

Who benefits most from interconnectivity?

A view on productivity and employment effects of innovative IT systems

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SEEK Conference Mannheim, October 2015

About

Software, IT hardware and telecommunication channels are more and more connected with each other.

- Are firms that use interconnected technologies more productive than firms using traditional ICT systems?
- Which employment effects can we expect?

- ▶ I find that the effects of interconnected ICT heavily depend on firm size.
- ▶ Medium firms experience positive productivity effects, driven by employment cuts.
- ▶ Large firms see negative productivity effects and extend their IT departments.
- ▶ Network/spillover effects beyond the investments.

ICT has gone through periodic transformations

Computing paradigms since the 1950s

Centralized IT architecture in the late 1950s

- ▶ Mainframe computers (universities, governmental organizations), running the organization's own software applications

Decentralization in the 1980s

- ▶ With hardware becoming smaller, cheaper and more powerful
- ▶ Client/server structures

The internet

- ▶ Years 2000: IT (storage, computing) and Communication (Networks) constitute one single system → resources are interconnected and shared among users
- ▶ Years 2010: Flexible outsourcing of IT services → Cloud Computing; Smart Factories/Industry 4.0

Established IT measures do not include interconnectivity

- ▶ The literature often finds a positive productivity effect of ICT in firms (elasticity 0.05-0.06 in a meta study) (Cardona et al 2013)
- ▶ Established ICT measures
 - ▶ number of PCs per employee in the firm
 - ▶ investments in PCs
 - ▶ ICT capital stock
(Brynjolfsson & Hitt 2003; Black & Lynch 2001)
- ▶ But the technology has changed:
 - ▶ More services, not captured by traditional measures
 - ▶ New and other tasks executed by PCs
 - ▶ Potentially new and other mechanisms triggered

Expected effects of interconnectivity and sharing

- ▶ Centralization and higher utilization of IT capacities
→ more efficient use of ICT capital, higher productivity
- ▶ Complementarity of ICT investment and organizational change:
 - ▶ More proficient ICT
 - ▶ Decision making at another hierarchical level: CT centralizes, IT decentralizes (Bloom et al 2009)
→ Employment effects (Michaels et al 2010)
- ▶ Lower information and communication costs
→ better decision making may enhance sales
- ▶ Market level: Lowering barriers to entry, esp. for SME, if resources are shared among different companies (Etro 2009)
- ▶ Firm heterogeneity: Effects expected to vary according to firm characteristics.

Data

- ▶ CI Technology Database (CITDB) by Harte Hanks market intelligence company
- ▶ Merged with Bureau van Dijk ORBIS balance sheet data
- ▶ Unbalanced panel 2000-2007, interpolated
- ▶ Prior use by Bresnahan et al. 2002 QJE; Forman et al. 2012 AER; Kretschmer et al. 2012 AER

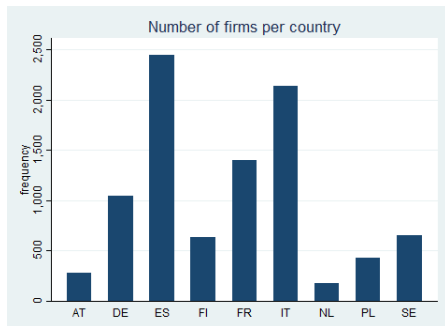
Data

Sample size

	Observations		Firms	
	N	%	N	%
Sample	40,715	100	9,067	100
Industries				
Manufacturing	25,527	62.69	5,487	60.52
Services	12,895	31.67	3,031	33.43
Other	2,293	5.63	549	6.05
Firm size				
Small (< 50)	10,107	24.82		
Medium (50-249)	21,022	50.50		
Large (\geq 250)	10,219	24.55		

