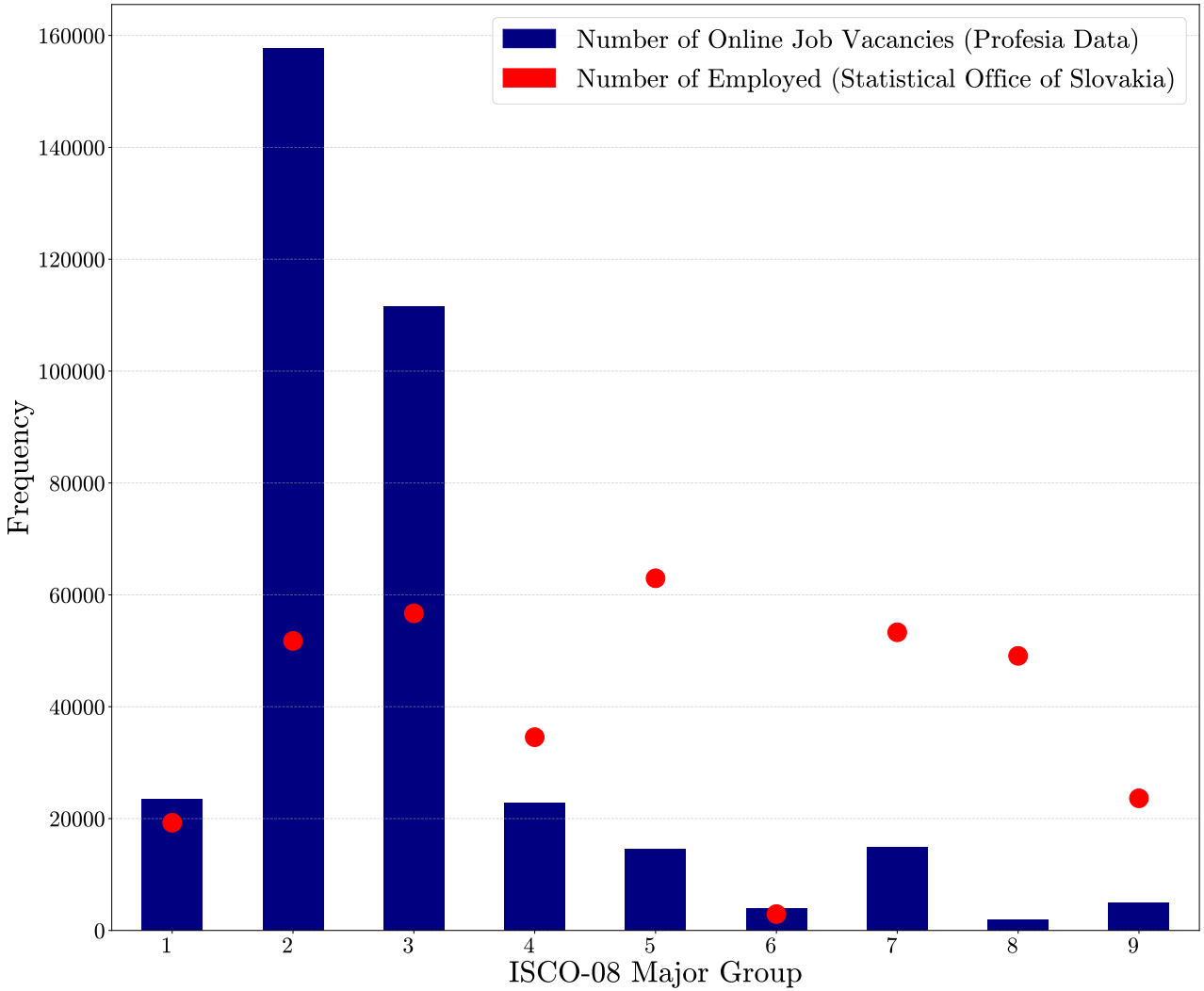


Skills topics by ISCO Major Groups. Figure displays at maximum 20 identified topics from BERTopic model from a random sample of 1500 skills on average per major group. Topics are labeled based on 10 representative documents of each topic group using an API call to ChatGPT 3.5 Turbo. Source: Profesia data.

Labelling keywords for each technology

- *Robots* [robot*∨mechatroni(c|cs)∨cyber-physical∨system∨computer∨vision∨control systems∨sensor]
- *Software* [software∨algorithm∨computer program∨data structure]
- *Artificial Intelligence* [artificial intelligence∨machine learning∨neural network∨deep learning]

Be aware of a biases...



