# Unslicing the Pie: AI innovation and the labor share in European regions

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# Background

- AI under the lens for its effects on productivity (positive) and labor market (ambiguous / heterogeneous)

- AI decouples productivity gains from wages and employment outcomes

- Unclear whether AI functions like robots or operates differently, given its intangible nature and implementation of cognitive tasks

- Most of the literature focused on AI adoption, here we look at AI innovation

# Characteristics of AI innovation

- It exploits dynamic returns (Igna & Venturini 2022) ⇒ Technological concentration

- It yields large productivity gains (Damioli & al. 2021; Marioni & al. 2024) ⇒ Large rents to reap

- It is spatially concentrated (WIPO 2019, EPO 2021) ⇒ Geographical inequality

# Gaps of the literature

AI innovation and the labor share on income:

- Does AI innovation affect the relative distribution of income across factors (capital vs labor)?

- Does AI innovation widen regional income disparities?

- Which mechanisms are behind the income effect of AI innovation?

# Possible mechanisms

1. Distribution of innovation rents: profits grow more than wage income, leading to a fall in the labor share

2. Business reconfiguration: change in skill demand (high vs low-skilled; routinised vs non-routinised)

3. Change in market structure: growth of low-labor intensive companies such as big-tech / superstar firms

4. Structural change / Reallocation effects: growth of service industries, de-specialisation of labor intensive and manufacturing regions

