Management, Skills and Productivity

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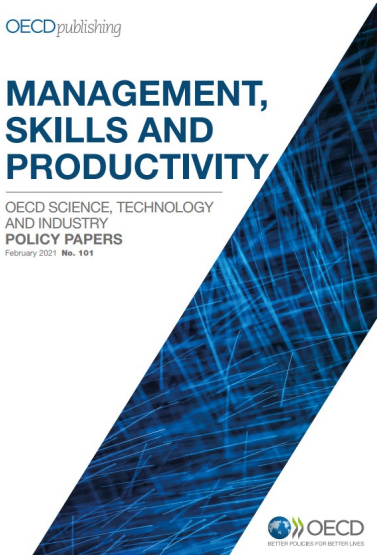
BETTER POLICIES FOR BETTER LIVES

Framing the problem

- Link to paper: Management, Skills and Productivity
- Organisational Capital (OC) is including – but not limited to – managers.
- OC, workforce skills and firm productivity seemingly go hand in hand.
- However, more needs to be known
  - On the extent to which industries invest in OC;
  - About the way workforce skills and the skills of the OC staff relate to productivity.
- This study looks at the way numeracy skills, as well as task-based skills such as information and communication technology (ICT) and STEM skills influence productivity.
  - Do differences emerge in the way the skills of the OC workers and of the other workers relate to industry performance?
  - And how does skill dispersion relate to productivity levels?



Main takeaways

Methods

- Conditional correlations: OLS regression
- Exploring causation: Three-step approach combining Heckman selection model and the use of instrumental variables

Main findings

- Cognitive skills correlate positively with productivity.
- The positive correlation between STEM skills and productivity is larger for OC workers.
- Skill dispersion hurts industry performance.
- ICT skills dispersion triggers a "**lost in translation**" type of mechanism
  - whereby differences in the ICT task-based skills of OC and non-OC workers impinge upon the economic productivity of sectors
  - an ICT skill gap between the two groups may create difficulties in communication and cooperation

Data

The work builds on

- Cognitive and task-based skill-related indicators (Grundke et al., 2017) using data from the Programme of the International Assessment of Adult Competencies (PIAAC)
  - PIAAC is a programme of assessment and analysis of adult skills and the major survey conducted as part of PIAAC is the Survey of Adult Skills.
  - There are currently 3 rounds available covering over 40 countries/economies.
  - It measures adults' proficiency in key information-processing skills - literacy, numeracy and problem solving - and gathers information and data on how adults use their skills at home, at work and in the wider community.
- Estimates of investment in OC (Le Mouel and Squicciarini, 2015)
- Output information from the OECD Structural Analysis (STAN) database

All data is at the industry country level.

Indicators of job-related task and skill requirements based on PIAAC

Indicator of job related skill requirements	Items included in the construction of the indicator
ICT skills	G_Q05e Frequency of excel use G_Q05g Frequency of programming language use G_Q05d Frequency of transactions through internet (banking, selling/buying) G_Q05a Frequency of email use G_Q05c Frequency of simple internet use G_Q05f Frequency of word use G_Q05h Frequency of real-time discussions through ICT Computer G_Q01b Frequency of Reading letters, emails, memos G_Q02a Frequency of Writing letters, emails, memos G_Q06 Level of Computer Use required for the job F_Q06b Frequency of working physically over long periods
STEM-quantitative skills	G_Q03f Frequency of preparing charts and tables G_Q03g Frequency of Use simple algebra and formulas G_Q03h Frequency of Use complex algebra and statistics

Note: Compilation based on PIAAC.
Source: Grundke et al., 2017

We follow the approach implemented by Grundke et al. (2017) who use an advanced exploratory factor analysis based on Conti et al. (2014).

Selection of OC-related occupations

Organisational Capital (OC) staff is defined as the part of a firm's workforce whose knowledge and tasks affect the long-term functioning of firms (Le Mouel and Squicciarini, 2015).

These include:

- developing objectives and strategies;
- organising, planning and supervising production;
- managing human resources.

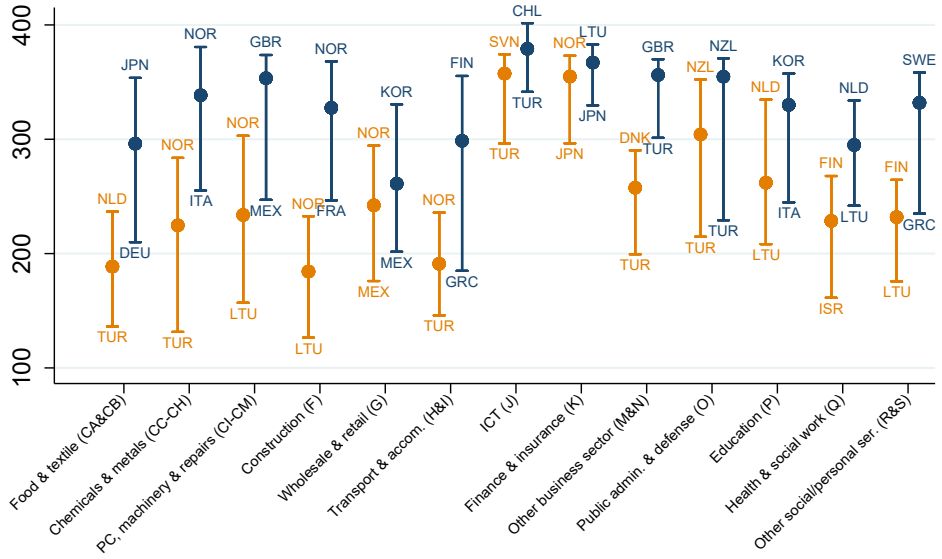
According to this definition, OC includes, but is not limited to, managers.

ISCO 3 digit	ISCO Title	O*NET	PIAAC
110, ..., 143	**Managers**	**X**	**X**
213	Life science professionals	X	
214	Engineering professionals (excluding electrotechnology)	X	
216	Architects, planners, surveyors and designers	X	
220	Health professionals, except doctors	X	X
221	Medical doctors	X	X
232	Vocational education teachers		X
233	Secondary education teachers		X
234	Pre- and primary school teachers		X
242	Administration professionals	X	
243	Sales, marketing and public relations professionals	X	
252	Database and network professionals	X	
261	Legal professionals		X
262	Librarians, archivists and curators	X	
263	Social and religious professionals	X	X
312	Mining, manufacturing and construction supervisors	X	X
322	Nursing and midwifery		X
331	Financial and mathematical associate professionals	X	
334	Administrative and specialised secretaries	X	
343	Artistic, cultural and culinary associate professionals	X	
522	Shop salespersons	x	

