# ARTIFICIAL INTELLIGENCE TECHNOLOGIES, SKILLS DEMAND AND EMPLOYMENT: EVIDENCE FROM LINKED JOB ADS DATA

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# MOTIVATION

- large number of innovations in the area of Artificial Intelligence (AI) in the recent years
- the implications of AI for establishments' labour demand are widely discussed see e.g., Acemoglu et al. (2022); Copestake et al. (2023); Gathmann/Grimm (2023); Gonschor/Storm (2023)
- two main theoretical effect channels: Acemoglu/Restrepo (2018, 2019)
  - AI may automate human tasks
  - new AI technologies require solving of new human tasks
- Which effect dominates?

# RESEARCH QUESTIONS

1. How large is AI activity in Germany?

2. Do we see evidence for sizeable displacement of human tasks due to AI?

# STRATEGY AND CONTRIBUTION

Data and methodology

- extracting AI skills demand from German job ads data based on text mining algorithms Stops et al. (2021)

- particularly, we extract those skills, which are required to adopt, apply or develop AI

- we take this as a signal for activities in adopting, applying or developing AI in the establishment

- linking such data with administrative establishment data

Major contribution to the literature

- direct measure of AI activity at the establishment level

- analysing the relationship of labour demand and AI activity at the establishment level

# IDENTIFYING AI ACTIVITY USING JOB ADS: EXAMPLE

Your responsibilities:

- Design, development and performance evaluation of neural network inference on on-board processors, in particular system-on-chips.
- Evaluation and deployment of different inference methods and tools for neural networks (compilers, autocoding, embedded software, FPGA design) depending on the project requirements.
- Hardware/Software optimisation and implementation of payload data processing functions on processors (e.g. uC/uP, DSP, GPU, AI accelerators) and FPGA-based (e.g. MPSoC, RfSoC) platforms.
- Simulation/Verification of the designed SW or VHDL components using appropriate Tool environment
- Design, verification and validation of demonstrators for future spacecraft missions.

Your profile:

- Completed studies in computer science, engineering or comparable
- Excellent software design, problem solving and debugging skills
- Experience with SoC, FPGA or/and GPU acceleration for AI
- Experience with SW/HW parallelism, and asynchronous processing
- Experience with embedded systems, and real time OS
- Excellent programming skills of Embedded C/C
- Good understanding of Deep Learning workloads and processing requirements
- Good understanding of design, training and validation of machine learning techniques for tasks such as prediction, classification, semantic segmentation, and object detection
- Fluent German and English skills spoken and written

# DATA ON GERMAN JOB ADS

| Year | Number of vacancies | Vacancies w/o temporary work | Due date |
|------|---------------------|------------------------------|----------|
| 2015 | 458,404 | 297,888 | 15/10 |
| 2016 | 475,075 | 375,179 | 15/10 |
| 2017 | 663,894 | 442,383 | 15/10 |
| 2018 | 695,145 | 481,569 | 15/10 |
| 2019 | 644,653 | 446,693 | 15/10 |

Source: JOBBÖRSE of the German Federal Employment Agency (FEA). Job ads with full support by the FEA. Cross-sections.

Industry distribution 2015   Industry distribution 2019   Requirement level distribution

# ESTABLISHMENT HISTORY PANEL (BHP)

We link these data with the Establishment History Panel (BHP) provided by the Federal Employment Agency.

- data on all establishments which have at least one employee subject to social security contributions in Germany Ganzer et al. (2022)
- we exploit the establishments' employment levels for the relevant period and various characteristics as covariates

# HOW LARGE IS AI ACTIVITY?
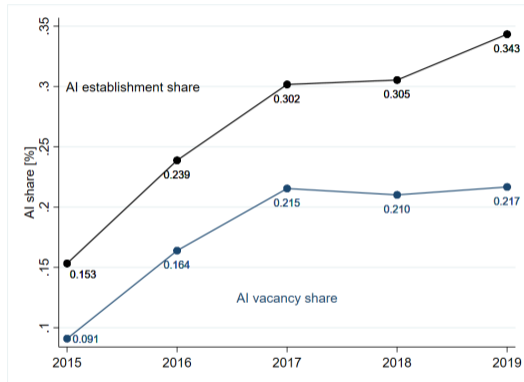


*Note: Vacancies from temporary work agencies are excluded. The AI vacancy share is the share of vacancies requiring at least one AI skill. The AI establishment share is the share of establishments posting at least one AI vacancy per year.*

# SHARE OF AI VACANCIES PER SECTOR
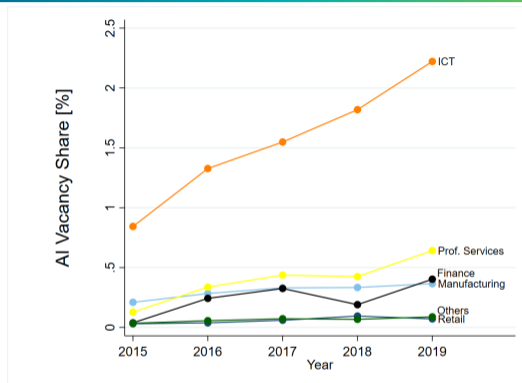


*Note: Vacancies from temporary work agencies are excluded. The AI vacancy share is the share of vacancies requiring at least one AI skill. Data on the sectors of the posting establishments are from the BHP.*

## THE MODEL

**How is AI activity in 2015 related to employment growth?**

$$\Delta y_{e,t_{19}-t_{15}} = \alpha + \beta \frac{v^{AI}_{e,t_{15}}}{v^{ALL}_{e,t_{15}}} + x'_{e,t_{15}} \gamma + \epsilon_{e,t_{19}-t_{15}},$$

where

- $\Delta y_{e,t_{19}-t_{15}}$: employment growth

- $\alpha$: intercept

- $\frac{v^{AI}_{e,t_{15}}}{v^{ALL}_{e,t_{15}}}$: AI vacancy share in 2015

- $x'_{e,t_{15}}$: establishment prop. in 2015 (size, number of vacancies, AKM effects 2014-2021, age, sector, federal state, occupational shares) & AI activity after 2015