More

Country distribution

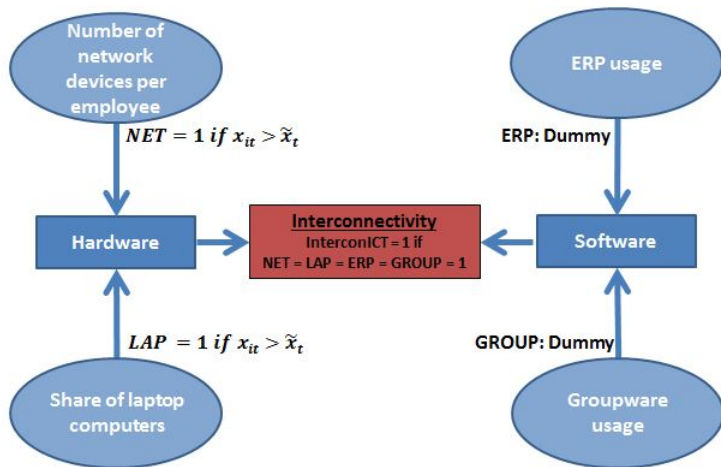


Interconnectivity variable

Input:

- ▶ Enterprise Resource Planning software (ERP)
 - ▶ Platform for a wide range of software products supporting day-to-day business operations and decision-making (Hitt et al 2002)
- ▶ Groupware (GROUP)
 - ▶ Collaborative software for communication, conferencing, coordination, file exchange (e.g. Microsoft Outlook/Exchange oder IBM Lotus Notes/Domino)
- ▶ Number of network devices per employee (NET)
- ▶ Share of laptops among all firm PCs (LAP)

Interconnectivity variable



Identification strategy

Augmented Cobb-Douglas production function in intensive form:

$$y_{it} = \beta_0 + \beta_1 k_{it} + \beta_2 m_{it} + \beta_3 \text{InterconICT}_{i(t-1)} + \gamma_i + \gamma_{t*ind} + \varepsilon$$

- ▶ y_{it} , k_{it} , m_{it} : company sales/capital/materials per employee in year t (ln)
- ▶ $\text{InterconICT}_{i(t-1)}$: Interconnectivity dummy, 1 year lag → exclude contemporaneous reverse causality
- ▶ γ_i : Firm fixed effects, controlling for unobserved, time invariant firm heterogeneity
- ▶ γ_{t*ind} : Year*industry fixed effects, controlling for industry-specific shocks in the panel period (2-digit level)
- ▶ ICT investments are included in the capital variable (*total assets*) → Embodied technical change
- ▶ Interconnectivity dummy represents additional value such as spillover or network effects → Disembodied technical change

Labor productivity

	All sizes (1)	Small (2)	Medium (3)	Large (4)
	ln(Y/L)	ln(Y/L)	ln(Y/L)	ln(Y/L)
L.InterconlCT	0.00493 (0.00695)	0.0172 (0.0130)	0.0183* (0.00934)	-0.0261* (0.0158)
ln(K/L)	0.144*** (0.0168)	0.140*** (0.0192)	0.107*** (0.0274)	0.202*** (0.0418)
ln(M/L)	0.475*** (0.0230)	0.450*** (0.0346)	0.464*** (0.0348)	0.550*** (0.0550)
Constant	2.790*** (0.114)	3.030*** (0.149)	2.970*** (0.192)	2.210*** (0.254)
Firm FE	Yes	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes	Yes
r ²	0.680	0.703	0.716	0.660
Observations	31852	7990	16212	7650
N. of firms	9068	2202	4490	2376

Standard errors in parentheses

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

- ▶ No effect across all firm size groups.
- ▶ Positive association between interconnectivity and labor productivity for medium-sized firms
- ▶ Negative association for large firms
- ▶ What drives these effects?
Does interconnectivity enhance output (Y) or reduce labor (L)?

Sales

	All sizes (1)	Small (2)	Medium (3)	Large (4)
	ln(Sales)	ln(Sales)	ln(Sales)	ln(Sales)
L.InterconICT	-0.00517 (0.00647)	-0.000881 (0.0115)	0.00451 (0.00884)	-0.0279* (0.0156)
ln(K)	0.125*** (0.0201)	0.122*** (0.0252)	0.0736*** (0.0203)	0.205*** (0.0553)
ln(M)	0.491*** (0.0235)	0.459*** (0.0352)	0.482*** (0.0307)	0.565*** (0.0626)
Constant	4.597*** (0.305)	4.429*** (0.327)	5.068*** (0.347)	3.592*** (0.976)
Firm FE	Yes	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes	Yes
r2	0.680	0.728	0.691	0.681
Observations	31852	7990	16212	7650
N. of firms	9068	2202	4490	2376