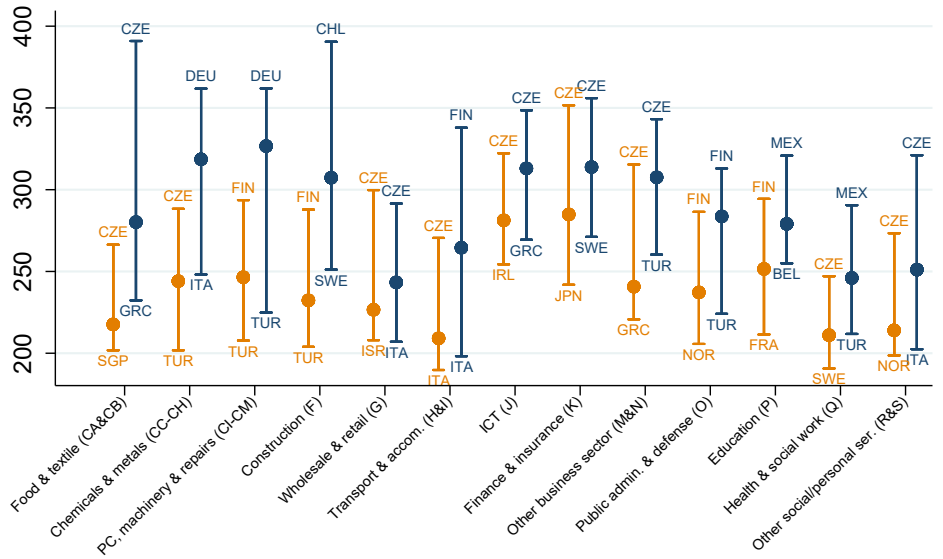
Note: Based on PIAAC data and O*NET data (version 16.0)
Source: Le Mouel and Squicciarini, 2015

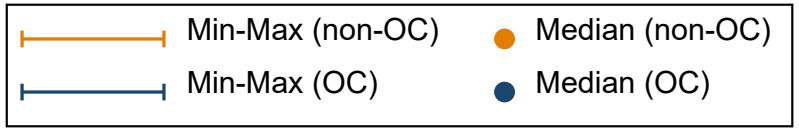
Median skill scores by industry

A) ICT task-based skill scores



B) STEM-quantitative skill scores





Note: Figures are based on country specific averages by industry. Countries included in the analysis: AUT, BEL, CAN, CHL, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HUN, IRL, ISR, ITA, JPN, KOR, LTU, MEX, NLD, NOR, NZL, POL, SGP, SVK, SVN, SWE, TUR and first wave of USA. The sample consists of 402 and 401 observations when examining ICT and STEM skills, respectively. Sample sizes are too small to construct median ICT task-base skill scores for food & textile (CA&CB) in Korea and other social & personal services (R&S) in Turkey, and too small to construct STEM skills for ICT in Turkey.
Source: Authors' own compilation based on PIAAC data.

Median skill scores by industry

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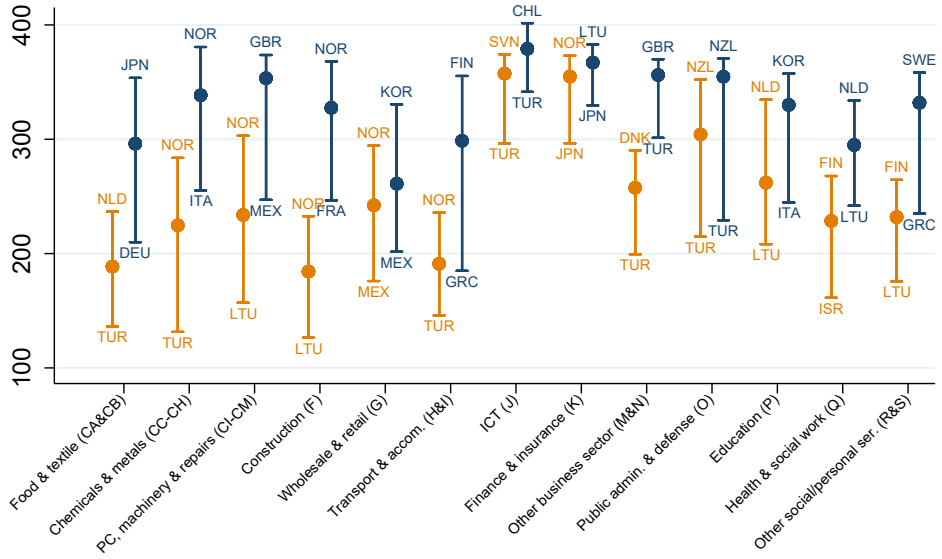
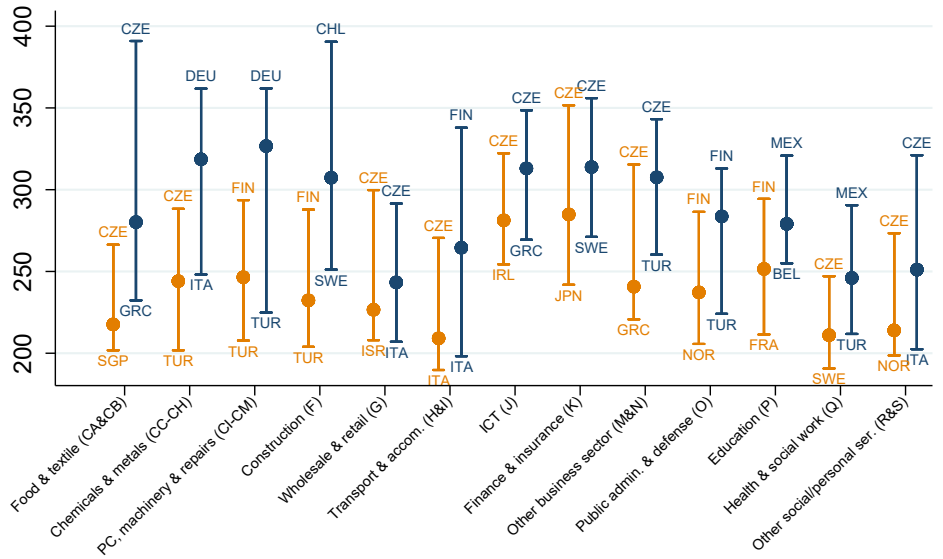
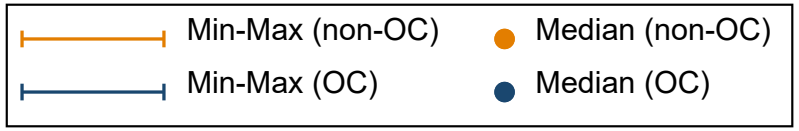