# What we do

1. Assess the effect of AI on the labor share of European regions since the uptake of the new technology

2. Uncover the causal nature of the effect

3. Show heterogeneity in the effect across skill groups

4. Identify the underlying mechanism

# Layout of the presentation

1. Empirical model and Data

2. Baseline results: Dynamic regressions

3. Sensitivity analysis

4. Identification: Event analysis

5. Mechanisms

# Labor share and cumulative change (2000-17)
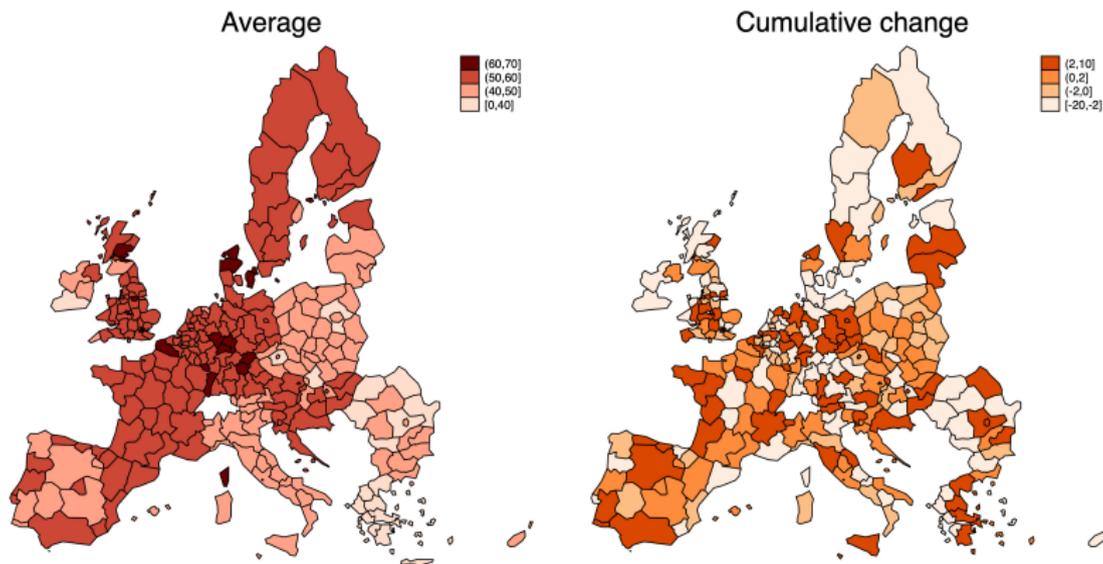


Notes: LS - Labor compensation over gross value added

# AI and ICT specialisation, RCA (avg. 2000-17)

AI

ICT
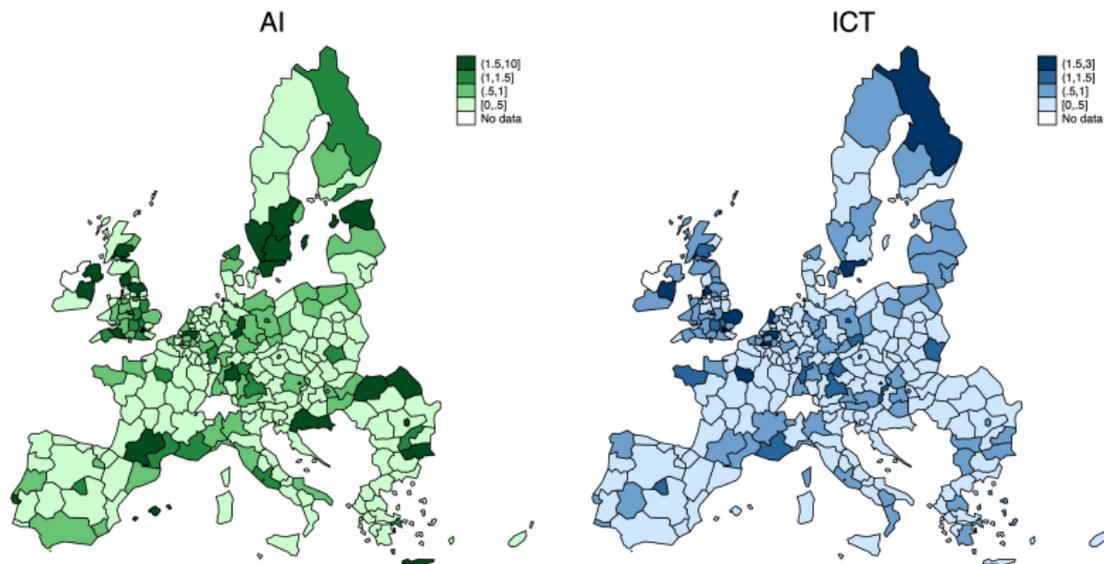


**Notes**: RCA - Index of technological Revealed Comparative Advantages

# Empirical framework

We extend Karabarbounis & Neiman (2014), O'Mahony & al.(2022)

$$LS = f(A, k)$$

- $A$: index of factor-specific technical change
- $k$: capital intensity

- $\partial LS/\partial A < 0$ (or $\partial LS/\partial k < 0$)   capital and labor substitute
- $\partial LS/\partial A > 0$ (or $\partial LS/\partial k > 0$)    capital and labor complement

# Empirical specification (1)

$$\ln LS_{jt} = \alpha_{j0} + \alpha_1 \ln k_{jt} + \alpha_2 \ln A_{jt} + \alpha_3 \ln X_{jt} + CSD_t + \epsilon_{jt}$$

- $LS=$ compensation of employees / value added (current prices)
- $k=$ capital / employment  (or value added in constant prices)
    1. $tk=$ tangible (physical) capital
    2. $ik=$ intangible (R&D) capital
    3. $ik=$ realised knowledge (patent) capital
        3.1 AI innovation
        3.2 4IR innovation (robotics, IoT, additive manuf., etc.)
        3.3 ICT innovation
        3.4 General innovation
- $A=$ technical change (exogenous):
    1. TFP: Total Factor Productivity (caveats)
    2. ALP: Avg. Labor Productivity (output per worker or hour)

# Empirical specification (2)

$$\ln LS_{jt} = \alpha_{j0} + \alpha_1 \ln k_{jt} + \alpha_2 \ln A_{jt} + \alpha_3 \ln X_{jt} + CSD_t + \epsilon_{jt}$$

- $X =$ Controls:
- $CSD =$ Cross-sectional dependence:
  1. Time dummies, $TD$ (Weak CSD)
  2. Common correlated Effects, $CCE$ (Strong CSD)
  3. Spatial dependence (proximity (km) weighted spatial lag)
- $j =$ NUTS2 (#278), $t = 2000, ..., 2017$
- $\alpha_{j0}$ region FEs, $\epsilon_{jt}$ spherical errors