## Employment growth 2015 - 2019 and AI skills demand, all establishments

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Overall Employment Growth | | | | | | | | |
| AI vacancy share in 2015 | 0.061 | 0.023 | 0.023 | 0.023 | 0.021 | -0.007 | 0.015 | -0.014 | -0.027 |
| | (0.051) | (0.049) | (0.049) | (0.049) | (0.049) | (0.047) | (0.048) | (0.045) | (0.045) |
| Observations | 33680 | 33680 | 33680 | 33680 | 33680 | 33680 | 33680 | 33680 | 33680 |
| | Employment growth in unskilled jobs | | | | | | | | |
| AI vacancy share in 2015 | 0.165 | 0.128 | 0.123 | 0.128 | 0.127 | 0.130 | 0.130 | 0.136 | 0.126 |
| | (0.123) | (0.122) | (0.122) | (0.122) | (0.122) | (0.122) | (0.123) | (0.123) | (0.122) |
| Observations | 34114 | 34114 | 34114 | 34114 | 34114 | 34114 | 34114 | 34114 | 34114 |
| Covariates (fixed for 2015): | | | | | | | | | |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** p $<$ 0.01, ** p $<$ 0.05, * p $<$ 0.10

# Employment growth 2015 - 2019 and AI skills demand, all establishments

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Employment growth in skilled jobs | | | | | | | | |
| AI vacancy share in 2015 | 0.030 | -0.002 | 0.000 | -0.002 | -0.005 | -0.015 | 0.001 | -0.021 | -0.026 |
| | (0.070) | (0.067) | (0.067) | (0.066) | (0.067) | (0.068) | (0.067) | (0.068) | (0.067) |
| Observations | 33582 | 33582 | 33582 | 33582 | 33582 | 33582 | 33582 | 33582 | 33582 |
| | Employment growth in complex jobs | | | | | | | | |
| AI vacancy share in 2015 | 0.024 | 0.047 | 0.046 | 0.048 | 0.048 | 0.031 | 0.054 | 0.028 | 0.025 |
| | (0.073) | (0.073) | (0.073) | (0.073) | (0.073) | (0.072) | (0.074) | (0.073) | (0.072) |
| Observations | 33648 | 33648 | 33648 | 33648 | 33648 | 33648 | 33648 | 33648 | 33648 |
| | Employment growth in highly complex jobs | | | | | | | | |
| AI vacancy share in 2015 | 0.125* | 0.139* | 0.137* | 0.140* | 0.141* | 0.125* | 0.129* | 0.141* | 0.124* |
| | (0.076) | (0.076) | (0.076) | (0.075) | (0.076) | (0.073) | (0.075) | (0.076) | (0.072) |
| Observations | 34048 | 34048 | 34048 | 34048 | 34048 | 34048 | 34048 | 34048 | 34048 |
| Covariates (fixed for 2015): | | | | | | | | | |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

# EXTENSIONS AND ROBUSTNESS

- the finding of no evidence for sizeable displacement effects is robust to:
  - excluding AI producing sectors ICT and professional services  `w/o AI producing`
  - estimating the relationship between AI activity in 2015 and employment growth by *employees' qualification level*  `qualification levels`
  - testing for a short-run relationship of AI activity and employment growth  `short-run relationship`
- AI activity in 2015 correlates with establishment AI exposure but is unrelated to software exposure (Webb, 2020)  `AI exposure`
- AI activity in 2015 is related to a slightly larger turnover of other (non-AI) skills  `Skill Change`

# SUMMARY

- link of job ads and administrative establishment data to test for relationship of AI activity and employment growth
- we find:
  - low but increasing AI activities in Germany between 2015 and 2019
  - no evidence for sizeable displacement of human tasks
    - no significant difference in overall employment growth
    - higher employment growth in highly complex jobs

# CONTACT

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# REPRESENTATIVENESS – INDUSTRY SHARES IN THE VACANCY DATA AND THE IAB JOB VACANCY SURVEY (2015)
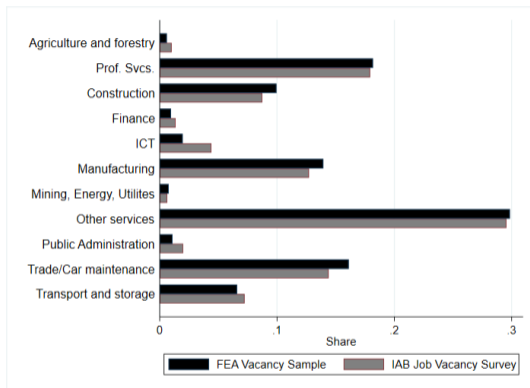


*Note: Vacancies from temporary work agencies are excluded. The IAB Job Vacancy Survey is a representative survey on labour demand and recruitment processes in Germany (Bossler et al., 2022).*

Job ads per year

# REPRESENTATIVENESS – INDUSTRY SHARES IN THE VACANCY DATA AND THE IAB JOB VACANCY SURVEY (2019)



*Note: Vacancies from temporary work agencies are excluded. The IAB Job Vacancy Survey is a representative survey on labour demand and recruitment processes in Germany (Bossler et al., 2022).*

Job ads per year

*Note: Vacancies from temporary work agencies are excluded. The IAB Job Vacancy Survey is a representative survey on labour demand and recruitment processes in Germany (Bossler et al., 2022).*