B) STEM-quantitative skill scores





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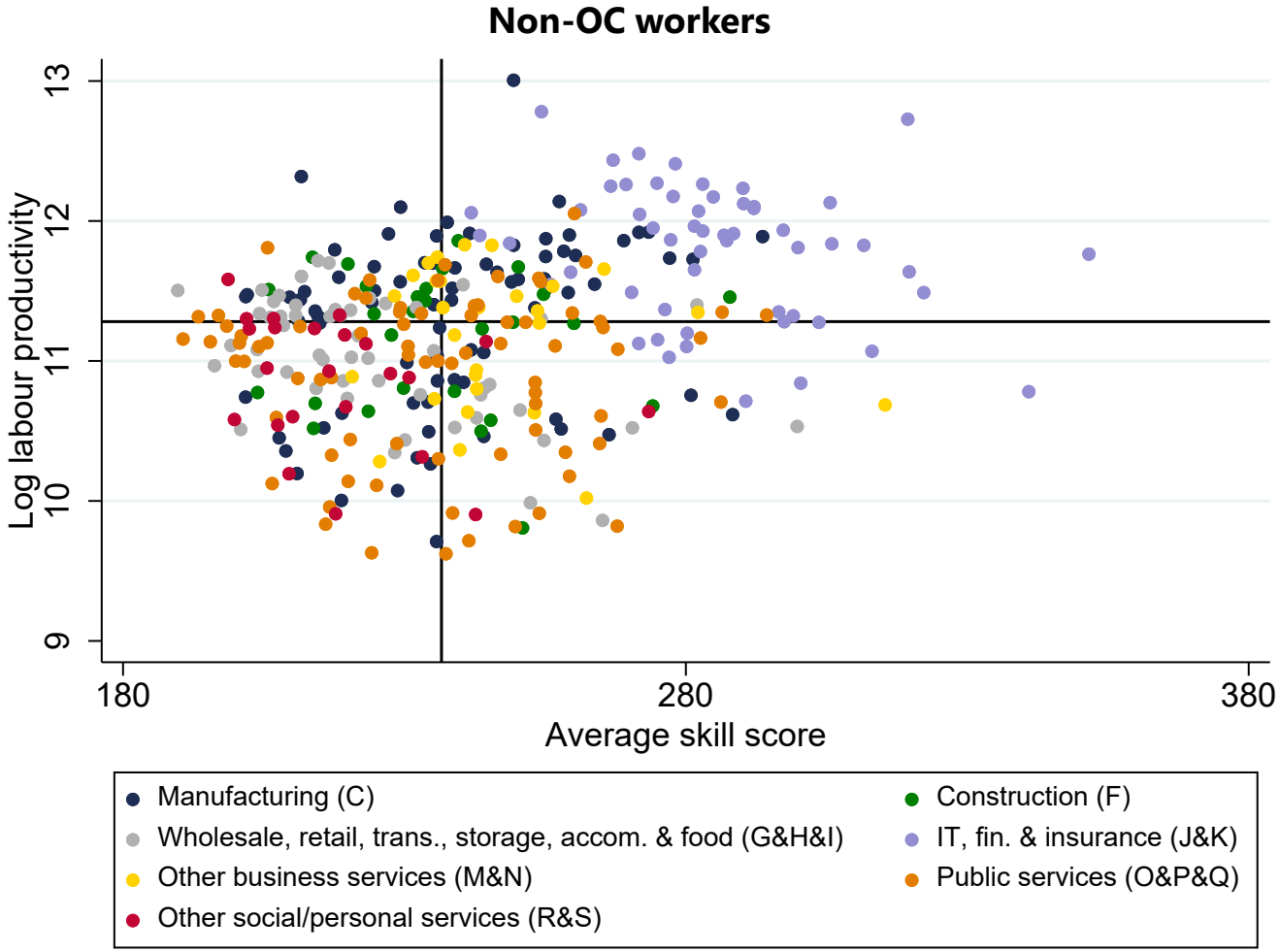
Mean STEM-quantitative skill scores and productivity



Note: Figures are based on country specific averages by industry. Industries are colour-coded by industry clusters to aid the reader. Countries included in the analysis: AUT, BEL, CAN, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HUN, IRL, ISR, ITA, JPN, KOR, LTU, NLD, NOR, NZL, POL, SVK, SVN, SWE, TUR and first wave of USA. However, some industries are missing for EST, ISR, JPN, NZL, and TUR. The sample consists of 343 observations.

The model

Skill score of non-OC workers

Skill score ratio between OC and non-OC workers

$$\ln(LP)_{i,k} = a_0 + a_1 ICTxOC_{i,k} + a_2 STEMxOC_{i,k} + a_3 ICTratio_{i,k} + a_4 STEMratio_{i,k} + a_5 numeracy_{i,k} + a_6 numeracy10/90_{i,k} + x_{i,k}'\beta + \mu_i + \delta_c$$

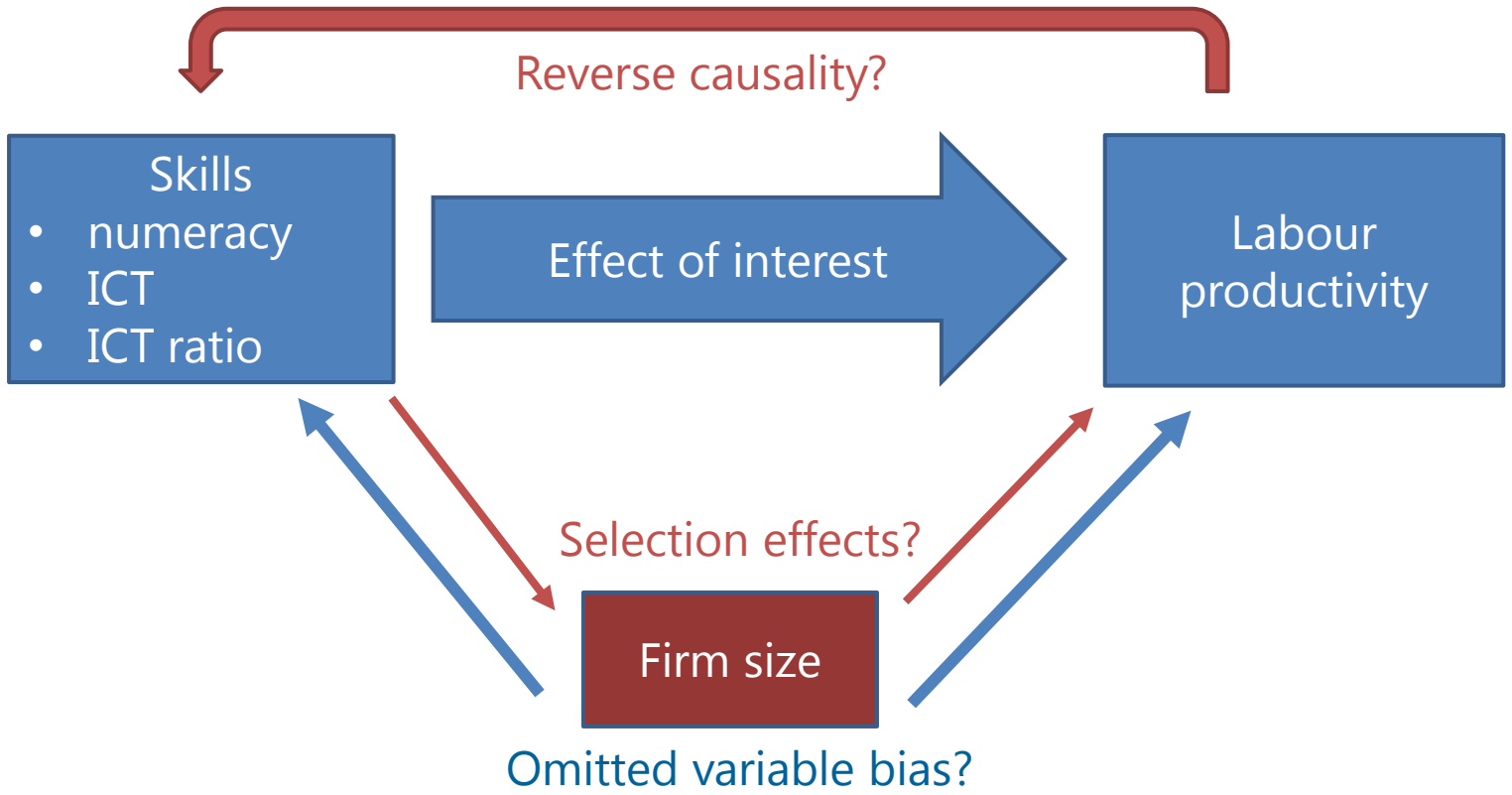
Cognitive skills and their dispersion

Skills
- numeracy
- ICT
- ICT ratio

→ Effect of interest → Labour productivity

Log of LP	Log of labour productivity measured as value added in Million USD per employee
ICT score (non-OC)	Average ICT skill score of non-OC occupations
ICT score ratio (OC/non-OC)	Ratio between the average ICT skill scores of the OC-relevant and the OC-non-relevant occupations
STEM score (non-OC)	Average STEM skill score of non-OC workers
STEM score ratio (OC/non-OC)	Ratio between the average STEM skill scores of the OC-relevant and the OC-non-relevant occupations
Numeracy score	Average numeracy skill score of all workers
Numeracy score (Perc10/Perc90)	Ratio between the top and the bottom 10 percentile of the average numeracy score of all workers