# Econometric issues

- Omitted factors:
    1. Factor substitutability: Labor Productivity / Total Factor productivity. Tangible / Intangible assets ...
    2. Technological knowledge: 4IR, ICT or General innovations
    3. AI concentration: Within- vs between-region concentration
    4. Structural characteristics: tech specialisation, structural change, demographic dynamics, institutional setting

- Simultaneity:
    1. Long-run: dynamic regression with ARDL(1,1) specification
    2. Short-run: Event analysis based on Local Projection DiD

- Measurement:
    1. Country-level wage by skill
    2. Wage regionalisation through industry composition

# Data (278 NUTS2 regions, 2000-17)

- Labor share (total): Compensation of employees <u>over</u> Gross value added (Eurostat)

- Skill classification (ISCEDI): <u>Low</u>  0-2 educational levels. <u>Medium</u>  3-4 educational levels. <u>High</u>  5-8 educational levels.
- Employees by skill: Eurostat Regional Statistics
- Wage by skill (at country level): EU KLEMS & Intan-Prod

- Patents: OECD EPO Regpat. WIPO (2019) IPC/CPC classification for AI. Inaba & Squicciarini (2017) J-tag classification for ICT

- Tangible capital: Gross fixed capital stock (Eurostat)
- Intangible capital: R&D stock (Eurostat)

