Intangibles and labor-augmenting technical change

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Artificial intelligence and the next generation of competences :
How Digital – and Artificial Intelligence will impact jobs and competences profiles?

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Introduction

- Corrado et al. (2016) suggest that innovations are combination of increased IA accumulation related to new knowledge products that can be commercialized and new technology that shows up as an increase in TFP
- Commercial or marketable intangibles may accumulate the same way as other capital while the main interest is on their effect on labor-augmenting technological change, which may or may not be freely available to all
- The effects of IA on labor-augmenting productivity as an extension to Hellerstein et al. (1999) and Ilmakunnas and Piekkola (2014) but IA deepening is included
- Broad measures of intangibles (IA) using full register-based data of Finnish firms 1994-2014 from Statistics Finland relying on Innodrive 6th framework programme 2008-2011
- Main results: Research and development (R&D) important in marketable IA and organizational capital (OC) such as management and marketing in labor-augmenting technological change.

Measuring IA

- IAs are measured from investments in intangibles from the labor incomes of employees within selected occupations that are related to innovation-type work.
  - The EU Innodrive 2008-2011 sixth framework project (FP6): A) time shares spent on innovative work that affect the future. B) IA investment: IA work combined with the use of other factor inputs: intermediate input (value added from upstream industry such as NACE M) and tangibles.
- The way how OC, R&D work is combined with intermediate investment and tangibles measure well them
  - intermediates used approximate well purchased OC from NACE M Professional, scientific and technical activities (expenditures and performance match each other) as well broad R&D (from R&D type work + survey-based external).
  - The broad R&D primarily based on R&D related occupations (including engineering) + external survey-based R&D.
- Note: considering own-account IA and purchased IA as separate in the knowledge production function may lead to double accounting for OC.

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Summary table, thousand €2010

Variables, including IA stocks	Mean	Q1	Median	Q3	Std	Obs 0/ Share %
Value added per empl.	95.7	48.9	69.1	103.0	161.0	119531.0
Productivity growth	-.0136	-.167	-.0145	.141	.459	100.0
R&D/L	35.4	8.39	18.8	40.3	74.1	100.0
R&D/L micro firms	46.1	14.1	28.4	57.2	82.6	28.5
R&D/L micro firms, performance	37.5	9.62	20.6	41.8	60.7	28.5
R&D/L small-market-share firms	35.3	8.36	17.2	39.1	51.0	18.8
R&D/L small-market-share firm, performance	21.8	5.39	11.9	26.0	30.7	18.8
R&D/L large-market-share firms	33.4	6.63	16.6	36.6	87.5	32.6
R&D/L large-market-share firm, performance	29.3	3.75	10.9	27.7	85.2	32.6
OC/L	10.6	3.0	6.0	12.8	13.0	100.0
OC/L micro firms	10.4	2.72	5.57	12.4	14.1	24.4
OC/L micro firm,s performance	17.8	3.64	7.96	16.8	44.7	24.4
OC/L small-market-share firms	9.67	2.46	5.15	12.0	11.5	19.5
OC/L small-market-share firm, performance	6.67	.903	3.17	7.65	16.0	19.5
OC/L large-market-share firms	11.1	3.09	6.27	13.5	13.3	34.7
OC/L large-market-share firms, performance	10.7	1.76	4.5	10.6	25.3	34.7
Operating income/L	21.7	3.39	8.38	18.4	101.0	70.7
Employment	110.0	14.0	30.0	71.0	483.0	100.0
Employment no IA workers	95.3	11.5	25.8	61.8	418.0	100.0
Tangible capital/L	173.0	14.0	32.4	85.3	1267.0	90.2
Export/L	66.2	1.12	13.7	69.5	195.0	31.2
Import/L	103.0	1.58	18.8	87.4	362.0	38.9
Market share	.0194	.000872	.00289	.0108	.0621	99.6
Foreign owned	.152	0.0	0.0	0.0	.359	100.0
Part of group	.455	0.0	0.0	1.0	.498	100.0
In thousand $2010.						

