Complementarities between Information Technology and Innovation

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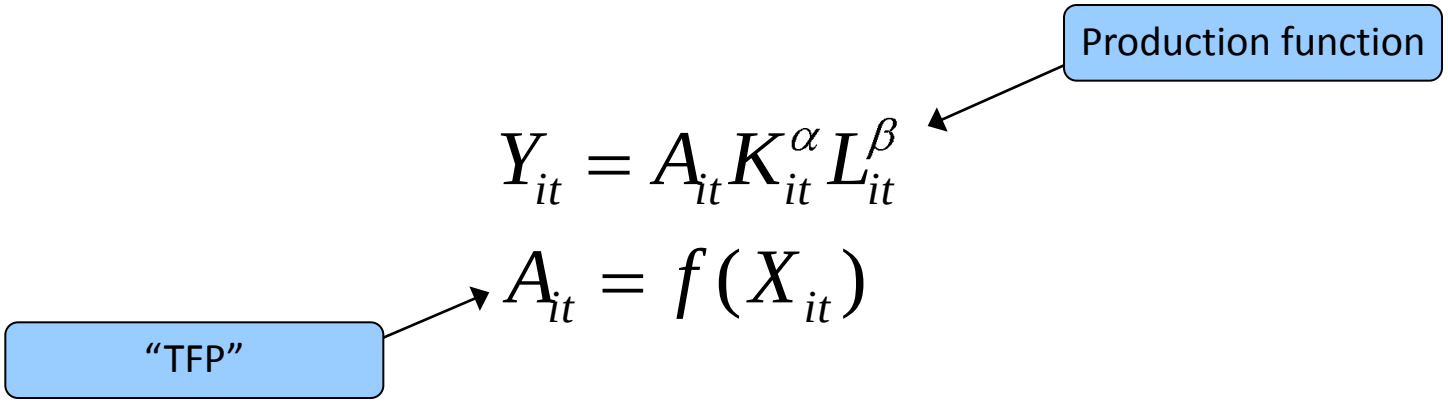
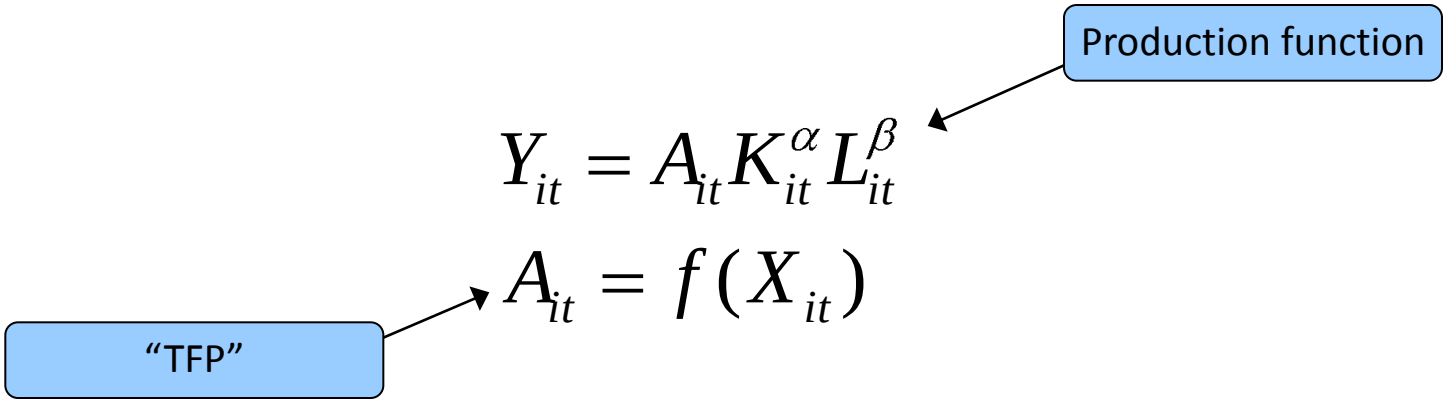
What drives productivity?



A_{it} is productivity

X_{it} are drivers of productivity

What drives productivity?