# DESCRIPTIVE EVIDENCE

# Labor share and AI innovation over time (2000-17)
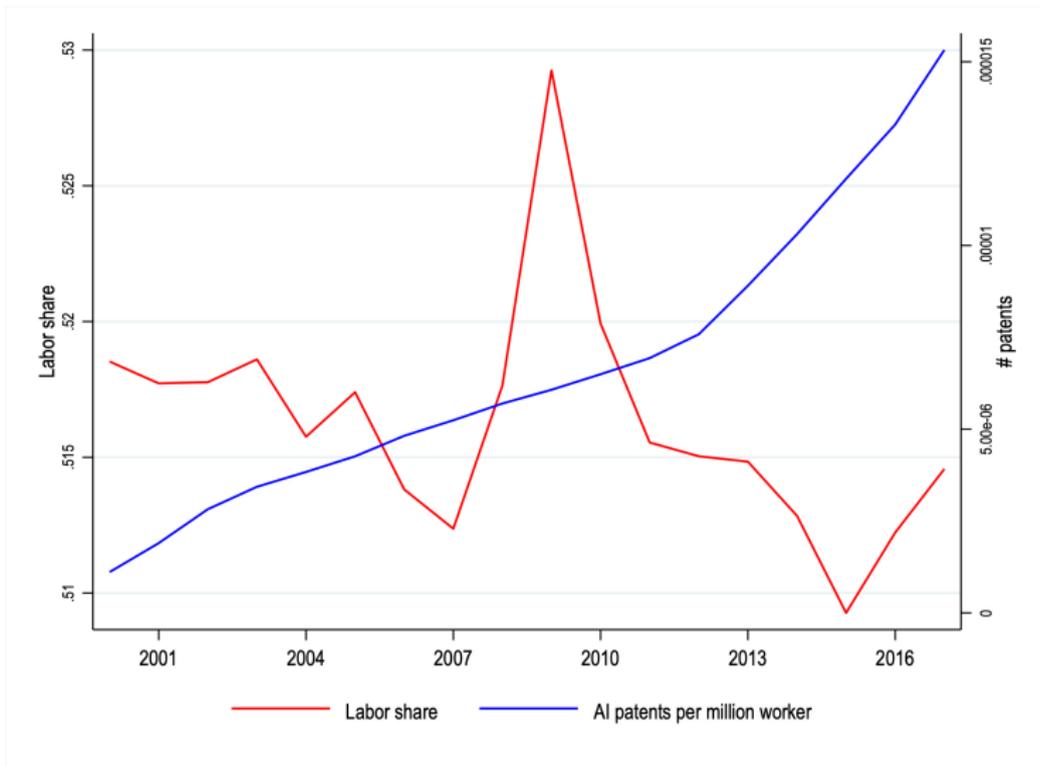
# Summary statistics

|  | Mean | SD | 25th pct. | 50th pct. | 75th pct. | 99th pct. |
|---|---|---|---|---|---|---|
| Labor share (Total %) | 51.8 | 7.2 | 46.4 | 53.7 | 57.3 | 63.7 |
| High-skilled LS | 12.2 | 7.0 | 7.1 | 10.0 | 16.9 | 31.2 |
| Medium-skilled LS | 23.6 | 7.6 | 19.4 | 23.6 | 29.7 | 37.5 |
| Low-skilled LS | 16.3 | 8.3 | 10.6 | 15.5 | 21.5 | 41.7 |
| AI patent stock p.w. (# per mln) | 7.4 | 21.4 | 0.0 | 0.7 | 5.3 | 120.0 |
| 4IR patent stock p.w. (# per mln) | 112.0 | 320.3 | 1.1 | 26.1 | 99.8 | 1862.7 |
| ICT patent stock p.w. (# per mln) | 145.2 | 526.3 | 1.7 | 25.5 | 92.5 | 2745.0 |
| All patent stock p.w. (excl. AI, 4IR, ICT, per mln) | 624.4 | 1439.5 | 48.4 | 363.0 | 1124.0 | 8054.6 |
| All patent stock p.w. (excl. AI) | 884.5 | 34.4 | 33.5 | 60.7 | 82.1 | 130.1 |
| Tangible capital stock p.w. (thousand euros) | 58.3 | 34.4 | 33.5 | 60.7 | 82.1 | 130.1 |
| R&D capital stock p.w. (thousand euros) | 2.9 | 3.8 | 0.1 | 1.7 | 4.0 | 16.5 |

ECONOMETRIC EVIDENCE

# Dynamic regressions

|  | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| AI patent stock per worker | -0.014*** | -0.011*** | -0.013*** | -0.010*** | -0.012*** | -0.011*** |
|  | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| ALP - Output per worker |  | 0.016* |  |  | 0.012 | 0.008 |
|  |  | (0.009) |  |  | (0.009) | (0.009) |
| ALP - Output per hour |  |  | 0.004 |  |  |  |
|  |  |  | (0.009) |  |  |  |
| TFP |  |  |  | -0.289*** |  |  |
|  |  |  |  | (0.005) |  |  |
| Tangible capital stock p.w. |  |  |  |  | 0.002*** | 0.002*** |
|  |  |  |  |  | (0.000) | (0.000) |
| R&D capital stock p.w. |  |  |  |  |  | -0.001*** |
|  |  |  |  |  |  | (0.000) |
| Obs. | 4,576 | 4,557 | 3,989 | 3,913 | 4,452 | 4,452 |
| R-squared | 0.384 | 0.349 | 0.363 | 0.197 | 0.348 | 0.348 |
| Regions | 278 | 277 | 236 | 236 | 262 | 262 |

**Notes:** The dependent variable is the labor share. All variables are in logarithmic form. Long-run estimates are derived from an ARDL(1,1) regression, which includes region and year fixed effects. Newey-West standard errors are in parentheses. ***, ** and * significant at 1, 5 and 10%, respectively.
**Controls**: Tangible capital stock per worker; R&D capital stock per worker; Output per worker.