Standard errors in parentheses

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

- ▶ Sales are decreasing with the implementation of InterconICT (implementation difficulties?)
- ▶ Negative productivity effect of InterconICT for large firms is driven by a negative sales effect
- ▶ No significant effect for smaller sized firms

Labor

	All sizes (1) ln(L)	Small (2) ln(L)	Medium (3) ln(L)	Large (4) ln(L)
L.InterconICT	-0.0202** (0.00825)	-0.0375** (0.0182)	-0.0257*** (0.00961)	-0.0000334 (0.0202)
ln(K)	0.143*** (0.0149)	0.147*** (0.0260)	0.101*** (0.0185)	0.200*** (0.0311)
ln(M)	0.221*** (0.0197)	0.197*** (0.0277)	0.215*** (0.0331)	0.256*** (0.0330)
Constant	1.579*** (0.220)	0.942*** (0.298)	1.924*** (0.320)	1.603*** (0.476)
Firm FE	Yes	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes	Yes
r2	0.233	0.252	0.240	0.318
Observations	31865	7997	16216	7652
N. of firms	9069	2203	4490	2376

Standard errors in parentheses

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

- ▶ Negative association between interconnectivity and the number of employees in the firm, esp. for small and medium-sized firms
- ▶ Employment is decreasing with the implementation of interconnective ICT
- ▶ Positive productivity effect of InterconICT for medium-sized firms is driven by a negative employment effect.
- ▶ No significant effect for large firms

IT employees

Which group of jobs is affected by the introduction of interconnectivity?

Total IT employees / Programmers and Web developers

	All sizes (1) ln(IT empl)	Small (2) ln(IT empl)	Medium (3) ln(IT empl)	Large (4) ln(IT empl)	All sizes (5) ln(IT dev)	Small (6) ln(IT dev)	Medium (7) ln(IT dev)	Large (8) ln(IT dev)
L.InterconICT	0.0345** (0.0164)	-0.0575** (0.0293)	0.0343 (0.0212)	0.107** (0.0419)	0.0387 (0.0257)	-0.0161 (0.0657)	-0.00360 (0.0316)	0.106** (0.0529)
ln(K)	0.121*** (0.0181)	0.0805*** (0.0271)	0.0912*** (0.0228)	0.199*** (0.0443)	0.135*** (0.0261)	0.0914 (0.0595)	0.0943*** (0.0267)	0.166*** (0.0449)
ln(M)	0.193*** (0.0195)	0.151*** (0.0332)	0.160*** (0.0249)	0.268*** (0.0371)	0.136*** (0.0321)	0.0776 (0.0526)	0.0895*** (0.0274)	0.188*** (0.0527)
Constant	-1.564*** (0.240)	-1.107*** (0.284)	-1.302*** (0.313)	-2.685*** (0.493)	-1.311*** (0.349)	-0.583 (0.469)	-0.680** (0.345)	-1.931*** (0.509)
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
r2	0.206	0.352	0.250	0.222	0.173	0.413	0.250	0.213
Observations	24607	5355	12994	6258	10318	1263	5272	3783
N. of firms	7674	1702	3895	2077	3830	515	1904	1411

Standard errors in parentheses

Standard errors clustered on the firm level

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

Employment effects of introducing interconnectivity

Small firms:

- ▶ Total staff ↓
- ▶ Num of IT employees ↓
- ▶ Interconnectivity potentially allows small firms to use outsourcing services and cloud computing

Medium firms:

- ▶ Total staff ↓
- ▶ No significant effect on number of IT staff or developers
- ▶ Interconnective IT potentially substitutes non-IT jobs

Large firms:

- ▶ Total staff constant
- ▶ Num of IT employees ↑, esp. developers
- ▶ Potentially more IT services and maintenance required, inhouse solution; substitution effect

Robustness checks

3-digit industry controls

Varying the computation of the dummy

- ▶ Use p80 as a cutoff point, instead of p50 \Rightarrow Strikter criterion
- ▶ Use p20 as a cutoff point, instead of p50 \Rightarrow Less strikt criterion

Decomposing the indicator

- ▶ Results are not driven by a certain input variable
- ▶ The combination of interconnective hardware and software components seems to be crucial.