Job ads per year
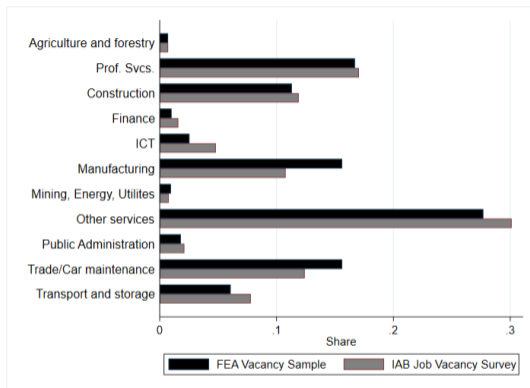
# REPRESENTATIVENESS – VACANCY SHARE PER SKILL LEVEL IN THE VACANCY DATA AND THE IAB JOB VACANCY SURVEY (2019)



*Note: Vacancies from temporary work agencies are excluded. The IAB Job Vacancy Survey is a representative survey on labour demand and recruitment processes in Germany (Bossler et al., 2022).*
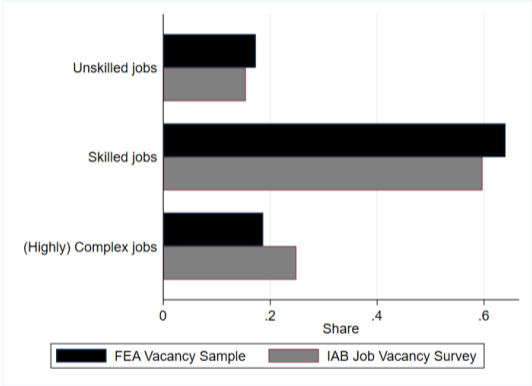
Job ads per year

# AI VACANCY SHARES BY REQUIRED SKILL LEVEL
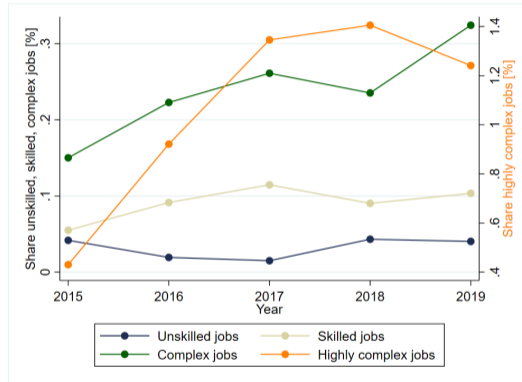


*Note: Vacancies from temporary work agencies are excluded. The AI vacancy share is the share of vacancies requiring at least one AI skill.*

# SHARE OF ESTABLISHMENTS WITH AI ACTIVITY PER SECTOR
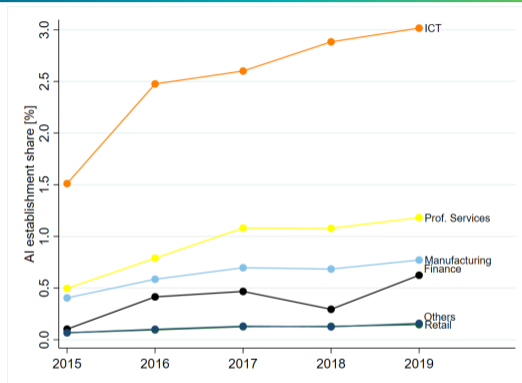


*Note: Vacancies from temporary work agencies are excluded. The AI establishment share is the share of establishments posting at least one AI vacancy per year. The data on the sector of the posting establishment is from the BHP.*

Note: ICT = Information and Communication Technology
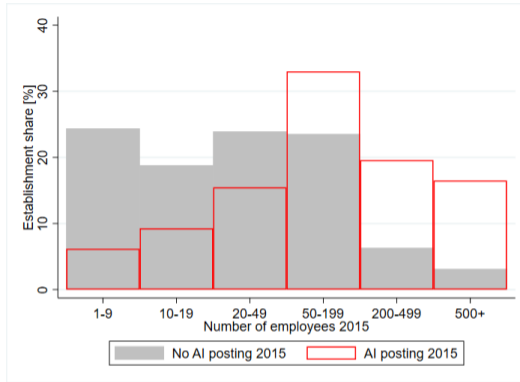
**Establishment shares for different employment levels, with and without AI vacancy posting, 2015.**

*Note: Establishment employment levels based on data from the Establishment History Panel (BHP).*
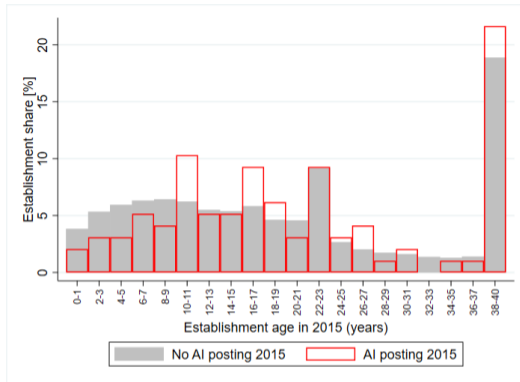
**Establishment shares by establishment age in years, with and without AI vacancy posting, 2015.**

*Note: Establishment age calculated based on data from the Establishment History Panel (BHP). Since the BHP contains data starting in 1975, there is a high share of firms being documented as founded in 1975. The relatively high share of establishments with an age of 25 years arises due to reunification in Germany.*
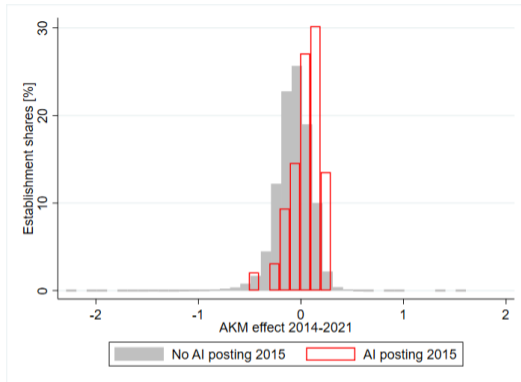
**Distribution of establishments over AKM effects.**