# Dynamic regression

Dynamic (ARDL) estimates robust to controlling for:

- Institutional characteristics (government quality, business dynamism, physical infrastructure, digital infrastructure)

- Threshold effects (25th, 50th and 75th percentiles)

- Count data nature (inverse hyperbolic sine transformation)

- Spatial (and other) dependence (spatial lag and CCE)

- Dynamic adjustment (optimal lag structure)

# Identification: Launch of AI innovation (LP-DiD)
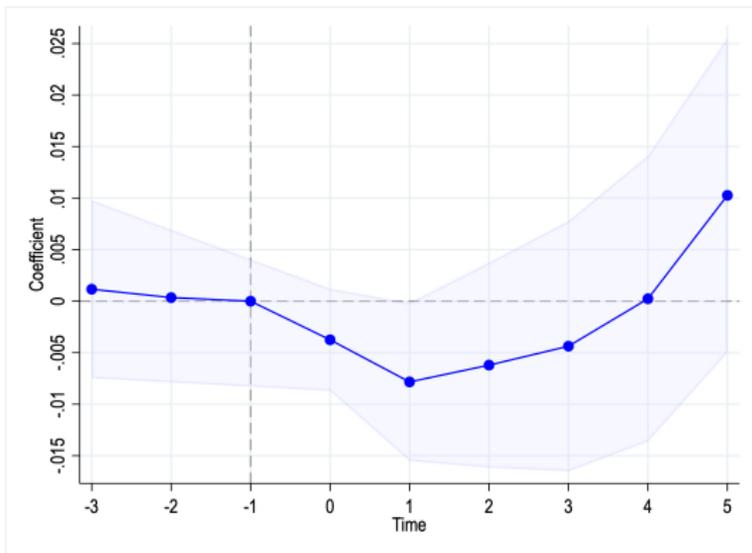


We run Local Projections DiD regressions (Dube et al. 2023)

$$LS_{jt} = \eta_j + \delta \cdot AI_{jt} + TD + \epsilon_{jt} \qquad LS_{jt+h} - LS_{jt-1} = \delta_h^{LP} \cdot \Delta AI_{jt} + \zeta \cdot X_{jt} + TD + \varepsilon_{jt}$$

$AI=1$ since the year of AI launch (post-treatment)

# Quantification of effects

|              | Mean    | 25 pct.  | 50 pct   | 75 pct   | 99 pct   |
|--------------|---------|----------|----------|----------|----------|
| Lower bound  | -0.09%  | -0.10%   | -0.09%   | -0.08%   | -0.07%   |
| Upper bound  | -0.31%  | -0.35%   | -0.30%   | -0.28%   | -0.26%   |

- By multiplying the estimated effect for the observed changes, we can quantify the explained variation of LS due to AI

- AI has reduced the labor share by 0.1-0.3 pct points (down from an average of 52%)

  Small (hopefully) but significant effect

Table: Quantification of effects: country-specific scenario

| # | Country | Lower bound | Upper bound | # | Country | Lower bound | Upper bound |
|---|---------|-------------|-------------|---|---------|-------------|-------------|
| 1 | AT | -0.12% | -0.44% | 11 | HR | -0.09% | -0.33% |
| 2 | BE | -0.10% | -0.36% | 12 | HU | -0.03% | -0.10% |
| 3 | BG | 0.18% | 0.63% | 13 | **IE** | **-0.17%** | **-0.60%** |
| 4 | CZ | 0.01% | 0.04% | 14 | IT | -0.09% | -0.30% |
| 5 | **DE** | **-0.10%** | **-0.36%** | 15 | NL | -0.08% | -0.27% |
| 6 | DK | -0.08% | -0.30% | 16 | PT | -0.16% | -0.58% |
| 7 | EL | -0.07% | -0.24% | 17 | RO | 0.04% | 0.13% |
| 8 | ES | -0.06% | -0.23% | 18 | SE | -0.11% | -0.40% |
| 9 | FI | -0.09% | -0.32% | 19 | SK | 0.19% | 0.67% |
| 10 | FR | -0.11% | -0.39% | 20 | UK | -0.07% | -0.24% |