Hausse of candidate variables for X_{it}

(e.g. Bartelsman and Doms (2000), Syverson (2011))

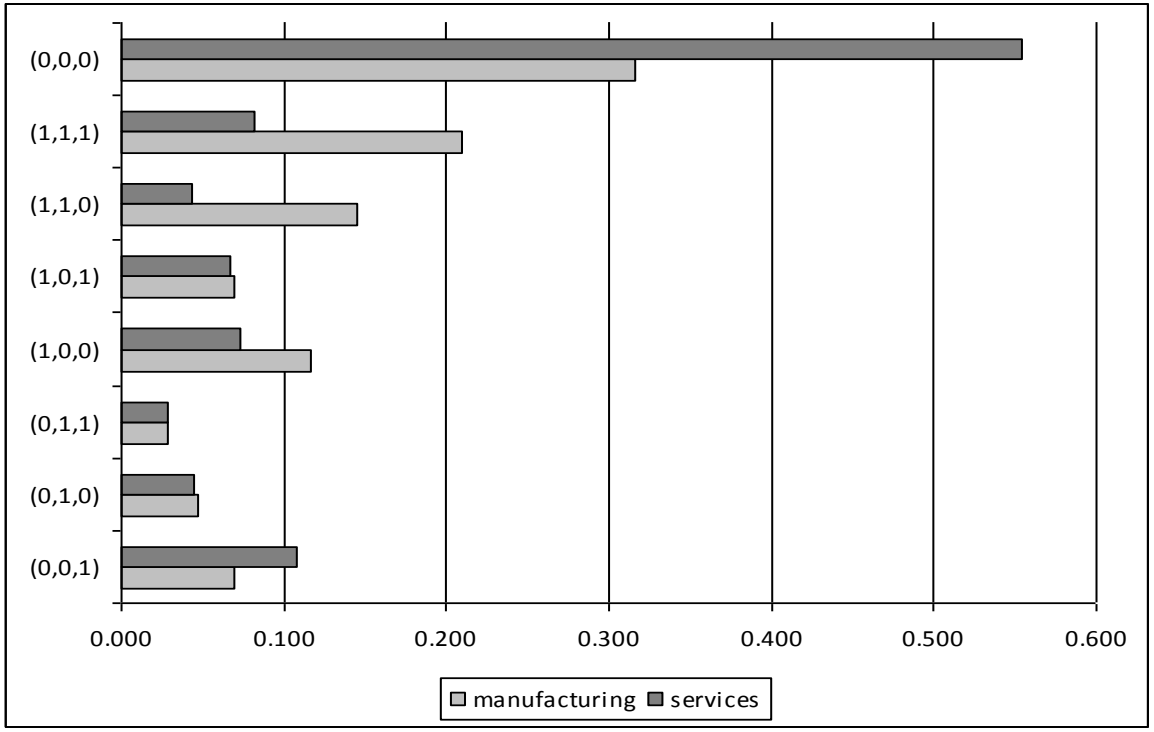
Our focus…

- **Adoption of** new technologies
- For example:
  - Innovation
    - Product, process
    - Organizational, marketing
  - E-business
    - E-commerce, ERP, CRM, SCM

Stage 1: Adoption

- Modelling the adoption of new technologies
  - What drives adoption?
  - Are there (anticipated) complementarities in the adoption phase?

Adoption profiles



PROD	PROC	ORG
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

Adoption phase: comparing joint and marginal probabilities

Joint probability A and B:	$Pr(A \cap B)$
Marginal probabilities:	$Pr(A)$, $Pr(B)$
Joint probability A and B if independent:	$Pr(A) \times Pr(B)$

'simultaneity ratio' $R(A,B) = Pr(A \cap B) / (Pr(A) \times Pr(B))$

→ increase in joint probability with respect to independence

Simultaneity of adoptions

Table 5: Marginal and Joint Sample Probabilities for Innovation Types.