Endogeneity and selection effects



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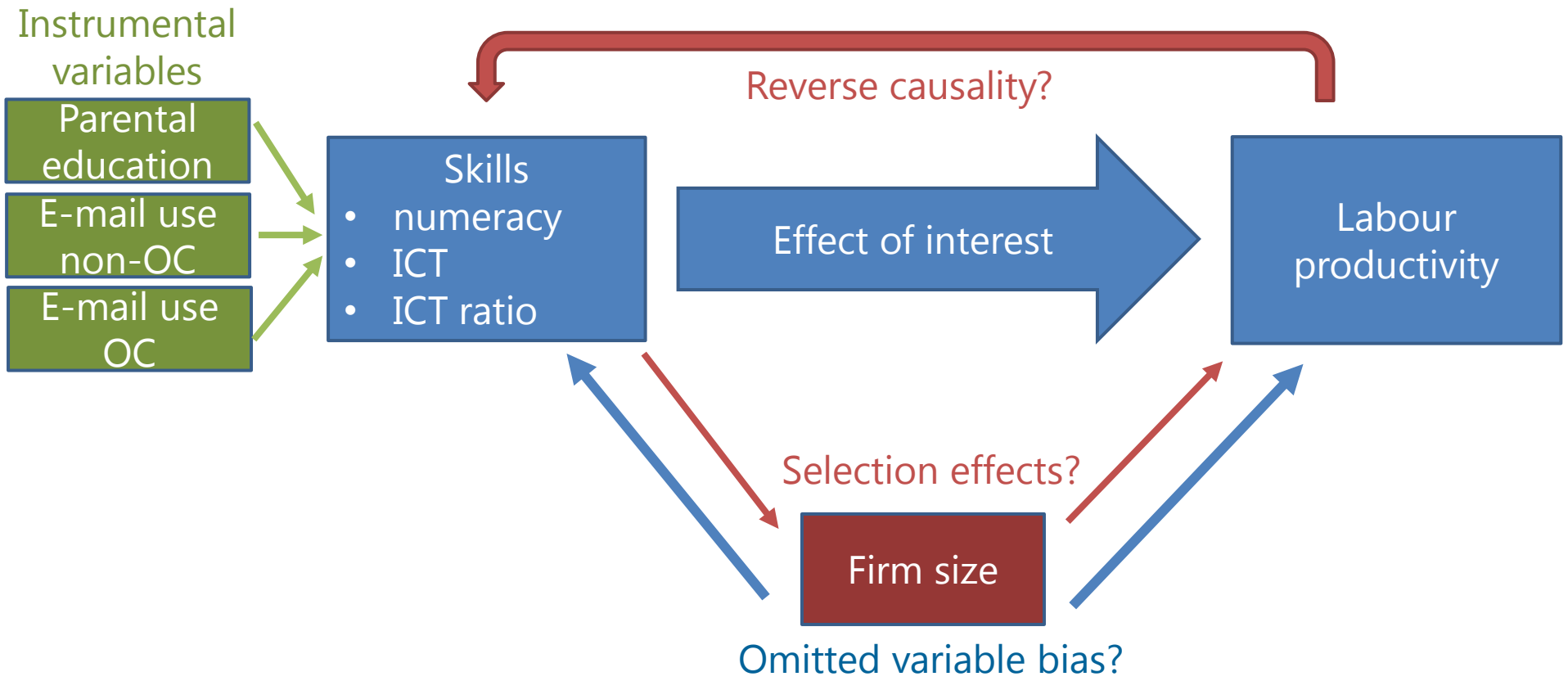

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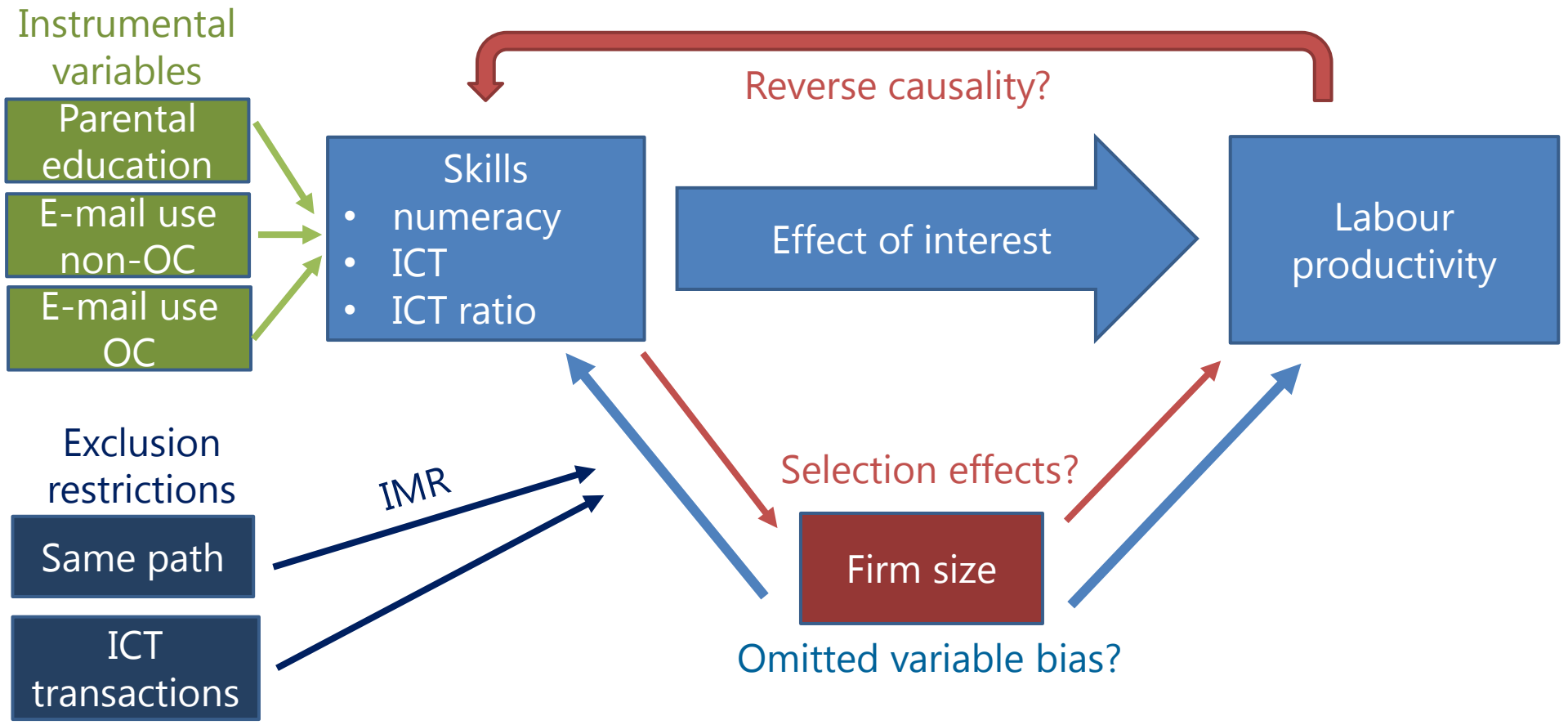