MECHANISMS

# The impact of AI innovation by skill (2010-2017)

| | (1) | (2) | (3) Labor share | (4) | (5) | (6) Employment share | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Total | | High skill | Medium skill | Low skill | High skill | Medium skill | Low skill |
| AI patent stock p.w. | -0.016*** | -0.025*** | -0.033*** | -0.034*** | -0.020*** | -0.005 | 0.002 | 0.012** |
| | (0.001) | (0.002) | (0.008) | (0.003) | (0.007) | (0.005) | (0.003) | (0.006) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Period | 2000-17 | 2010-17 | 2010-17 | 2010-17 | 2010-17 | 2010-17 | 2010-17 | 2010-17 |
| Obs | 4,452 | 2,080 | 1,944 | 1,944 | 1,944 | 1,944 | 1,944 | 1,944 |
| R-squared | 0.347 | 0.520 | 0.447 | 0.401 | 0.528 | 0.303 | 0.551 | 0.474 |
| Regions | 262 | 260 | 243 | 243 | 243 | 243 | 243 | 243 |

**Notes:** T The dependent variable is the labor share, expressed as the ratio of employees' compensation to regional gross value added (at current prices) in columns (1)-(5) and the share of employment by skill type on total employment in columns (6)-(8). All variables are in logarithmic form. Long-run estimates are obtained from an ARDL(1,0) regression. Region and year fixed effects are included in the regression. Newey-West standard errors.***, ** and * significant at 1, 5 and 10%, respectively.

# The impact of AI concentration by skill (2010-2017)

|  | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
|  | High skill | | Medium skill | | Low skill | |
| AI patent stock p.w. | -0.033*** | -0.044*** | -0.034*** | -0.037*** | -0.020*** | -0.011 |
|  | (0.008) | (0.008) | (0.003) | (0.003) | (0.007) | (0.007) |
| AI concentration (within-region) |  | -0.004 |  | -0.006** |  | -0.009 |
|  |  | (0.009) |  | (0.003) |  | (0.009) |
| AI concentration (between-region) |  | -0.694 |  | -0.699*** |  | 0.097 |
|  |  | (0.434) |  | (0.199) |  | (0.365) |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Obs. | 1,944 | 1,944 | 1,944 | 1,944 | 1,944 | 1,944 |
| R-squared | 0.447 | 0.449 | 0.401 | 0.403 | 0.528 | 0.531 |
| Regions | 243 | 243 | 243 | 243 | 243 | 243 |

**Notes:** The dependent variable is the labor share, expressed as the ratio of employees' compensation to regional gross value added (at current prices). All variables are in logarithmic form. Long-run estimates are obtained from an ARDL(1,0) regression. Region and year fixed effects are included in the regression. Newey-West standard errors.***, ** and * significant at 1, 5 and 10%, respectively.
**AI concentration:** Within-region patent concentration ratio (CR4). Between-region region's share on European patents). **Controls:** R&D capital stock per worker; Non-AI patent stock per worker

# Results' summary and developments

- Assessment of effects of AI innovation on the factor income distribution in European regions

- AI may have been explaining (a little of) the widening regional inequality

- Labor share has fallen between 0.1 - 0.3 pct points, down from 52%, because of:

  1. High & medium skilled: substitution effect $\Rightarrow$ relative wage compression $\Rightarrow$ reduced rent sharing

  2. Low skilled: restatement effect $\Rightarrow$ larger employment share $\Rightarrow$ no rent sharing. This offsets the substitution effect

  3. No overlap with regional specialisation / market concentration

Thank you for the attention

APPENDIX:

Additional results

# Role of the institutional setting (2010-2017)

|  | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| AI patent stock p.w. | -0.016*** | -0.025*** | -0.035*** | -0.023*** | -0.024*** | -0.026*** |
|  | (0.001) | (0.002) | (0.003) | (0.003) | (0.003) | (0.003) |
| Regional characteristic |  |  | 0.001 | -1.201*** | 0.042*** | 0.055 |
|  |  |  | (0.006) | (0.077) | (0.007) | (0.041) |
|  |  |  | Govern-ment quality | Business dynamism | Physical infrastruc-ture | Digital infrastruc-ture |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| Period | 2000-17 | 2010-17 | 2010-17 | 2010-17 | 2010-17 | 2010-17 |
| Obs | 4,452 | 2,080 | 864 | 752 | 1,088 | 1,024 |
| R-squared | 0.347 | 0.520 | 0.533 | 0.512 | 0.572 | 0.565 |
| Regions | 262 | 260 | 108 | 94 | 136 | 128 |