*Note: AKM effects are estimated by Lochner/Seth/Wolter (2023) and represent establishment-specific wage premia (considering the log daily real wage).*

**Distribution of establishments by job shares in different required skill levels, with and without AI vacancy posting, 2015.**

*Note: Employment shares are calculated based on data from the Establishment History Panel.*

## Employment growth 2015 - 2019 and AI vacancy share 2015, w/o the AI producing sectors ICT, professional services and temporary work

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Overall Employment Growth | | | | | | | | |
| AI vacancy share in 2015 | 0.013 | -0.027 | -0.028 | -0.027 | -0.029 | -0.046 | -0.032 | -0.049 | -0.063 |
| | (0.055) | (0.051) | (0.051) | (0.052) | (0.051) | (0.054) | (0.053) | (0.051) | (0.050) |
| Observations | 31992 | 31992 | 31992 | 31992 | 31992 | 31992 | 31992 | 31992 | 31992 |
| | Employment growth in unskilled jobs | | | | | | | | |
| AI vacancy share in 2015 | 0.225 | 0.179 | 0.174 | 0.179 | 0.178 | 0.156 | 0.180 | 0.170 | 0.157 |
| | (0.160) | (0.159) | (0.159) | (0.159) | (0.159) | (0.159) | (0.159) | (0.162) | (0.161) |
| Observations | 32335 | 32335 | 32335 | 32335 | 32335 | 32335 | 32335 | 32335 | 32335 |
| Covariates (fixed for 2015): | | | | | | | | | |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

# Employment growth 2015 - 2019 and AI vacancy share 2015, w/o the AI producing sectors ICT and professional services and temporary work

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| **Employment growth in skilled jobs** | | | | | | | | | |
| AI vacancy share in 2015 | 0.001 | -0.027 | -0.025 | -0.025 | -0.028 | -0.039 | -0.025 | -0.042 | -0.045 |
| | (0.067) | (0.062) | (0.062) | (0.061) | (0.062) | (0.063) | (0.062) | (0.060) | (0.060) |
| Observations | 31824 | 31824 | 31824 | 31824 | 31824 | 31824 | 31824 | 31824 | 31824 |
| **Employment growth in complex jobs** | | | | | | | | | |
| AI vacancy share in 2015 | 0.003 | 0.032 | 0.029 | 0.034 | 0.033 | 0.022 | 0.037 | 0.014 | 0.007 |
| | (0.080) | (0.078) | (0.078) | (0.078) | (0.078) | (0.077) | (0.078) | (0.079) | (0.079) |
| Observations | 31984 | 31984 | 31984 | 31984 | 31984 | 31984 | 31984 | 31984 | 31984 |
| **Employment growth in highly complex jobs** | | | | | | | | | |
| AI vacancy share in 2015 | 0.105 | 0.124 | 0.121 | 0.125 | 0.125 | 0.120 | 0.119 | 0.127 | 0.116 |
| | (0.087) | (0.086) | (0.086) | (0.085) | (0.086) | (0.082) | (0.085) | (0.086) | (0.082) |
| Observations | 32439 | 32439 | 32439 | 32439 | 32439 | 32439 | 32439 | 32439 | 32439 |
| **Covariates (fixed for 2015):** | | | | | | | | | |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$    extensions/robustness

# Skill requirement change 2015 - 2019, effects of AI skills demand 2015, all establishments

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Total skill change | | | | | | | | |
| AI vacancy share in 2015 | -0.009* | -0.008 | -0.008 | -0.008 | -0.008 | -0.007 | -0.008 | -0.008 | -0.007 |
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| Observations | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 |
| | Positive skill change | | | | | | | | |
| AI vacancy share in 2015 | 0.009 | 0.012 | 0.011 | 0.011 | 0.012 | 0.008 | 0.012 | 0.007 | 0.006 |
| | (0.008) | (0.008) | (0.008) | (0.007) | (0.008) | (0.007) | (0.007) | (0.007) | (0.007) |
| Observations | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 |
| | Negative skill change | | | | | | | | |
| AI vacancy share in 2015 | 0.017** | 0.019** | 0.018** | 0.019** | 0.019** | 0.014* | 0.015* | 0.019** | 0.013* |
| | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) | (0.007) | (0.008) | (0.008) | (0.007) |
| Observations | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 | 27555 |
| Covariates (fixed for 2015): | | | | | | | | | |
| Change in AI vacancy share | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$   extensions/robustness

# Skill requirement change 2015 - 2019, effects of AI skills demand, w/o AI producing sectors ICT and professional services

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Total skill change | | | | | | | | |
| AI vacancy share in 2015 | -0.010* | -0.009 | -0.009 | -0.009 | -0.008 | -0.008 | -0.008 | -0.008 | -0.008 |
| | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| Observations | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 |
| | Positive skill change | | | | | | | | |
| AI vacancy share in 2015 | 0.001 | 0.005 | 0.004 | 0.005 | 0.005 | 0.003 | 0.005 | 0.003 | 0.002 |
| | (0.009) | (0.008) | (0.008) | (0.008) | (0.008) | (0.007) | (0.008) | (0.007) | (0.006) |
| Observations | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 |
| | Negative skill change | | | | | | | | |
| AI vacancy share in 2015 | 0.011 | 0.013 | 0.013 | 0.014 | 0.014 | 0.011 | 0.011 | 0.014 | 0.010 |
| | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.008) | (0.008) | (0.009) | (0.007) |
| Observations | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 | 26082 |
| Covariates (fixed for 2015): | | | | | | | | | |
|     Change in AI vacancy share | yes | yes | yes | yes | yes | yes | yes | yes | yes |
|     AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
|     Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
|     Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
|     AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
|     Establishment age | no | no | no | no | yes | no | no | no | yes |
|     Economic sectors | no | no | no | no | no | yes | no | no | yes |
|     Federal states | no | no | no | no | no | no | yes | no | yes |
|     Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