Median firm has 19 R&D per employee (L) and 6 OC per employee (in thousand 2010€)

Main results

- OC improves productivity 240-320% with strongest effect in large firms (with market power) showing the pivotal role that management and marketing has in productivity improvement.
- R&D labor driven improvement in productivity is less 160-190% than OC driven
- Labor augmenting productivity improvement is strongest in large firms.
- Knowledge spillovers are most important among SMEs (i.e. lower in large firms with market power, rely on internal knowledge?).
- R&D leads to commercialized innovations and hence contribute more to the accumulation of IAs and hence to innovations that are not freely available or shared, these also improve R&D driven technological change.

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Methodology

Production function

$$Y_{it} = \left(AL_{it}\right)^{1-\sum_m \alpha_{mi} - \alpha_{ki}} \prod_m \left(R_{mit}\right)^{\alpha_{mi}} K_{it}^{\alpha_{Ki}}$$

$$\log AL = \log L + \log\left[1 + (a_R - 1)L_R / L + (a_O - 1)L_O / L\right] \approx \log L + (a_R - 1)L_R / L + (a_O - 1)L_O / L$$

$$\ln Y_{it} = \alpha_{Yj} \ln Y_{it-1} + \alpha_{Lj} \ln L_{it} + \alpha_{wmj} \sum_{m,i\in j} (\hat{a}_{mit} - 1)\frac{L_{mit}}{L_{it}} + \sum_{m,i\in j} \alpha_{mi} \ln R_{mit}$$

$$+ \alpha_{Kj} \ln K_{it} + \alpha_{Zj} \ln Z_{it} + e_{it}$$

where $\alpha_{wmj}(\hat{a}_{wmit} - 1) = \alpha_{Lj}(\hat{\hat{a}}_{wmjt} - 1)$ so that $\hat{\hat{a}}_{wmit} = \alpha_{wmj}(\hat{a}_{wmit} - 1) / \alpha_{Lj} + 1$ $\hat{\hat{a}}_{wmit}$ is $\bar{w}_{mit} / \bar{w}_{Lit}$

- Cobb-Douglas production function A=quality, L=employees, R_m, m=R&D,OC, K=tangible capital, a_R = quality of R&D work, a_{OC} = quality of OC work, in estimation eqution Z controls, e is residual, $\hat{\hat{a}}_{wmit}$ is hourly wage ratio of type IA_m to skilled workers

Labor-augmenting technical change from production function estimates at firm level, OLS

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	Micro firms < 10 employees	Low-market share firms	High-market share firms
		R&D	
Compensation ratio	1.15	1.06	1.24
Quality adjusted technical change median	1.59	1.17	1.86
Quality adjusted P25-P75 range	1.15 - 1.96	0.74 - 1.79	0.89 - 3.5
Long-term multiplier	2.06	1.90	2.14
		OC	
Compensation ratio	1.09	1.11	1.27
Quality adjusted technical change median	2.53	2.43	3.19
Quality adjusted P25-P75 range	1.03 - 3.22	0.61 - 3.94	1.02 - 5.39
Long-term multiplier	2.11	1.88	2.19

Table shows median technical change. P25-P75 range and long-term multiplier are from (11); the former shows range of quality adjusted technical range at percentiles 25% and 75% of overall distribution calculated at median employment coefficients and the latter shows the multiplier for all the short-term effects $1/(1-a_Y)$, where a_Y is coefficient of lagged value added.

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Table 4. Labor-augmenting technological change background variable at industry level OLS

	R&D technical change		OC technical change	
	All firms	Large-market-share firms	All firms	Large-market-share firms
R&D asset	13.630*	24.702**	-6.540*	-10.640**
	(5.653)	(7.731)	(3.004)	(3.947)
R&D asset squared	-0.714*	-1.235**	0.328*	0.488*
	(0.282)	(0.391)	(0.150)	(0.200)
OC asset	-0.616	-0.158	-0.624	-0.849*
	(0.545)	(0.866)	(0.329)	(0.353)
Export	-0.473	-1.814***	0.679	0.938***
	(0.440)	(0.532)	(0.351)	(0.197)
Import	0.818*	1.910***	-0.662	-0.897***
	(0.416)	(0.540)	(0.371)	(0.213)
Tangible capital	0.263	-0.526	0.025	1.291**
	(0.688)	(1.267)	(0.303)	(0.417)
Small-market-share firm	3.439	-	1.308	-
	(1.789)		(0.862)	
Large-market-share firm	3.533	-	-2.404*	-
	(1.860)		(1.033)	
Observations	2230	2230	1222	1222
R squared	0.249	0.230	0.369	0.416

All except dummy variables are in logs. Dummies cover 33 NACE 2-digit industries, 18 NACE3 regions and years. P-values: * p < 0.05, ** p < 0.01, *** p < 0.001.