**Notes:** The dependent variable is the labor share, expressed as the ratio of employees' compensation to regional gross value added (at current prices). All variables are in logarithmic form. Long-run estimates using data from 2000 are obtained from an ARDL(1,1), while those using data from 2010 are derived from an ARDL(1,0). Region and year fixed effects are included in the regression. Newey-West standard errors are in parentheses. ***, ** and * significant at 1, 5 and 10%, respectively.
**Controls**: Output per worker; Tangible capital stock per worker (column (1) only); R&D capital stock per worker; Total patent stock (excluding AI) per worker.

# Econometric issues: lag selection

|                                    | (1)        | (2)        | (3)        | (4)        |
|------------------------------------|------------|------------|------------|------------|
| AI patent stock p.w. (elasticity)  | -0.016***  | -0.014***  | -0.011***  | -0.016***  |
|                                    | (0.001)    | (0.001)    | (0.001)    | (0.003)    |
| Adjustment term                    | -0.214***  | -0.220***  | -0.249***  | -0.352***  |
|                                    | (0.014)    | (0.014)    | (0.016)    | (0.014)    |
| Lags                               | 1,1        | 1,1        | 3,3        | 5,5        |
| Time period                        | 2000-18    | 2000-18    | 2000-18    | 2000-18    |
| Controls                           | Yes        | No         | No         | No         |
| Obs                                | 4,452      | 4,576      | 3,945      | 3,419      |
| R-squared                          | 0.347      | 0.384      | 0.422      | 0.420      |
| Regions                            | 262        | 278        | 263        | 263        |

**Notes:** The dependent variable is the labor share, expressed as the log-ratio of employees' compensation to regional gross value added (at current prices). Newey-West standard errors are in parentheses. ***, ** and * significant at 1, 5 and 10%, respectively.
**Controls**: Output per worker; tangible capital stock per worker; R&D capital stock per worker; all patent stock per worker (excluding AI).

# Econometric issues: threshold effects

|                                    | (1)       | (2)       | (3)       | (4)       | (5)       | (6)       | (7)       | (8)       |
|------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| AI patent stock p.w. (elasticity)  | -0.016*** | -0.014*** | -0.007*** | -0.007*** | 0.004***  | -0.013*** | -0.015*** | -0.024*** |
|                                    | (0.001)   | (0.001)   | (0.001)   | (0.001)   | (0.001)   | (0.003)   | (0.004)   | (0.005)   |
| Adjustment term                    | -0.214*** | -0.220*** | -0.214*** | -0.203*** | -0.207*** | -0.332*** | -0.301*** | -0.366*** |
|                                    | (0.014)   | (0.014)   | (0.017)   | (0.022)   | (0.027)   | (0.056)   | (0.075)   | (0.084)   |
| AI sample (percentiles)            | 100       | 100       | 25        | 50        | 75        | 25        | 50        | 75        |
| Time period                        | 2000-18   | 2000-18   | 2000-18   | 2000-18   | 2000-18   | 2010-18   | 2010-18   | 2010-18   |
| Controls                           | Yes       | No        | No        | No        | No        | No        | No        | No        |
| Obs                                | 4,452     | 4,576     | 3,456     | 2,299     | 1,156     | 1,656     | 1,093     | 544       |
| R-squared                          | 0.347     | 0.384     | 0.389     | 0.389     | 0.361     | 0.572     | 0.541     | 0.604     |
| Regions                            | 262       | 278       | 208       | 137       | 68        | 208       | 137       | 68        |

**Notes:** The dependent variable is the labor share, expressed as the log-ratio of employees' compensation to regional gross value added (at current prices). Newey-West standard errors are in parentheses. ***, ** and * significant at 1, 5 and 10%, respectively.
**Controls**: Output per worker; tangible capital stock per worker; R&D capital stock per worker; all patent stock per worker (excluding AI).