A	B	Pr(A)	Pr(B)	Pr(A ∧ B)	Pr(A ∧ B)/Pr(A)Pr(B)
Manufacturing (N = 2,973)					
prod	proc	0.540	0.430	0.355	1.529
proc	org	0.430	0.376	0.237	1.471
org	prod	0.376	0.540	0.279	1.373
Services (N = 4,535)					
prod	proc	0.265	0.198	0.125	2.377
proc	org	0.198	0.284	0.110	1.951
org	prod	0.284	0.265	0.148	1.967

Clear positive mutual dependence between all types of innovation in manufacturing…

… possibly even stronger in services

What's driving this?

- Why simultaneous adoption?
- Two competing theories:
  - Complementarities in the production process (Milgrom and Roberts, 1990, 1995)
  - Cost advantages in simultaneous adoption (adjustment cost, see e.g. Shapiro, 1986, Asphjell et al 2010)

Econometric modelling of joint dependence

Estimation of adoption equations:

$$\Pr(\text{PROD} = 1) = \Phi(a_{12}\text{PROC}, a_{13}\text{ORG}, b_1 Z_1),$$
$$\Pr(\text{PROC} = 1) = \Phi(a_{21}\text{PROD}, a_{23}\text{ORG}, b_2 Z_2),$$
$$\Pr(\text{ORG} = 1) = \Phi(a_{31}\text{PROD}, a_{32}\text{PROC}, b_3 Z_3)$$

where Z_k are drivers of adoption, including ICT

- multivariate probit (MVP) model
- with simultaneous discrete dependent variables (see Lewbel, 2007)
- Identification of sum of coefficients on simultaneous terms only (e.g. $a_1 = a_{12} + a_{21}$)
- Complementarity if the sum > 0 (e.g. $a_1 > 0$)

Estimation results adoption equations (manufacturing)

Manufacturing (N = 2,973)	product innovation		process innovation		organizational innovation	
part of enterprise group	0.053	(0.458)	0.008	(0.868)	0.133 ***	(0.000)
foreignly owned	-0.087	(0.214)	-0.002	(0.972)	-0.013	(0.718)
cooperation on innovation	1.010 ***	(0.000)	0.503 ***	(0.000)	0.155 ***	(0.000)
exporter	0.257 ***	(0.000)	0.088	(0.108)	0.001	(0.983)
usage of IT systems	0.407 ***	(0.000)	0.120 *	(0.091)	0.112 **	(0.048)
intensity of broadband usage	0.590 ***	(0.000)	-0.269 ***	(0.001)	0.242 ***	(0.001)
employment (log)	0.103 ***	(0.001)	0.102 ***	(0.000)	0.092 ***	(0.000)
receives funding for innovation	1.025 ***	(0.000)	0.283 ***	(0.000)		
complementarity with						
product	-					
process	0.661 ***	(0.000)	-			
organizational	0.236 ***	(0.000)	0.219 ***	(0.000)	-	

- Significant positive cross-dependence between innovations
- Positive impact of ICT variables (IT systems, broadband (exception: process innovation))

Estimation results adoption equations (services)

Services (N = 4,535)	product innovation		process innovation		organizational innovation	
part of enterprise group	0.048	0.377	0.048	0.225	0.074 **	0.010
foreignly owned	0.174 ***	0.004	-0.151 ***	0.001	0.044	0.213
cooperation on innovation	1.222 ***	0.000	0.855 ***	0.000	0.076 **	0.047
exporter	0.034	0.527	0.170 ***	0.000	0.008	0.780
usage of IT systems	0.075	0.188	0.137 ***	0.001	0.176 ***	0.000
intensity of broadband usage	0.571 ***	0.000	0.097 **	0.032	0.229 ***	0.000
employment (log)	0.007	0.719	0.102 ***	0.000	0.074 ***	0.000
receives funding for innovation	1.298 ***	0.000	0.221 ***	0.007		
complementarity with						
product	-					
process	0.728 ***	0.000	-			
organizational	0.516 ***	0.000	0.340 ***	0.000	-	

- Significant positive cross-dependence between innovations
- Positive impact of ICT variables (IT systems (exception product innovation), broadband)

Stage 2: Productivity effects from joint adoption

Complementarity:

compare productivity gains of *combined* adoption to *individual* adoption

$$VA/L = \alpha_1 K + \alpha_2 L + \Sigma_i \gamma_i 1[\text{profile}_i]$$

Endogeneity:

Innovation dummies are endogenous, therefore replaced by estimated propensities (from MVP, cf. Griffith et al. 2006)

PROD	PROC	ORG
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1

Estimation results augmented production function

	Manufacturing (N = 2836)		Services (N = 4304)	
	coeff.	se.	coeff.	se.
IT capital	-0.004	0.005	-0.005	0.005
non-IT capital	0.202 ***	0.012	0.211 ***	0.010
employment	-0.202 ***	0.023	-0.373 ***	0.019
innovation profiles				
0,0,0,1	5.084 **	2.261	2.194	1.417
0,0,1,0	2.312	1.885	2.754 **	1.293
0,0,1,1	0.560	1.102	3.005 ***	0.603
0,1,0,0	3.236	1.844	3.232 **	1.333
0,1,0,1	-1.278	1.152	4.341 ***	1.561
0,1,1,0	-0.397	0.797	-2.549 ***	0.526
0,1,1,1	4.425 **	2.035	3.399 **	1.576
1,0,0,0	1.311	1.517	1.215	1.475
1,0,0,1	1.754	2.337	8.072 ***	2.844
1,0,1,0	1.609	1.430	0.180	1.177
1,0,1,1	3.701 *	2.109	1.686	2.311
1,1,0,0	0.627	0.972	0.785	0.617
1,1,0,1	5.563 ***	1.367	6.008 ***	2.088
1,1,1,0	2.632 **	1.172	1.213	1.156
1,1,1,1	0.168	0.956	4.623 ***	1.255
IT × product	-0.054 **	0.024	-0.117 ***	0.036
IT × process	0.039	0.024	0.112 **	0.044
IT × organizational	-0.023	0.026	0.259 ***	0.046
IT × marketing	0.148 ***	0.039	-0.286 ***	0.089
R^2	0.35		0.38	

No significant effect of IT-capital, and (quite substantial) decreasing returns-to-scale in both sectors

[Manufacturing]

Significant innovation dummies include three types of innovation, where individual adoption is not signficant (except for marketing)

[Services]

Signs of complementarity, e.g. product and marketing. Exception: process and organizational innovation?

[Manufacturing]

Interaction terms with IT systems positive only for marketing

[Services]

Interaction terms with IT only positive for organizational innovation

Productivity effects from joint adoption

For example,

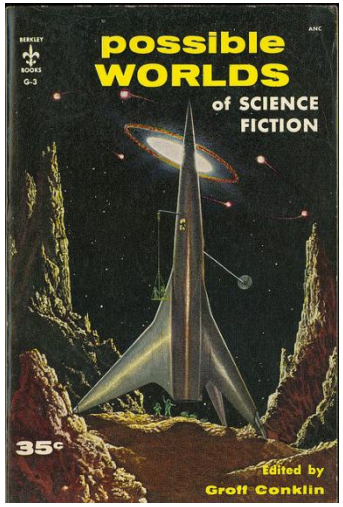
- gains to joint product-process innovation: $\gamma_{11k} - \gamma_{000}$
- gains to individual adoption: $(\gamma_{01k} - \gamma_{000}) + (\gamma_{10k} - \gamma_{000})$
  - for $k \in \{0,1\}$ (joint organizational innovation yes or no)
- complementarity if
  - $\gamma_{11k} - \gamma_{000} > (\gamma_{01k} - \gamma_{000}) + (\gamma_{10k} - \gamma_{000})$
  - test: Kodde-Palm (1984), Lokshin et al. (2011)

Conclusions

Preliminary stuff, but some patterns:

- descriptive evidence for joint adoption of innovation
- econometric evidence for simultaneity in the adoption equation
- positive role for IT in enabling innovation
- signs of complementarity in production process for a selection of combinations
- mixed results for interaction of IT with innovation

For the (near) future…



– Theoretical model for simultaneous adoption

– Reassess augmented production function (three types of innovation)

– Test complementarities in productivity equation

– Other adoptions? (E-business, going international, cooperation, merging/takeovers, …)

– International comparisons?