## Summary statistics for outcome variables

| Variable | Mean | Median | Min | Max |
|---|---|---|---|---|
| *Skill change indices (2015-2019):* | | | | |
| Net skill change | 0.485 | 0.500 | -4.086 | 5.000 |
| Positive skill change | 1.624 | 1.000 | 0.000 | 13.000 |
| Negative skill change | 1.139 | 0.667 | 0.000 | 12.000 |
| *Employment growth (2015-2019):* | | | | |
| Overall Employment growth | 7.900 | 5.195 | -99.687 | 100.000 |
| Employment growth (unskilled jobs) | 6.569 | 0.000 | -100.000 | 200.000 |
| Employment growth (skilled jobs) | 5.704 | 0.000 | -100.000 | 120.000 |
| Employment growth (complex jobs) | -2.797 | 0.000 | -100.000 | 100.000 |
| Employment growth (highly complex jobs) | -0.763 | 0.000 | -100.000 | 100.000 |

*Note: All industries included. The skill change indices are defined as above. Employment growth rates are in per cent. Observations above the 95th percentile are excldued.*

## Employment growth 2015 - 2019 and AI vacancy share 2015, all establishments including temporary work establishments

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Overall Employment Growth | | | | | |
| AI vacancy share in 2015 | 0.088* | 0.054 | 0.043 | 0.052 | 0.055 | -0.001 | 0.048 | 0.001 | -0.033 |
| | (0.050) | (0.050) | (0.050) | (0.049) | (0.050) | (0.048) | (0.049) | (0.044) | (0.044) |
| Observations | 36232 | 36232 | 36232 | 36232 | 36232 | 36232 | 36232 | 36232 | 36232 |
| | | | | Employment growth in unskilled jobs | | | | | |
| AI vacancy share in 2015 | 0.184 | 0.148 | 0.136 | 0.146 | 0.149 | 0.138 | 0.152 | 0.154 | 0.128 |
| | (0.123) | (0.123) | (0.122) | (0.122) | (0.122) | (0.122) | (0.123) | (0.122) | (0.121) |
| Observations | 36697 | 36697 | 36697 | 36697 | 36697 | 36697 | 36697 | 36697 | 36697 |
| Covariates (fixed for 2015): | | | | | | | | | |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** p < 0.01, ** p < 0.05, * p < 0.10

## Employment growth 2015 - 2019 and AI vacancy share 2015, all establishments including temporary work establishments

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Employment growth in skilled jobs | | | | | | | | |
| AI vacancy share in 2015 | 0.058 | 0.034 | 0.023 | 0.028 | 0.035 | -0.011 | 0.037 | 0.000 | -0.036 |
| | (0.069) | (0.068) | (0.068) | (0.067) | (0.068) | (0.068) | (0.069) | (0.069) | (0.067) |
| Observations | 36155 | 36155 | 36155 | 36155 | 36155 | 36155 | 36155 | 36155 | 36155 |
| | Employment growth in complex jobs | | | | | | | | |
| AI vacancy share in 2015 | 0.063 | 0.092 | 0.079 | 0.089 | 0.094 | 0.053 | 0.098 | 0.062 | 0.036 |
| | (0.074) | (0.074) | (0.074) | (0.074) | (0.074) | (0.073) | (0.075) | (0.073) | (0.072) |
| Observations | 36289 | 36289 | 36289 | 36289 | 36289 | 36289 | 36289 | 36289 | 36289 |
| | Employment growth in highly complex jobs | | | | | | | | |
| AI vacancy share in 2015 | 0.168** | 0.183** | 0.175** | 0.180** | 0.184** | 0.160** | 0.158** | 0.186** | 0.147** |
| | (0.074) | (0.075) | (0.075) | (0.073) | (0.074) | (0.071) | (0.074) | (0.074) | (0.071) |
| Observations | 36705 | 36705 | 36705 | 36705 | 36705 | 36705 | 36705 | 36705 | 36705 |
| Covariates (fixed for 2015): | | | | | | | | | |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

## Employment growth 2015 - 2019 and AI vacancy share 2015, w/o the AI producing sectors ICT, professional services, including temporary work

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Overall Employment Growth | | | | | | | | |
| AI vacancy share in 2015 | 0.042 | 0.006 | -0.008 | 0.004 | 0.006 | -0.040 | 0.003 | -0.029 | -0.066 |
| | (0.054) | (0.053) | (0.053) | (0.052) | (0.053) | (0.055) | (0.054) | (0.051) | (0.049) |
| Observations | 34543 | 34543 | 34543 | 34543 | 34543 | 34543 | 34543 | 34543 | 34543 |
| | Employment growth in unskilled jobs | | | | | | | | |
| AI vacancy share in 2015 | 0.248 | 0.202 | 0.189 | 0.200 | 0.202 | 0.162 | 0.206 | 0.192 | 0.159 |
| | (0.160) | (0.159) | (0.159) | (0.159) | (0.159) | (0.159) | (0.159) | (0.160) | (0.160) |
| Observations | 34915 | 34915 | 34915 | 34915 | 34915 | 34915 | 34915 | 34915 | 34915 |
| Covariates (fixed for 2015): | | | | | | | | | |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** p < 0.01, ** p < 0.05, * p < 0.10