Applying a traditional ICT measure to the sample

- ▶ Number of PCs; Number of PCs per employee
- ▶ Traditional ICT does not yield the same effects in our sample

Summary

- ▶ First attempt to measure computerized production and administration technology
- ▶ Positive association between labor productivity and interconnectivity, mostly in small/medium-sized firms.
- ▶ Result driven by the negative effect of InterconICT on employment → Job cuts, outsourcing or substitution?
- ▶ Firm size is an important firm characteristic in the context of interconnectivity and "Industrie 4.0".
- ▶ Next step: Explore task structure in order to deepen understanding of employment effects

Thank you



	Num. of obs	%	Num. of firms	% of interconnective firms	
				in 2000	in 2007
Total sample	41,625	100.00	9,193	0.14	0.27
Firm size					
Small (< 50)	10,384	24.95	2,235	0.13	0.30
Medium (50 – 249)	21,022	50.50	4,545	0.14	0.25
Large (> 250)	10,219	24.55	2,413	0.15	0.27
Industries					
Primary	458	1.10	121	0.08	0.33
Construction	1,800	4.32	421	0.12	0.24
Food	2,627	6.31	603	0.15	0.23
Textile	2,159	5.19	472	0.13	0.16
Wood	2,597	6.24	546	0.09	0.14
Print	1,195	2.87	250	0.15	0.27
Chemical	3,408	8.19	713	0.23	0.35
Metal	3,390	8.14	731	0.08	0.14
Machinery	4,278	10.28	885	0.15	0.34
Electronics	2,091	5.02	426	0.17	0.36
Transport Equipment	1,461	3.51	309	0.07	0.15
Instruments	503	1.21	111	0.26	0.37
Miscellaneous	2,344	5.63	502	0.11	0.21
Transportation	1,348	3.24	314	0.07	0.17
Utilities	915	2.20	237	0.18	0.33
Wholesale	4,933	11.85	1090	0.17	0.40
Retail	1,900	4.56	457	0.11	0.21
Financial sector	240	0.58	63	0.09	0.4
Business services	2,189	5.26	522	0.15	0.39
Other services	1,102	2.65	241	0.10	0.24
Health, Education, Social	572	1.37	154	0.00	0.09
Public Administration	115	0.28	25	0.17	0.23

Notes: Industry groups are built according to two-digit SIC codes. The last columns indicate the percentage of firms with interconnective IT in the respective categorie and year.

	Num. of obs	Mean	Std. dev.	Median	Min.	Max.
Employees	41,625	324.79	1710.31	119	1	105,261
Sales (in million \$)	41,625	105.949	677.63	26.75	0	62,851.28
Capital (in million \$)	41,625	27.78	517.49	3.36	0	81,604.35
Materials (in million \$)	41,625	59.59	379.09	12.50	0	37,824.12
ERP	41,625	0.89	0.30		0	1
Groupware	41,625	0.91	0.28		0	1
Num. of network devices per employee	41,625	0.75	1.05	0.55	0	94.07
Share of laptops among all firm PCs	41,625	0.13	0.15	0.09	0	1
Interconnectivity (InterconICT)	41,625	0.25	0.43		0	1

Notes: Unbalanced panel data from 2000 to 2007. Descriptive statistics are based on observations, not firms.