# Econometric issues: patent count data

|                                      | (1)       | (2)       | (3)          | (4)          |
|--------------------------------------|-----------|-----------|--------------|--------------|
| AI patent stock p.w. (elasticity)    | -0.016*** | -0.014*** | -0.022       | -0.005***    |
|                                      | (0.001)   | (0.001)   | (0.025)      | (0.001)      |
| AI patent stock p.w. (Arcsinh)       |           |           | -0.024***    | -0.401***    |
|                                      |           |           | (0.002)      | (0.005)      |
| Adjustment term                      | -0.214*** | -0.220*** | -0.220***    | -0.333***    |
|                                      | (0.014)   | (0.014)   | (.0138)      | (.040)       |
| Model                                | Dynamic ARDL | Dynamic ARDL | Dynamic ARDL | Dynamic ARDL |
| Time period                          | 2000-18   | 2000-18   | 2000-18      | 2010-18      |
| Specification                        | Log-log   | Log-log   | Log-Arcsinh  | Log-Arcsinh  |
| Controls                             | Yes       | No        | No           | No           |
| Obs                                  | 4,452     | 4,576     | 4298         | 2224         |
| R-squared                            | 0.347     | 0.384     | 0.410        | 0.572        |
| Regions                              | 262       | 278       | 278          | 281          |

**Notes:** The dependent variable is the labor share, expressed as the log-ratio of employees' compensation to regional gross value added (at current prices). The stock of AI patents per worker is measured as $\log(1 + z)/L$ in columns (1)-(2). Columns (3) and (4) report the coefficients estimated with the arcsin transformation of the explanatory variable ($\tilde{\beta}$) and the associated elasticity $\beta = \left( \frac{\tilde{\beta}}{\bar{y}} \cdot \frac{\bar{x}}{\sqrt{\bar{x}^2+1}} \right)$, where the bars denote the mean of the dependent and explanatory variables (in logs and non-transformed, respectively) over the sample period. Newey-West standard errors are in parentheses. ***, ** and * significant at 1, 5 and 10%, respectively.
**Controls**: Output per worker; tangible capital stock per worker; R&D capital stock per worker; all patent stock per worker (excluding AI).

# Spatial dependence

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| AI patent stock p.w. | -0.016*** | -0.016*** | -0.016*** | -0.017*** | -0.011*** | -0.006*** | -0.012*** |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.003) |
| Labor share (spatial lag) | | -0.049*** | | -0.083*** | -0.080*** | -0.080*** | -0.076** |
| | | (0.010) | | (0.011) | (0.011) | (0.012) | (0.034) |
| AI patent stock p.w. (spatial lag) | | | 0.003** | 0.009*** | 0.007*** | 0.008*** | 0.001 |
| | | | (0.001) | (0.002) | (0.002) | (0.002) | (0.004) |
| Adjustment term | -0.214*** | -0.214*** | -0.214*** | -0.213*** | -0.216*** | -0.230*** | -0.761*** |
| | (0.014) | (0.014) | (0.014) | (0.014) | (0.014) | (0.014) | (0.043) |
| Cross-Sectional Dependence | TD | TD | TD | TD | NO | NO | CCE |
| Controls | Yes | Yes | Yes | Yes | Yes | No | No |
| Obs. | 4,452 | 4,452 | 4,452 | 4,420 | 4,420 | 4,471 | 4,208 |
| R-squared | 0.347 | 0.347 | 0.347 | 0.347 | 0.342 | 0.400 | 0.937 |
| Regions | 262 | 262 | 262 | 260 | 260 | 263 | 263 |

**Notes:** The dependent variable is the labor share, expressed as the ratio of employees' compensation to regional gross value added (at current prices). All variables are in logarithmic form. Long-run estimates are derived from an ARDL(1,1) regression, which includes region and year fixed effects. Newey-West standard errors are in parentheses. ***, ** and * significant at 1, 5 and 10%, respectively.
**Controls**: Output per worker; Tangible capital stock per worker; R&D capital stock per worker; All patent stock per worker (excluding AI).