# Employment growth 2015 - 2019 and AI vacancy share 2015, w/o the AI producing sectors ICT and professional services; including temporary work

|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Employment growth in skilled jobs | | | | | |
| AI vacancy share in 2015 | 0.032 | 0.010 | -0.005 | 0.006 | 0.009 | -0.036 | 0.012 | -0.017 | -0.053 |
| | (0.065) | (0.063) | (0.063) | (0.061) | (0.063) | (0.063) | (0.064) | (0.063) | (0.061) |
| Observations | 34418 | 34418 | 34418 | 34418 | 34418 | 34418 | 34418 | 34418 | 34418 |
| | | | | Employment growth in complex jobs | | | | | |
| AI vacancy share in 2015 | 0.048 | 0.084 | 0.067 | 0.082 | 0.083 | 0.050 | 0.089 | 0.058 | 0.024 |
| | (0.082) | (0.080) | (0.080) | (0.080) | (0.079) | (0.079) | (0.081) | (0.083) | (0.079) |
| Observations | 34623 | 34623 | 34623 | 34623 | 34623 | 34623 | 34623 | 34623 | 34623 |
| | | | | Employment growth in highly complex jobs | | | | | |
| AI vacancy share in 2015 | 0.158* | 0.178** | 0.167** | 0.174** | 0.177** | 0.167** | 0.157* | 0.180** | 0.148* |
| | (0.085) | (0.085) | (0.085) | (0.083) | (0.085) | (0.079) | (0.084) | (0.085) | (0.081) |
| Observations | 35094 | 35094 | 35094 | 35094 | 35094 | 35094 | 35094 | 35094 | 35094 |
| Covariates (fixed for 2015): | | | | | | | | | |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

# Employment growth 2015 - 2019 by employee's qualification levels, effects of AI skills demand, all establishments w/o temporary work

|  | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Unskilled Employment Growth | | | | | |
| AI vacancy share in 2015 | -0.097 | -0.120 | -0.119 | -0.120 | -0.128 | -0.128 | -0.114 | -0.132 | -0.138 |
| | (0.103) | (0.096) | (0.096) | (0.095) | (0.095) | (0.095) | (0.096) | (0.094) | (0.095) |
| Observations | 34152 | 34152 | 34152 | 34152 | 34152 | 34152 | 34152 | 34152 | 34152 |
| | | | | Qualified Employment Growth | | | | | |
| AI vacancy share in 2015 | 0.007 | -0.004 | -0.004 | -0.003 | -0.006 | -0.027 | -0.006 | -0.036 | -0.045 |
| | (0.049) | (0.048) | (0.048) | (0.048) | (0.048) | (0.047) | (0.048) | (0.046) | (0.046) |
| Observations | 33847 | 33847 | 33847 | 33847 | 33847 | 33847 | 33847 | 33847 | 33847 |
| | | | | Highly Qualified Employment Growth | | | | | |
| AI vacancy share in 2015 | 0.071 | 0.078 | 0.076 | 0.079 | 0.078 | 0.056 | 0.058 | 0.078 | 0.047 |
| | (0.062) | (0.061) | (0.061) | (0.060) | (0.061) | (0.059) | (0.060) | (0.060) | (0.057) |
| Observations | 33562 | 33562 | 33562 | 33562 | 33562 | 33562 | 33562 | 33562 | 33562 |
| Covariates (fixed for 2015): | | | | | | | | | |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

# Employment growth 2015 - 2019 by employee's qualification levels, effects of AI skills demand, establishments w/o AI producing sectors and temporary work

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | Unskilled Employment Growth | | | | | | | | |
| AI vacancy share in 2015 | -0.168 | -0.190* | -0.188* | -0.189* | -0.195* | -0.188* | -0.182* | -0.195* | -0.197* |
| | (0.113) | (0.102) | (0.102) | (0.102) | (0.103) | (0.102) | (0.102) | (0.103) | (0.104) |
| Observations | 32398 | 32398 | 32398 | 32398 | 32398 | 32398 | 32398 | 32398 | 32398 |
| | Qualified Employment Growth | | | | | | | | |
| AI vacancy share in 2015 | 0.000 | -0.010 | -0.011 | -0.009 | -0.011 | -0.027 | -0.011 | -0.031 | -0.042 |
| | (0.057) | (0.055) | (0.055) | (0.054) | (0.055) | (0.054) | (0.054) | (0.051) | (0.051) |
| Observations | 32159 | 32159 | 32159 | 32159 | 32159 | 32159 | 32159 | 32159 | 32159 |
| | Highly Qualified Employment Growth | | | | | | | | |
| AI vacancy share in 2015 | 0.063 | 0.080 | 0.078 | 0.083 | 0.081 | 0.075 | 0.075 | 0.082 | 0.066 |
| | (0.080) | (0.077) | (0.077) | (0.075) | (0.077) | (0.073) | (0.075) | (0.075) | (0.070) |
| Observations | 31792 | 31792 | 31792 | 31792 | 31792 | 31792 | 31792 | 31792 | 31792 |
| Covariates (fixed for 2015): | | | | | | | | | |
| AI vacancy posting 2016-19 | yes | yes | yes | yes | yes | yes | yes | yes | yes |
| Establishment size | no | yes | yes | yes | yes | yes | yes | yes | yes |
| Number of all vacancies | no | no | yes | no | no | no | no | no | yes |
| AKM effects 2014-2021 | no | no | no | yes | no | no | no | no | yes |
| Establishment age | no | no | no | no | yes | no | no | no | yes |
| Economic sectors | no | no | no | no | no | yes | no | no | yes |
| Federal states | no | no | no | no | no | no | yes | no | yes |
| Occupational shares | no | no | no | no | no | no | no | yes | yes |