Back

OLS Cross section

	All sizes (1)	Small (2)	Medium (3)	Large (4)	All sizes (5)	Small (6)	Medium (7)	Large (8)
	ln(Y/L)	ln(Y/L)	ln(Y/L)	ln(Y/L)	ln(Y/L)	ln(Y/L)	ln(Y/L)	ln(Y/L)
L.InterconICT	0.225*** (0.00715)	0.187*** (0.0157)	0.243*** (0.00960)	0.209*** (0.0139)	0.150*** (0.00678)	0.0751*** (0.0145)	0.178*** (0.00901)	0.150*** (0.0132)
ln(K/L)	0.0735*** (0.00223)	0.0687*** (0.00450)	0.0775*** (0.00307)	0.0909*** (0.00482)	0.0764*** (0.00223)	0.0618*** (0.00423)	0.0788*** (0.00307)	0.101*** (0.00508)
ln(M/L)	0.466*** (0.00213)	0.452*** (0.00415)	0.466*** (0.00290)	0.482*** (0.00480)	0.477*** (0.00227)	0.472*** (0.00438)	0.471*** (0.00308)	0.503*** (0.00529)
Constant	3.055*** (0.0111)	3.231*** (0.0225)	3.016*** (0.0152)	2.887*** (0.0229)	2.570*** (0.0586)	3.437*** (0.121)	2.291*** (0.0716)	2.241*** (0.148)
Firm FE	No	No	No	No	No	No	No	No
Industry Dummies	No	No	No	No	Yes	Yes	Yes	Yes
Year dummies	No	No	No	No	Yes	Yes	Yes	Yes
r2	0.649	0.632	0.664	0.655	0.708	0.716	0.725	0.718
Observations	31852	7990	16212	7650	31852	7990	16212	7650

Standard errors in parentheses

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

Robustness checks

- ▶ Varying the computation of the dummy
- ▶ Cutoff point p80

	All sizes (1)	Small (2)	Medium (3)	Large (4)
	ln(Y/L)	ln(Y/L)	ln(Y/L)	ln(Y/L)
L.InterconICT (p80)	-0.00969 (0.0161)	0.0529** (0.0254)	0.00431 (0.0199)	-0.111*** (0.0375)
ln(K/L)	0.144*** (0.0168)	0.140*** (0.0192)	0.107*** (0.0274)	0.201*** (0.0416)
ln(M/L)	0.475*** (0.0230)	0.450*** (0.0345)	0.464*** (0.0348)	0.552*** (0.0546)
Constant	2.791*** (0.114)	3.015*** (0.148)	2.973*** (0.192)	2.196*** (0.253)
Firm FE	Yes	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes	Yes
r2	0.680	0.703	0.716	0.662
Observations	31852	7990	16212	7650
N. of firms	9068	2202	4490	2376

Standard errors in parentheses

Standard errors clustered on the firm level

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

► Decomposing the indicator

	All sizes (1) ln(Y/L)	Small (2) ln(Y/L)	Medium (3) ln(Y/L)	Large (4) ln(Y/L)
L.ERP	-0.00399 (0.0101)	0.0101 (0.0166)	0.00320 (0.0101)	-0.0572 (0.0417)
L.Groupware	-0.00105 (0.0102)	-0.00815 (0.0207)	-0.000215 (0.0106)	-0.0122 (0.0321)
L.Network devices / empl	0.000470 (0.00106)	0.0177* (0.00963)	0.00101 (0.00102)	-0.00331 (0.00230)
L.Share of laptops	-0.0341 (0.0256)	0.0100 (0.0533)	-0.00601 (0.0351)	-0.151*** (0.0572)
ln(K/L)	0.144*** (0.0168)	0.139*** (0.0192)	0.107*** (0.0274)	0.203*** (0.0418)
ln(M/L)	0.475*** (0.0230)	0.450*** (0.0346)	0.464*** (0.0348)	0.550*** (0.0549)
Constant	2.804*** (0.115)	3.006*** (0.150)	2.952*** (0.191)	2.275*** (0.255)
Firm FE	Yes	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes	Yes
r2	0.680	0.703	0.716	0.661
Observations	31852	7990	16212	7650
N. of firms	9068	2202	4490	2376

Standard errors in parentheses

Standard errors clustered on the firm level

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

- ▶ Applying a traditional ICT measure to our sample
- ▶ PC intensity

	All sizes (1)	Small (2)	Medium (3)	Large (4)
	ln(Y/L)	ln(Y/L)	ln(Y/L)	ln(Y/L)
L.PCs / empl	-0.000633 (0.000918)	-0.00125 (0.00151)	-0.000598 (0.00119)	0.00302 (0.00231)
ln(K/L)	0.143*** (0.0171)	0.137*** (0.0196)	0.107*** (0.0277)	0.204*** (0.0430)
ln(M/L)	0.474*** (0.0232)	0.447*** (0.0349)	0.465*** (0.0351)	0.549*** (0.0555)
Constant	2.864*** (0.121)	3.048*** (0.150)	2.882*** (0.186)	2.173*** (0.261)
Firm FE	Yes	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes	Yes
r2	0.678	0.699	0.715	0.660
Observations	31125	7786	15852	7487
N. of firms	9012	2196	4460	2356