Estimation results of skills on value added per employee

Dependent variable	VA
Numeracy	0.018**
	(0.008)
ICT non-OC	-0.003
	(0.004)
ICT ratio	-0.242**
	(0.112)
STEM non-OC	0.014***
	(0.005)
STEM ratio	0.302**
	(0.128)
Numeracy ratio	-0.843
	(0.600)
Log NFA	0.160***
	(0.021)
Skill intensity	0.769**
	(0.284)
Constant	7.341***
	(0.379)
Observations	260
R-squared	0.917
Ind. cluster (7)	YES
Country FE	YES

- At the industry level, cognitive skill endowment of the overall working population correlates positively with labour productivity. This is the case especially for numeracy and STEM-related skills.

Note: Countries included in the analysis: AUT, BEL, CAN, CZE, DEU, DNK, EST, FIN, FRA, GBR, GRC, HUN, IRL, ITA, LTU, NLD, NOR, POL, SVK, SVN, SWE and first wave of USA. The seven industry clusters include: manufacturing (C); construction (F); wholesale, retail trade and repair of motor vehicles, transportation, storage and accommodation and food services (G&H&I); IT, financial and insurance activities (J&K); other business services (M&N); public services (O&P&Q) and other social and personal services (R&S). The three industry clusters include manufacturing (C), other businesses (F-N, R&S) and public sector services (O&P&Q). Robust standard errors are clustered at the country level. *, **, and *** indicate that coefficients are significant at the 10%, 5% and 1% levels, respectively.
Source: Author's own compilation.

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- At the industry level, cognitive skill endowment of the overall working population correlates positively with labour productivity. This is the case especially for numeracy and STEM-related skills.
- The positive correlation of STEM skills with productivity is generally larger in the case of OC workers.
- Skills dispersion hurts industry performance, especially dispersion between ICT skills of OC staff and other non-OC workers.
- A "lost in translation" mechanism seemingly exists, whereby differences in the ICT task-based skills of OC and non-OC-related workers impinges upon the economic performance of sectors.

Note: Countries included in the analysis: AUT, BEL, CAN, CZE, DEU, DNK, EST, FIN, FRA, GBR, GRC, HUN, IRL, ITA, LTU, NLD, NOR, POL, SVK, SVN, SWE and first wave of USA. The seven industry clusters include: manufacturing (C); construction (F); wholesale, retail trade and repair of motor vehicles, transportation, storage and accommodation and food services (G&H&I); IT, financial and insurance activities (J&K); other business services (M&N); public services (O&P&Q) and other social and personal services (R&S). The three industry clusters include manufacturing (C), other businesses (F-N, R&S) and public sector services (O&P&Q). Robust standard errors are clustered at the country level. *, **, and *** indicate that coefficients are significant at the 10%, 5% and 1% levels, respectively.
Source: Author's own compilation.

Exploring causality: comparison

	OLS	2SLS
Dependent variable	VA	VA
IMR		0.027
		(0.020)
Numeracy	0.018**	0.026
	(0.008)	(0.058)
ICT non-OC	-0.003	-0.018
	(0.004)	(0.019)
ICT ratio	-0.242**	-0.334
	(0.112)	(0.444)
STEM non-OC	0.014***	0.026***
	(0.005)	(0.008)
STEM ratio	0.302**	0.309
	(0.128)	(0.434)
Numeracy ratio	-0.843	-0.637
	(0.600)	(1.136)
Log NFA	0.160***	0.190***
	(0.021)	(0.021)
Skill intensity	0.769**	0.840***
	(0.284)	(0.303)
Constant	7.341***	6.656***
	(0.379)	(1.679)
Observations	260	260
R-squared	0.917	0.913
Ind. cluster (7)	YES	YES
Country FE	YES	YES

- The coefficient for STEM for non-OC workers remains statistically significant, suggesting that a one-point increase in the STEM score (non-OC) is related to a 2.6 percent increase in labour productivity.
- Both STEM and ICT ratio remain significant when using fewer instruments.
- All together, these results can be interpreted as additional evidence confirming the OLS results.

Note: Countries included in the analysis: AUT, BEL, CAN, CZE, DEU, DNK, EST, FIN, FRA, GBR, GRC, HUN, IRL, ITA, LTU, NLD, NOR, POL, SVK, SVN, SWE and first wave of USA. The seven industry clusters include: manufacturing (C); construction (F); wholesale, retail trade and repair of motor vehicles, transportation, storage and accommodation and food services (G&H&I); IT, financial and insurance activities (J&K); other business services (M&N); public services (O&P&Q) and other social and personal services (R&S). The three industry clusters include manufacturing (C), other businesses (F-N, R&S) and public sector services (O&P&Q). Robust standard errors are clustered at the country level. *, **, and *** indicate that coefficients are significant at the 10%, 5% and 1% levels, respectively.
Source: Author's own compilation.

Sensitivity check: gross output (GO)

	OLS	2SLS	2SLS
Dependent variable	VA	VA	GO
IMR		0.027	0.052**
		(0.020)	(0.021)
Numeracy	0.018**	0.026	0.013
	(0.008)	(0.058)	(0.081)
ICT non-OC	-0.003	-0.018	-0.018
	(0.004)	(0.019)	(0.025)
ICT ratio	-0.242**	-0.334	-0.676*
	(0.112)	(0.444)	(0.360)
STEM non-OC	0.014***	0.026***	0.018
	(0.005)	(0.008)	(0.011)
STEM ratio	0.302**	0.309	0.692*
	(0.128)	(0.434)	(0.402)
Numeracy ratio	-0.843	-0.637	-0.187
	(0.600)	(1.136)	(1.738)
Observations	260	260	260
R-squared	0.917	0.913	0.928
Ind. cluster FE (7)	YES	YES	YES
Controls & Country FE	YES	YES	YES

- Our results are robust for gross output
  - positive significant coefficient for STEM ratio
  - negative significant coefficient for ICT ratio

Note: Countries included in the analysis: AUT, BEL, CAN, CZE, DEU, DNK, EST, FIN, FRA, GBR, GRC, HUN, IRL, ITA, LTU, NLD, NOR, POL, SVK, SVN, SWE and first wave of USA. The seven industry clusters include: manufacturing (C); construction (F); wholesale, retail trade and repair of motor vehicles, transportation, storage and accommodation and food services (G&H&I); IT, financial and insurance activities (J&K); other business services (M&N); public services (O&P&Q) and other social and personal services (R&S). The three industry clusters include manufacturing (C), other businesses (F-N, R&S) and public sector services (O&P&Q). Robust standard errors are clustered at the country level. *, **, and *** indicate that coefficients are significant at the 10%, 5% and 1% levels, respectively. Controls in all models include log of net fixed assets per employee and skill intensity. Share of OC workers is additionally included in the GO model.
Source: Author's own compilation.