*** p < 0.01, ** p < 0.05, * p < 0.10    extensions/robustness

# Relationship of AI activity and Webb AI/software exposure 2015, w/o temporary work

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | All establishments | | | AI using sectors | | |
| Webb AI exposure 2015 | 0.055*** | | 0.078*** | 0.040** | | 0.055** |
| | (0.020) | | (0.026) | (0.017) | | (0.024) |
| Webb software exposure 2015 | | 0.022 | -0.039 | | 0.017 | -0.026 |
| | | (0.020) | (0.026) | | (0.016) | (0.023) |
| Observations | 33663 | 33663 | 33663 | 31977 | 31977 | 31977 |
| | | | | | | |
| Covariates (fixed for 2015): | | | | | | |
| Establishment size | yes | yes | yes | yes | yes | yes |
| Number of vacancies | yes | yes | yes | yes | yes | yes |
| AKM effects 2014-2021 | yes | yes | yes | yes | yes | yes |
| Establishment age | yes | yes | yes | yes | yes | yes |
| Economic sectors | yes | yes | yes | yes | yes | yes |
| Federal states | yes | yes | yes | yes | yes | yes |

*Notes:* This tables shows the relationship between our AI activity measures and the Webb (2020) AI and software exposure index at the establishment level in 2015. Our AI activity measures is the AI vacancy share in 2015. The Webb AI (software) exposure index is a weighted average of occupation-specific AI (software) scores at the establishment level where employment shares of the respective occupations are the weights. We estimate the model with OLS. Included covariates are establishment size, federal state, economic sector, AKM effects, overall vacancies and establishment age in 2015.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$   extensions/robustness

# Employment growth and AI vacancy share using panel data, all establishments w/o temporary work

| | OLS | OLS | OLS | FE | FE |
|---|---|---|---|---|---|
| | Overall Employment | | | | |
| L.AI vacancy share per year [%] | 0.020** | 0.018** | 0.017* | 0.005 | 0.005 |
| | (0.008) | (0.008) | (0.009) | (0.012) | (0.012) |
| Observations | 467556 | 467556 | 329217 | 467556 | 329217 |
| | | | | | |
| | Unskilled jobs | | | | |
| L.AI vacancy share per year [%] | -0.001 | -0.002 | -0.010 | -0.001 | -0.001 |
| | (0.016) | (0.016) | (0.020) | (0.040) | (0.040) |
| Observations | 473003 | 473003 | 332363 | 473003 | 332363 |
| | | | | | |
| Year fixed effects | yes | yes | yes | yes | yes |
| AKM effects 2014-2021 | no | yes | yes | no | no |
| Establishment size | yes | yes | yes | yes | yes |
| Number of all vacancies | yes | yes | yes | yes | yes |
| Establishment age | yes | yes | yes | yes | yes |
| Economic sectors | yes | yes | yes | yes | no |
| Federal states | yes | yes | yes | yes | yes |
| Occupational shares | yes | yes | yes | yes | yes |
| Restricted to $\geq$ 3 observations | no | no | yes | no | yes |

*** p < 0.01, ** p < 0.05, * p < 0.10

## Employment growth and AI vacancy share in the previous year using panel data, all establishments w/o temporary work

| | OLS | OLS | OLS | FE | FE |
|---|---|---|---|---|---|
| | Skilled jobs | | | | |
| L.AI vacancy share per year [%] | 0.002 | 0.000 | -0.002 | -0.019 | -0.013 |
| | (0.011) | (0.011) | (0.011) | (0.019) | (0.018) |
| Observations | 466779 | 466779 | 327513 | 466779 | 327513 |
| | Complex jobs | | | | |
| L.AI vacancy share per year [%] | 0.016 | 0.015 | 0.002 | -0.021 | -0.021 |
| | (0.014) | (0.014) | (0.016) | (0.025) | (0.025) |
| Observations | 468612 | 468612 | 328649 | 468612 | 328649 |
| | Highly complex jobs | | | | |
| L.AI vacancy share per year [%] | 0.012 | 0.011 | 0.018 | -0.010 | -0.010 |
| | (0.012) | (0.012) | (0.014) | (0.022) | (0.022) |
| Observations | 474462 | 474462 | 332565 | 474462 | 332565 |
| | | | | | |
| Year fixed effects | yes | yes | yes | yes | yes |
| AKM effects 2014-2021 | no | yes | yes | no | no |
| Establishment size | yes | yes | yes | yes | yes |
| Number of all vacancies | yes | yes | yes | yes | yes |
| Establishment age | yes | yes | yes | yes | yes |
| Economic sectors | yes | yes | yes | yes | no |
| Federal states | yes | yes | yes | yes | yes |
| Occupational shares | yes | yes | yes | yes | yes |
| Restricted to $\geq$ 3 observations | no | no | yes | no | yes |

*** p $<$ 0.01, ** p $<$ 0.05, * p $<$ 0.10

## Employment growth and AI vacancy share in the previous year using panel data, AI using establishments w/o temporary work

| | OLS | OLS | OLS | FE | FE |
|---|---|---|---|---|---|
| | Overall Employment | | | | |
| L.AI vacancy share per year [%] | 0.013 | 0.011 | 0.012 | 0.003 | 0.002 |
| | (0.009) | (0.009) | (0.009) | (0.014) | (0.013) |
| Observations | 440385 | 440385 | 310904 | 440385 | 310904 |
| | Unskilled Jobs | | | | |
| L.AI vacancy share per year [%] | -0.008 | -0.008 | -0.020 | -0.035 | -0.035 |
| | (0.019) | (0.019) | (0.023) | (0.044) | (0.044) |
| Observations | 444880 | 444880 | 313519 | 444880 | 313519 |
| | | | | | |
| Year fixed effects | yes | yes | yes | yes | yes |
| AKM effects 2014-2021 | no | yes | yes | no | no |
| Establishment size | yes | yes | yes | yes | yes |
| Number of all vacancies | yes | yes | yes | yes | yes |
| Establishment age | yes | yes | yes | yes | yes |
| Economic sectors | yes | yes | yes | yes | no |
| Federal states | yes | yes | yes | yes | yes |
| Occupational shares | yes | yes | yes | yes | yes |
| Restricted to $\geq$ 3 observations | no | no | yes | no | yes |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