Standard errors in parentheses

Standard errors clustered on the firm level

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

Do younger firms benefit less/more from interconnectivity?

	Observations		Firms	
	N	%	N	%
Sample	40,715	100	9,067	100
Firm age				
New (< 5 y)	1,394	3.42		
Young (5-9 y)	3,187	7.83		
Medium (10-14y)	4,578	11.25		
Established (>15)	31,544	77.50		

	Very young (1) ln(Y/L)	Young (2) ln(Y/L)	Medium (3) ln(Y/L)	Established (4) ln(Y/L)
L.InterconICT	-0.00653 (0.0291)	-0.0676 (0.0516)	0.0317* (0.0185)	0.00843 (0.00802)
ln(K/L)	0.253*** (0.0588)	0.160*** (0.0580)	0.155*** (0.0399)	0.140*** (0.0205)
ln(M/L)	0.671*** (0.0783)	0.378*** (0.0707)	0.396*** (0.0671)	0.485*** (0.0256)
Constant	2.121*** (0.249)	3.168*** (0.520)	2.116*** (0.178)	2.648*** (0.136)
Firm FE	Yes	Yes	Yes	Yes
Year*Industry FE	Yes	Yes	Yes	Yes
r2	0.909	0.644	0.741	0.678
Observations	848	2361	3487	25151
N. of firms	433	1068	1525	7327

Standard errors in parentheses

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

Short-term vs. long-term

- ▶ Fixed effects estimations consider changes on a year-to-year basis
- ▶ Growth regressions allow for a more long-term view
- ▶ Specification:

$$\Delta y_i = \beta_0 + \beta_1 y_{i,00} + \beta_2 \Delta k_i + \beta_3 \Delta m_i + \beta_4 \text{InterconICT}_{i,00} + \gamma_{ind} + \varepsilon$$

- ▶ Δy_i , Δk_i , Δm_i : company growth rates for labor productivity / capital / materials between 2000 and 2007
- ▶ $\text{InterconICT}_{i,00}$: Interconnectivity dummy for the year 2000
- ▶ γ_{ind} : Industry controls
- ▶ Association between a firm's ICT status in 2000 (early adopter) and its subsequent productivity growth

Growth: Labor productivity

	All sizes (1) $\Delta Y/L$	Small (2) $\Delta Y/L$	Medium (3) $\Delta Y/L$	Large (4) $\Delta Y/L$
InterconICT_2000	0.138*** (0.0377)	0.0245 (0.0856)	0.116*** (0.0425)	0.224** (0.103)
ln(Y/L)_2000	-0.283*** (0.0182)	-0.326*** (0.0314)	-0.222*** (0.0232)	-0.268*** (0.0678)
$\Delta K/L$	0.128*** (0.0140)	0.114*** (0.0250)	0.0989*** (0.0178)	0.189*** (0.0417)
$\Delta M/L$	0.398*** (0.0149)	0.365*** (0.0272)	0.413*** (0.0179)	0.398*** (0.0486)
Constant	2.117*** (0.525)	2.607*** (0.543)	1.751*** (0.431)	0.737 (0.680)
Industry dummies	Yes	Yes	Yes	Yes
r2	0.642	0.824	0.615	0.446
Observations	1395	346	720	329

Standard errors in parentheses

Standard errors clustered on the firm level

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

- ▶ Positive association between initial interconnective ICT and labor productivity growth between 2000 and 2007
- ▶ Early adopters of new technologies have higher labor productivity growth than later or non-adopters
- ▶ Medium-sized firms: Positive productivity effects in the short- and long-run
- ▶ Large firms: Negative productivity effects in the short-run do not persist