Determinants of technical change at industry level

- R&D labor augmented technical change related to own capital deepening
  - At a decreasing rate
  - Negatively related to exports positively to imports
  - Negatively related to OC deepening (not significant)
- OC labor augmented technical change negatively related to own capital deepening
  - Positively related to exports negatively to import sin large firms
  - Micro firms are relatively less driven by this

Table 5. Labor productivity and knowledge spillovers at firm level

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Knowledge spillovers $\alpha_{spill,mk}$ from

$$\sum_k \alpha_{spill,mk} \sum_{i \in k,j} \frac{L_{imt}}{L_{jkmt}} (\hat{\hat{a}}_{kjmt} - 1)$$

- For each m=R&D, OC where $\hat{\hat{a}}_{kjmt}$ is from estimation of quality adjusted technical change. Aggregated to industry level j for each firm size k using each i firm's labor shares L_{imt} / L_{jkmt} as weights. The contribution to knowledge spillovers thus depends on the relative size of the firm.

	Micro firms < 10 employees	Low-market share firms	High-market share firms
VA/L lagged	0.6316***	0.5660***	0.6572***
	(0.0014)	(0.0051)	(0.0051)
Emloyee no IA	0.3289***	0.3467***	0.2858***
	(0.0014)	(0.0053)	(0.0049)
R&D knowledge spillover			
Micro firms	-0.5790***	-0.9183**	-1.1684***
	(0.0157)	(0.3216)	(0.1473)
Small-market-share firms	1.4078***	2.0431***	1.3127***
	(0.0379)	(0.1225)	(0.0795)
Large-market-share firms	0.0164***	-0.0054**	0.0051***
	(0.0014)	(0.0018)	(0.0012)
OC knowledge spillover			
Micro firms	-0.0862***	1.0931*	0.0157
	(0.0106)	(0.4732)	(0.0707)
Small-market-share firms	0.9664***	0.5989***	0.5369***
	(0.0439)	(0.0955)	(0.0884)
Large-market-share firms	0.0745***	-0.0709***	0.0483***
	(0.0054)	(0.0147)	(0.0105)
Quality adjusted technical change $a_{R\&D}$	0.1063***	0.3464***	0.3077***
	(0.0047)	(0.0201)	(0.0286)
Quality adjusted technical change a_{OC}	0.2104***	0.7328***	0.6793***
	(0.0073)	(0.0368)	(0.0274)
R&D asset	0.0183***	0.0155***	0.0116***
	(0.0001)	(0.0002)	(0.0003)
OC asset	0.0151***	0.0088***	0.0137***
	(0.0001)	(0.0003)	(0.0004)
K/L	0.0173***	0.0165***	0.0208***
	(0.0002)	(0.0008)	(0.0010)
K/L lagged	-0.0082***	-0.0107***	-0.0137***
	(0.0002)	(0.0008)	(0.0010)
Long-term multiplier	2.71	2.3	2.92
Observations	1146978	106880	101581
R squared	0.825	0.779	0.909

All except dummy variables are in logs. Dummies cover 33 NACE 2-digit industries, regions and years. P-values: * p < 0.05, ** p < 0.01, *** p < 0.001.

Labor productivity and knowledge spillovers at firm level

- Knowledge spillovers improving productivity stronger in other than micro firms
  - The very high spillovers in SMEs imply that substantial part of IA driven technological progress is from knowledge spillovers, i.e. SMEs do not internalize the positive effects in their innovation decisions
- Marketable IA (deepening) has very similar marginal returns irrespective of firm size
- OC labor is not only more important for labor-augmenting technological change in Finland than R&D but also creates larger knowledge spillovers in other than large firms
- R&D spillovers are concentrated in large firms

Open questions

- Why OC is so important in technological development? Are we overestimating the effects of major technological revolutions through R&D or do they enter better the analysis at more aggregate level and over longer period, e.g. new revolutions in energy production
- Large firms rely on internal knowledge? Usually frontier firms but knowledge spillovers in particular spread among SMEs but is this acknowledged or not
- R&D works as predicted in large firms since better measured?
- Among micro firms only the one with at least some IAs are selected: do not represent the entire population