Conclusions and policy implications

- Investments in cognitive skill are required, as cognitive skill endowment of the overall working population correlates positively with labour productivity. This is the case especially for numeracy and STEM-related skills.
- For OC workers, the focus should be on upgrading STEM skills, as the positive correlation between STEM skills and productivity is generally larger for them.
- We also find evidence about skills dispersion hurting industry performance, especially when it comes to skills related to the acquisition, processing and sharing of relevant information.
- ICT skills dispersion triggers a “lost in translation” type of mechanism, whereby differences in the ICT task-based skills of OC and non-OC-related workers impinges upon the economic productivity of sectors.

Thank you!

Management, Skills and Productivity

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Annex

Selection of OC-related occupations

ISCO 3 digit	ISCO Title	O*NET	PIAAC
110	Chief executives and legislators	X	X
121	Business services and administration managers	X	X
122	Sales, marketing and development managers	X	X
131	Production managers in agriculture		X
132	Manufacturing, mining, construction, and distribution managers	X	X
133	Information and communications technology service managers	X	X
134	Professional services managers	X	X
141	Hotel and restaurant managers	X	X
142	Retail and wholesale trade managers	X	X
143	Other services managers	X	X
213	Life science professionals	X	
214	Engineering professionals (excluding electrotechnology)	X	
216	Architects, planners, surveyors and designers	X	
220	Health professionals, except doctors	X	X
221	Medical doctors	X	X
232	Vocational education teachers		X
233	Secondary education teachers		X
234	Pre- and primary school teachers		X
242	Administration professionals	X	
243	Sales, marketing and public relations professionals	X	
252	Database and network professionals	X	
261	Legal professionals		X
262	Librarians, archivists and curators	X	
263	Social and religious professionals	X	X
312	Mining, manufacturing and construction supervisors	X	X
322	Nursing and midwifery		X
331	Financial and mathematical associate professionals	X	
334	Administrative and specialised secretaries	X	
343	Artistic, cultural and culinary associate professionals	X	
522	Shop salespersons	x	

Note: Based on PIAAC data and O*NET data (version 16.0)
Source: Le Mouel and Squicciarini, 2015

Sample size concerns?

- Average skill scores at the country-industry level cannot always be computed reliably for the group of OC-relevant occupations.
- We implement a multi-step procedure to impute missing values based on information obtained from countries that are similar in terms of overall skills profile and have enough observations to construct reliable scores.
- If workers in the same occupation in a considered cluster perform similar sets of tasks with similar frequencies, their occupational characteristic and skill endowment can, ceteris paribus, be expected to be similar.

	Countries
Cluster 1	Australia, Great Britain, Canada, Ireland, New Zealand, United States
Cluster 2	Denmark, Finland, Norway, Sweden
Cluster 3	Austria, Belgium, Czech republic, Estonia, Germany, Hungary, Netherlands
Cluster 4	France, Greece, Israel, Italy, Poland, Slovenia, Spain,
Cluster 5	Kazakhstan, Lithuania, Slovakia, Turkey
Cluster 6	Korea, Japan, Singapore
Cluster 7	Chile, Ecuador, Mexico, Peru

Source: Authors' own compilation based on PIAAC data and following Bechichi et al. (2018)

Sample size concerns – numerical example

1. Countries are grouped in clusters according to the similarity of their skill score distributions in each of the nine-digit occupation groups.
2. These clusters are used to construct weighted ratios of ICT and STEM skill scores of the OC and non-OC group. Weights are based on the country-industry specific sample size with a minimum threshold of 20 observations per cell.
3. The weighting mechanism devised avoids pure imputations from the other countries in the cluster and exploits to the maximum extent the country-specific information available.

Country	Sample size		Skill score		Ratio between OC and non-OC group		Sample weight	Revised ratio between OC and non-OC group	Revised skill score for OC group
	OC	Non-OC	OC	Non-OC					
A	5	25	240	**230**	1.04		$\frac{5}{20}=\frac{1}{4}$	$(\frac{1}{4}\,1.04)+(\frac{3}{4}\,1.15)=1.12$ 4	230 * 1.12 = **257.60**
B	25	40	**250**	**205**	1.22	$\frac{1.22+1.08}{2}=1.15$ 1	$1-\frac{1}{4}=\frac{3}{4}$	*unchanged* 3	*unchanged* 5
C	30	50	**270**	**250**	1.08			*unchanged*	*unchanged*

Exploring causality - equations

Selection

$$Prob(firmsize = 1 \mid ICTxOC, ICTratio, STEMxOC, STEMratio, numeracy, numeracy10/90, exclusion, x)$$
$$= a_0 + a_1 ICTxOC_{i,k} + a_2 ICTratio_{i,k} + a_3 STEMxOC_{i,k} + a_4 STEMratio_{i,k} + a_5 numeracy_{i,k} + a_6 numeracy10/90_{i,k} + a_7 exclusion_{i,k} + x_{i,k}'\beta + \mu_i + \delta_c$$

First stage

$$numeracy_{i,k} = a_0 + a_1 ICTxOC_{i,k} + a_2 ICTratio_{i,k} + a_3 STEMxOC_{i,k} + a_4 STEMratio_{i,k} + a_5 numeracy10/90_{i,k} + a_6 \hat{\lambda}_{i,k} + a_7 parent_{i,k} + x_{i,k}'\beta + \mu_i + \delta_c$$

$$ICTxOC_{i,k} = a_0 + a_1 ICTratio_{i,k} + a_2 STEMxOC_{i,k} + a_3 STEMratio_{i,k} + a_4 numeracy_{i,k} + a_5 numeracy10/90_{i,k} + a_6 \hat{\lambda}_{i,k} + a_7 emailxOC_{i,k} + x_{i,k}'\beta + \mu_i + \delta_c$$

$$ICTratio_{i,k} = a_0 + a_1 ICTxOC_{i,k} + a_2 STEMxOC_{i,k} + a_3 STEMratio_{i,k} + a_4 numeracy_{i,k} + a_5 numeracy10/90_{i,k} + a_6 \hat{\lambda}_{i,k} + a_7 emailOC_{i,k} + x_{i,k}'\beta + \mu_i + \delta_c$$

Second stage

$$\ln(LP)_{i,k} = a_0 + a_1 ICTxOC_{i,k} + a_2 ICTratio_{i,k} + a_3 STEMxOC_{i,k} + a_4 STEMratio_{i,k} + a_5 numeracy_{i,k} + a_6 numeracy10/90_{i,k} + a_7 \hat{\lambda}_{i,k} + x_{i,k}'\beta + \mu_i + \delta_c$$