# Employment growth and AI vacancy share in the previous year, AI using establishments w/o temporary work

|  | OLS | OLS | OLS | FE | FE |
|---|---|---|---|---|---|
| | Skilled jobs | | | | |
| L.AI vacancy share per year [%] | -0.000 | -0.002 | -0.008 | -0.037 * | -0.031 |
| | (0.011) | (0.011) | (0.010) | (0.020) | (0.019) |
| Observations | 439901 | 439901 | 309594 | 439901 | 309594 |
| | Complex jobs | | | | |
| L.AI vacancy share per year [%] | 0.021 | 0.020 | 0.012 | 0.001 | 0.001 |
| | (0.016) | (0.016) | (0.016) | (0.026) | (0.026) |
| Observations | 441787 | 441787 | 310562 | 441787 | 310562 |
| | Highly complex jobs | | | | |
| L.AI vacancy share per year [%] | 0.007 | 0.007 | 0.008 | -0.014 | -0.014 |
| | (0.014) | (0.014) | (0.015) | (0.024) | (0.024) |
| Observations | 447554 | 447554 | 314468 | 447554 | 314468 |
| | | | | | |
| Year fixed effects | yes | yes | yes | yes | yes |
| AKM effects 2014-2021 | no | yes | yes | no | no |
| Establishment size | yes | yes | yes | yes | yes |
| Number of all vacancies | yes | yes | yes | yes | yes |
| Establishment age | yes | yes | yes | yes | yes |
| Economic sectors | yes | yes | yes | yes | no |
| Federal states | yes | yes | yes | yes | yes |
| Occupational shares | yes | yes | yes | yes | yes |
| Restricted to $\geq$ 3 observations | no | no | yes | no | yes |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

# AI DEFINITION

We consider AI technologies as algorithms that process, identify, and act on patterns in unstructured data, like speech data, text, or images in systematic ways for different purposes, together with the machines, devices, and services that are controlled by these algorithms.
AI skills are defined as skills which are required to adopt, apply or develop AI methodologies.

# AI DICTIONARY

Creation of the AI dictionary in three steps:

1. Collecting AI skills from literature (Taddy, 2019; Alekseeva et al., 2021; Büchel et al., 2021; Acemoglu et al., 2022; Lightcast, 2022; OECD.AI, 2022) and web search

2. Definition of search items for these AI skills

3. Extensions of the dictionary
   - Generation of new search items using a word embedding approach relying on the job ads text data and string-in-string search
   - Validation of the automatically generated proposals by means of a two-stage consensual validation process
     - stage 1: validation of proposals by three experts working independently
     - stage 2: discussion of controversial proposals and reaching a final decision based on the majority principle

# THE REQUIRED SKILL LEVELS

We are able to observe the single occupations at the 5-digits level of the German classification of occupations 2010 (KldB 2010). The 5th digit of this code denotes the required skill level.

*unskilled jobs:*       no formal qualification or only short term training

*skilled jobs:*       (usually) formal vocational education training of at least 2 years

*complex jobs:*       (usually) university degree or master craftman's certificate

*highly complex jobs:*       (usually) university degree or similar and, beyond that, profound professional experience or further formal highly specialised qualification certificates like a doctorate or a habilitation

# DICTIONARY OF HARD SKILLS TERMS (W/O AI SKILL TERM)

- hard skills…are individual abilities to independently and autonomously cope with tasks and situations in specific occupational contexts
- taken from the BERUFENET:provides information for (almost) all known occupations in Germany (https://web.arbeitsagentur.de/berufenet/)
- hard skills dictionary consists of 7,270 requirements that are distinguishable in terms of content
- this includes 10,116 keywords and 23,158 different keyword combinations

Skill change measures

# SKILL REQUIREMENT CHANGE

**How is AI activity related to the change of hard skills demand?**

Three measures for the change of hard skills: see also Deming/Noray (2020); Acemoglu et al. (2022)

$$net\ skill\ change_{e, t_{15} - t_{19}} = \sum_{s=1}^{S} \left[ \underbrace{\left( \frac{skill^s_{e,t_{19}}}{v^{ALL}_{e,t_{19}}} \right)}_{\text{relative occurrence of skill } s \text{ in } t_{19}} - \underbrace{\left( \frac{skill^s_{e,t_{15}}}{v^{ALL}_{e,t_{15}}} \right)}_{\text{relative occurrence of skill } s \text{ in } t_{15}} \right],$$

where $s$ is a specific skill from total skills $S$. Additionally, we split the net skill change index:

$$net\ skill\ change_{e, t_{15} - t_{19}} = \underbrace{positive\ skill\ change_{e, t_{15} - t_{19}}}_{\text{'growing' skills}} - \underbrace{negative\ skill\ change_{e, t_{15} - t_{19}}}_{\text{'diminishing' skills}}$$

$$positive\ skill\ change_{e,t_0-t_1} = \sum_{s=1}^{S} \left[ \max \left\{ \left( \frac{skill_{e,t_1}^s}{v_{e,t_1}^{ALL}} \right) - \left( \frac{skill_{e,t_0}^s}{v_{e,t_0}^{ALL}} \right), 0 \right\} \right]$$

$$negative\ skill\ change_{e,t_0-t_1} = -\sum_{s=1}^{S} \left[ \min \left\{ \left( \frac{skill_{e,t_1}^s}{v_{e,t_1}^{ALL}} \right) - \left( \frac{skill_{e,t_0}^s}{v_{e,t_0}^{ALL}} \right), 0 \right\} \right],$$

where $s$ is a specific skill from total skills $S$.