Skill demand in the Slovak online labor market

Table: Summary statistics of wages, exposure to automation technologies and counts of skills conceptual categories

	count	mean	std	min	25%	50%	75%	max
Log(Monthly Wage)	337903	7.10	0.40	-2.30	6.80	7.03	7.31	9.16
Robots exposure	335734	0.19	1.01	-3.81	-0.41	0.21	1.05	1.65
Software exposure	335734	0.35	0.85	-3.41	0.08	0.34	0.97	1.63
AI and Machine Learning exposure	335734	0.27	0.86	-3.01	-0.01	0.40	0.89	1.70
Social skills	355845	0.65	1.12	0.00	0.00	0.00	1.00	20.00
Cognitive skills (narrow sense)	355845	1.83	2.65	0.00	0.00	1.00	2.00	35.00
Character skills	355845	0.44	0.85	0.00	0.00	0.00	1.00	13.00
Hand-foot-eye coordination skills	355845	0.54	0.89	0.00	0.00	0.00	1.00	10.00
Finger-dexterity skills	355845	0.40	0.79	0.00	0.00	0.00	1.00	13.00
Software (specific) skills and technical support	355845	0.43	1.04	0.00	0.00	0.00	0.00	14.00
People management skills	355845	0.55	1.09	0.00	0.00	0.00	1.00	18.00
Writing skills	355845	0.08	0.31	0.00	0.00	0.00	0.00	8.00
Customer service skills	355845	0.27	0.65	0.00	0.00	0.00	0.00	11.00
Physical skills	355845	0.05	0.23	0.00	0.00	0.00	0.00	6.00
Financial skills	355845	0.12	0.41	0.00	0.00	0.00	0.00	9.00
Machine Learning and AI skills	355845	0.06	0.34	0.00	0.00	0.00	0.00	9.00
Project management skills	355845	0.07	0.29	0.00	0.00	0.00	0.00	6.00
Language skills	355845	0.03	0.24	0.00	0.00	0.00	0.00	8.00
Computer (general) skills	355845	0.07	0.29	0.00	0.00	0.00	0.00	4.00

	Log(Monthly Wage)							
	Primary Sector		Secondary Sector		Private Services		Public & Social Services	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Social skills	0.06	0.03	0.03*	0.01*	0.02*	0.01**	0.01	0.02*
	(0.02)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
Cognitive skills (narrow sense)	0.04+	0.03	0.01+	0.01+	0.01**	0.01**	-0.01	-0.01
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Character skills	-0.02	-0.03	0.03*	0.02*	0.01*	0.01+	0.00	0.00
	(0.02)	(0.02)	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
Hand-foot-eye coordination skills	-0.01	-0.03+	0.00	0.01	-0.00	-0.00	-0.02	-0.01
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Finger dexterity skills	-0.03+	-0.02+	-0.00	0.01	0.00	0.01*	0.02	0.03
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.02)	(0.02)
Software-specific skills	-0.03	-0.01	0.00	0.01	0.01+	0.01+	-0.02	-0.00
	(0.02)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.02)	(0.01)
People management skills	0.02	-0.00	0.02+	0.02**	0.03**	0.03**	0.03+	0.03+
	(0.02)	(0.02)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
Writing skills	0.13	0.10	0.06+	0.04+	0.02	0.00	0.01	-0.02
	(0.12)	(0.06)	(0.02)	(0.02)	(0.01)	(0.01)	(0.03)	(0.02)
Customer service skills	-0.01	-0.02	0.04	0.03	0.01	0.00	-0.01	-0.01
	(0.03)	(0.04)	(0.02)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)
Physical skills	-0.05	0.00	-0.01	0.01	0.01	0.00	-0.04	-0.04
	(0.03)	(0.04)	(0.01)	(0.01)	(0.01)	(0.01)	(0.10)	(0.06)
Financial skills	-0.02	0.00	0.04+	0.04+	0.04**	0.03**	0.12	0.09
	(0.05)	(0.07)	(0.02)	(0.01)	(0.01)	(0.01)	(0.07)	(0.04)
Machine Learning and AI skills	-0.18	-0.06	0.05	0.05	0.03**	0.04**	0.11+	0.07
	(0.07)	(0.06)	(0.05)	(0.03)	(0.01)	(0.00)	(0.04)	(0.04)
Project management skills	0.02	-0.01	0.04+	0.01	0.03	0.02	0.01	0.00
	(0.05)	(0.04)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Language skills	0.03	-0.07	0.14+	0.02	0.01	0.00	0.12	0.10
	(0.12)	(0.09)	(0.05)	(0.02)	(0.01)	(0.01)	(0.08)	(0.04)
Computer general skills	0.09	0.04	0.01	0.00	-0.02	-0.03+	-0.03	-0.00
	(0.03)	(0.03)	(0.03)	(0.02)	(0.01)	(0.01)	(0.04)	(0.03)
Constant	6.98**	7.00**	6.96**	6.96**	7.03**	7.04**	7.12**	7.11**
	(0.01)	(0.01)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
Broad occupational groups FE	✓	✓	✓	✓	✓	✓	✓	✓
Industries FE	✓	✓	✓	✓	✓	✓	✓	✓
Other controls		✓		✓		✓		✓
Month FE		✓		✓		✓		✓
N	1044	1032	66114	65914	259294	249223	10138	10058
Adj. R^2	0.17	0.51	0.32	0.69	0.47	0.64	0.25	0.56
R^2 within	0.04	0.02	0.03	0.03	0.08	0.05	0.02	0.03