Correlations between skill indicators, OC and labour productivity

	Model 1	Model 2	Model 3	Model 4	Model 5
Numeracy score	0.024***	0.018**	0.031***	0.029**	0.018**
	(0.008)	(0.009)	(0.010)	(0.010)	(0.008)
ICT score (non-OC)	-0.004	-0.003	-0.005	-0.006	-0.003
	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)
ICT score ratio (OC/non-OC)	-0.234*	-0.246*	-0.256*	-0.275**	-0.242**
	(0.127)	(0.123)	(0.134)	(0.125)	(0.112)
STEM score (non-OC)	0.019***	0.014***	0.017**	0.012	0.014***
	(0.005)	(0.005)	(0.008)	(0.007)	(0.005)
STEM score ratio (OC/non-OC)	0.384**	0.299**	0.416***	0.301**	0.302**
	(0.147)	(0.125)	(0.129)	(0.113)	(0.128)
Numeracy score (Perc10/Perc90)	-0.606	-0.848	-0.555	-0.781	-0.843
	(0.635)	(0.599)	(0.585)	(0.515)	(0.600)
Log of net fixed assets per employee	0.163***	0.160***	0.147***	0.156***	0.160***
	(0.020)	(0.022)	(0.027)	(0.028)	(0.021)
Share of OC	0.000	-0.000	-0.000	-0.001	
	(0.001)	(0.001)	(0.001)	(0.001)	
Skill intensity		0.771**		0.850**	0.769**
		(0.281)		(0.360)	(0.284)
R&D expenditure (lagged)			0.002**	0.002***	
			(0.001)	(0.000)	
Constant	7.206***	7.349***	7.116***	7.000***	7.341***
	(0.404)	(0.378)	(0.578)	(0.517)	(0.379)
Observations	284	260	232	213	260
R-squared	0.908	0.917	0.918	0.927	0.917
Country FE	YES	YES	YES	YES	YES
Industry cluster (7 groups) FE	YES	YES	YES	YES	YES

Note: Countries included in the analysis: AUT, BEL, CAN, CZE, DEU, DNK, EST, FIN, FRA, GBR, GRC, HUN, IRL, ISR, ITA, JPN, KOR, LTU, NLD, NOR, POL, SVK, SVN, SWE and first wave of USA. Since there is no data available for the skills intensity variable for ISR, JPN and KOR, they are dropped in model 2, 4 and model 5. More observations are dropped when R&D is added to the model, mostly because R&D expenditure is often not available for the public sector. The seven industry clusters include: manufacturing (C); construction (F); wholesale, retail trade and repair of motor vehicles, transportation, storage and accommodation and food services (G&H&I); IT, financial and insurance activities (J&K); other business services (M&N); public services (O&P&Q) and other social and personal services (R&S). Robust standard errors are clustered at the country level. *, **, and *** indicate that coefficients are significant at the 10%, 5% and 1% levels, respectively.

Source: Author's own compilation

Exploring causality: selection model and first stages

Stages	Selection	First	First	First	**Second**
Dependent variable	Firm size	Numeracy	ICT non-OC	ICT ratio	VA
Samepath	0.009				
	(0.020)				
ICT trans.	0.097***				
	(0.033)				
Parent edu.	-0.050*	0.056***	0.024	-0.001	
	(0.030)	(0.015)	(0.052)	(0.002)	
Email non-OC	-0.027	-0.003	0.135***	-0.003**	
	(0.026)	(0.011)	(0.045)	(0.002)	
Email OC	0.017	0.011	0.032	0.004***	
	(0.020)	(0.011)	(0.037)	(0.001)	
IMR		0.088	0.318	0.017	0.027
		(0.121)	(0.360)	(0.011)	(0.020)
Numeracy					0.026
					(0.058)
ICT non-OC					-0.018
					(0.019)
ICT ratio					-0.334
					(0.444)
STEM non-OC	0.009	0.191***	0.780***	-0.005	0.026***
	(0.045)	(0.037)	(0.085)	(0.003)	(0.008)
STEM ratio	-1.384	1.330	-7.346***	1.016***	0.309
	(1.802)	(0.892)	(2.421)	(0.150)	(0.434)
Numeracy ratio	0.498	24.340***	27.86***	-0.552*	-0.637
	(3.847)	(3.697)	(10.04)	(0.294)	(1.136)
Log NFA	0.501**	0.404***	2.042***	-0.0149	0.190***
	(0.207)	(0.083)	(0.275)	(0.011)	(0.021)
Skill intensity	12.99***	2.299	7.016*	-0.156	0.840***
	(3.149)	(1.828)	(4.216)	(0.138)	(0.303)
Constant	-14.01***	17.930***	-36.12***	0.816***	6.656***
	(4.310)	(2.754)	(5.800)	(0.267)	(1.679)
Observations	260	260	260	260	260
R-squared					0.913
Ind. cluster (3)	YES				
Ind. cluster (7)		YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES
F-stat.		6.92	3.54	4.31	
Multi. F-stat.		15.95	16.00	15.98	

- ICT transactions at home is a relevant instrument for selection into larger firms.
- The IMR is not statistically significant, suggesting no selection effect, probably because it is already sufficiently controlled for by our fixed effects and other control variables.
- Parental education is strongly positively correlated with numeracy skills, which is in line with existing findings (Hanushek et al., 2015; Hampf et al., 2017).
- The share of e-mail use at home is a relevant instrument for ICT skills.

Note: Countries included in the analysis: AUT, BEL, CAN, CZE, DEU, DNK, EST, FIN, FRA, GBR, GRC, HUN, IRL, ITA, LTU, NLD, NOR, POL, SVK, SVN, SWE and first wave of USA. The seven industry clusters include: manufacturing (C); construction (F); wholesale, retail trade and repair of motor vehicles, transportation, storage and accommodation and food services (G&H&I); IT, financial and insurance activities (J&K); other business services (M&N); public services (O&P&Q) and other social and personal services (R&S). The three industry clusters include manufacturing (C), other businesses (F-N, R&S) and public sector services (O&P&Q). Robust standard errors are clustered at the country level. *, **, and *** indicate that coefficients are significant at the 10%, 5% and 1% levels, respectively.
Source: Author's own compilation.

Exploring causality, VA

Stages	OLS	Selection	First	Second	Selection	First	Second	Selection	First	First	Second	Selection	First	First	First	Second
Dependent variable	VA	Firm size	Numeracy	VA	Firm size	ICT non-OC	VA	Firm size	Numeracy	ICT non-OC	VA	Firm size	Numeracy	ICT non-OC	ICT ratio	VA
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Samepath		0.002						0.012				0.009				
		(0.023)						(0.020)				(0.020)				
ICT trans.					0.099***			0.104***				0.097***				
					(0.032)			(0.033)				(0.033)				
Parent edu.		-0.056*	0.055***					-0.046	0.059***	0.041		-0.050*	0.056***	0.024	-0.001	
		(0.030)	(0.014)					(0.030)	(0.015)	(0.043)		(0.030)	(0.015)	(0.052)	(0.002)	
Email non-OC					-0.029	0.110***		-0.018	-0.003	0.103***		-0.027	-0.003	0.135***	-0.003**	
					(0.025)	(0.036)		(0.025)	(0.012)	(0.029)		(0.026)	(0.011)	(0.045)	(0.002)	
Email OC												0.017	0.011	0.032	0.004***	
												(0.020)	(0.011)	(0.037)	(0.001)	
IMR			0.133	0.026		0.634**	0.034		0.098	0.633*	0.028		0.088	0.318	0.017	0.027
			(0.120)	(0.018)		(0.311)	(0.021)		(0.120)	(0.332)	(0.022)		(0.121)	(0.360)	(0.011)	(0.020)
Numeracy	0.018**			0.005	0.146	0.367**	0.026**				0.029					0.026
	(0.008)			(0.042)	(0.116)	(0.146)	(0.010)				(0.060)					(0.058)
ICT non-OC	-0.003	0.224***	0.038**	-0.002			-0.020				-0.021					-0.018
	(0.004)	(0.052)	(0.018)	(0.005)			(0.015)				(0.020)					(0.019)
ICT ratio	-0.242**	5.647***	-0.172	-0.241**	1.390	-15.32***	-0.517**	1.315	-0.788	-15.63***	-0.520*					-0.334
	(0.112)	(1.572)	(0.626)	(0.100)	(1.169)	(2.110)	(0.228)	(1.141)	(0.610)	(2.128)	(0.273)					(0.444)
STEM non-OC	0.014***	-0.140**	0.161***	0.016**	-0.020	0.684***	0.028**	0.020	0.194***	0.751***	0.027***	0.009	0.191***	0.780***	-0.005	0.026***
	(0.005)	(0.063)	(0.036)	(0.008)	(0.051)	(0.067)	(0.011)	(0.044)	(0.034)	(0.059)	(0.009)	(0.045)	(0.037)	(0.085)	(0.003)	(0.008)
STEM ratio	0.302**	-5.111**	2.108*	0.336**	-3.025	10.750***	0.503**	-1.865	2.562**	11.660***	0.497**	-1.384	1.330	-7.346***	1.016***	0.309
	(0.128)	(2.198)	(1.218)	(0.136)	(1.960)	(2.028)	(0.214)	(1.883)	(1.169)	(2.031)	(0.201)	(1.802)	(0.892)	(2.421)	(0.150)	(0.434)
Num. ratio	-0.843	-0.877	22.980***	-0.548	-3.429	10.380	-0.655	0.00779	23.85***	18.83**	-0.743	0.498	24.340***	27.860***	-0.552*	-0.637
	(0.600)	(3.941)	(3.449)	(1.006)	(4.616)	(9.353)	(0.638)	(3.700)	(3.628)	(8.411)	(1.073)	(3.847)	(3.697)	(10.04)	(0.294)	(1.136)
Log NFA	0.160***	0.297	0.316***	0.164***	0.470**	1.696***	0.193***	0.525**	0.397***	1.846***	0.192***	0.501**	0.404***	2.042***	-0.0149	0.190***
	(0.021)	(0.241)	(0.074)	(0.024)	(0.206)	(0.286)	(0.027)	(0.209)	(0.075)	(0.258)	(0.025)	(0.207)	(0.083)	(0.275)	(0.011)	(0.021)
Skill intensity	0.769**	12.680***	1.811	0.808***	11.960***	2.254	0.817***	13.210***	1.903	2.627	0.808***	12.990***	2.299	7.016*	-0.156	0.840***
	(0.284)	(3.385)	(1.880)	(0.276)	(3.185)	(2.832)	(0.265)	(3.169)	(1.920)	(3.170)	(0.272)	(3.149)	(1.828)	(4.216)	(0.138)	(0.303)
Constant	7.341***	-16.26***	19.620***	7.572***	-17.59***	-29.96***	6.707***	-15.35***	18.640***	-23.01***	6.640***	-14.01***	17.930***	-36.12***	0.816***	6.656***
	(0.379)	(4.554)	(2.743)	(0.960)	(4.897)	(6.612)	(0.703)	(4.523)	(2.599)	(6.232)	(1.706)	(4.310)	(2.754)	(5.800)	(0.267)	(1.679)
Observations	260	260	260	260	260	260	260	260	260	260	260	260	260	260	260	260
R-squared	0.917			0.917			0.913				0.912					0.913
Ind. cluster (3)		YES			YES			YES				YES				
Ind. cluster (7)	YES		YES	YES		YES	YES		YES	YES	YES		YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
F-stat.			14.87			9.20			7.76	6.78			6.92	3.54	4.31	
Multi. F-stat.			14.87			9.20			15.97	17.13			15.95	16.00	15.98	

Exploring causality, GO

Stages	OLS	Selection	First	First	First	Second
Dependent variable	GO	Firm size	Numeracy	ICT non-OC	ICT ratio	GO
	(1)	(2)	(3)	(4)	(5)	(6)
Samepath		0.017				
		(0.021)				
ICT trans.		0.096***				
		(0.033)				
Parent edu.		-0.047	0.050***	0.022	0.000	
		(0.030)	(0.015)	(0.053)	(0.002)	
Email non-OC		-0.035	0.004	0.137***	-0.005***	
		(0.026)	(0.011)	(0.044)	(0.001)	
Email OC		0.018	0.010	0.031	0.005***	
		(0.021)	(0.011)	(0.037)	(0.001)	
IMR			0.130	0.234	0.012	0.052**
			(0.110)	(0.376)	(0.009)	(0.021)
Numeracy	0.025					0.013
	(0.019)					(0.081)
ICT non-OC	-0.009*					-0.018
	(0.004)					(0.025)
ICT ratio	-0.316**					-0.676*
	(0.134)					(0.360)
STEM non-OC	0.007	0.017	0.191***	0.778***	-0.005	0.018
	(0.007)	(0.045)	(0.0337)	(0.0847)	(0.003)	(0.011)
STEM ratio	0.346	-1.983	2.617***	-6.834**	0.813***	0.692*
	(0.223)	(1.848)	(0.923)	(3.039)	(0.137)	(0.402)
Num. ratio	-0.606	0.889	23.56***	27.54***	-0.430*	-0.187
	(1.050)	(3.852)	(3.522)	(10.11)	(0.260)	(1.738)
Log NFA	0.200***	0.430**	0.517***	2.083***	-0.033***	0.218***
	(0.024)	(0.216)	(0.076)	(0.292)	(0.010)	(0.036)
Skill intensity	0.399	14.10***	1.690	6.727	-0.061	0.460
	(0.273)	(3.287)	(1.749)	(4.195)	(0.142)	(0.283)
Share of OC	-0.004***	-0.022*	0.023***	0.010	-0.004***	-0.005*
	(0.001)	(0.013)	(0.005)	(0.016)	(0.001)	(0.002)
Constant	7.730***	-13.01***	15.16***	-37.03***	1.252***	7.892***
	(0.259)	(4.387)	(2.767)	(6.906)	(0.272)	(1.968)
Observations	260	260	260	260	260	260
R-squared	0.929					0.928
Ind. cluster (3)		YES				
Ind. cluster (7)	YES		YES	YES	YES	YES
Country FE	YES	YES	YES	YES	YES	YES
F-stat.			5.55	3.81	6.55	
Multi. F-stat.			10.31	13.04	27.31	

Note: Countries included in the analysis: AUT, BEL, CAN, CZE, DEU, DNK, EST, FIN, FRA, GBR, GRC, HUN, IRL, ITA, LTU, NLD, NOR, POL, SVK, SVN, SWE and first wave of USA. The seven industry clusters include: manufacturing (C); construction (F); wholesale, retail trade and repair of motor vehicles, transportation, storage and accommodation and food services (G&H&I); IT, financial and insurance activities (J&K); other business services (M&N); public services (O&P&Q) and other social and personal services (R&S). The three industry clusters include manufacturing (C), other businesses (F-N, R&S) and public sector services (O&P&Q). Robust standard errors are clustered at the country level. *, **, and *** indicate that coefficients are significant at the 10%, 5% and 1% levels, respectively.
Source: Author's own compilation