Simultaneous adoption of technologies: Descriptive cross-country evidence from Europe

Michael Polder
Statistics Netherlands

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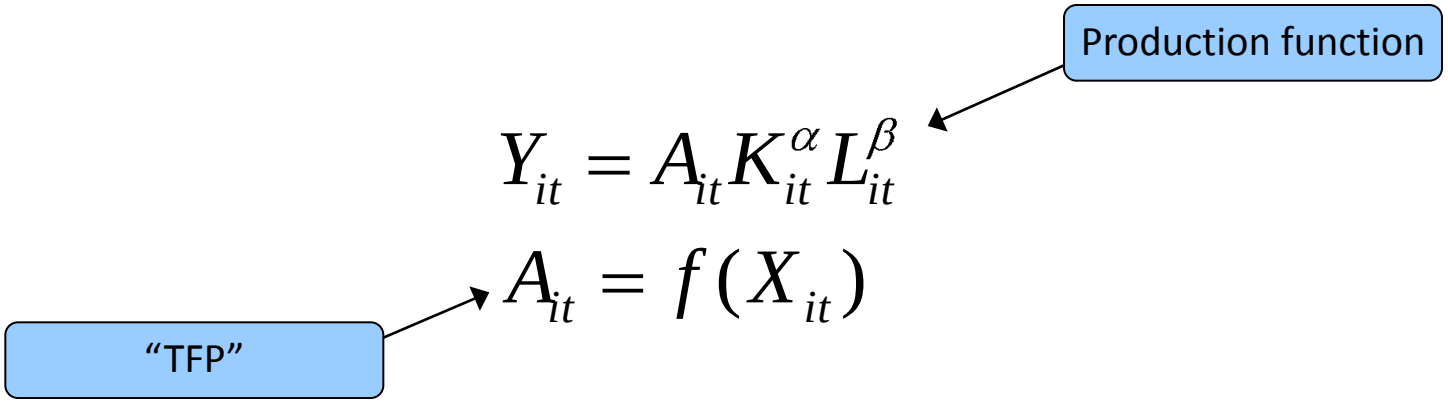
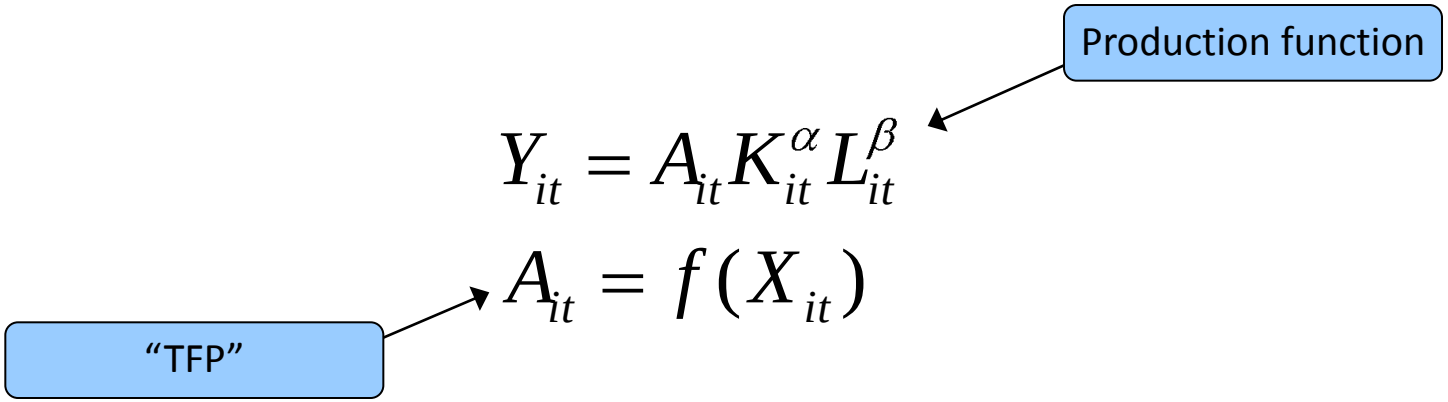
What drives productivity?



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
  - Stage 1: adoption decision
  - Stage 2: productivity effects of adoption

- For example:
  - Innovation
    - Product, process, organizational, marketing
  - E-business
    - E-commerce, ERP, CRM, SCM

Stage 1: adoption

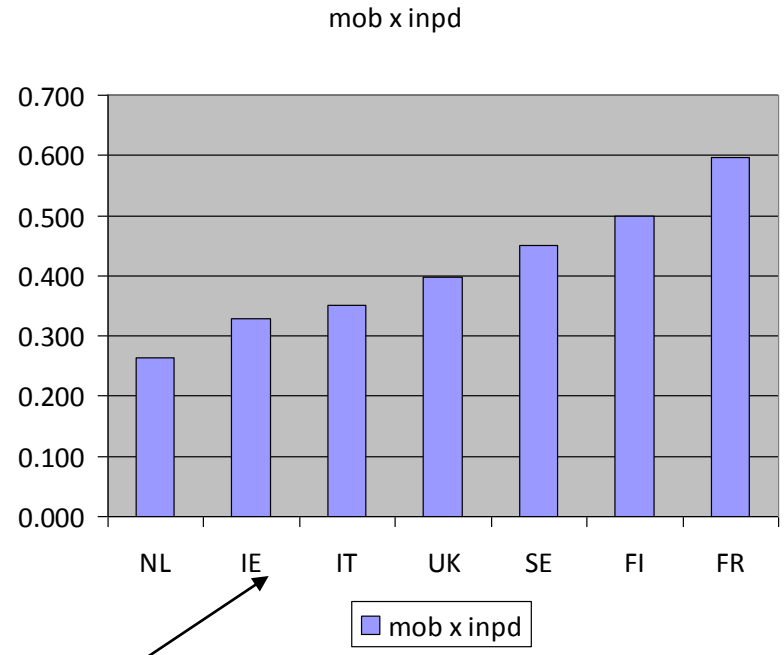
- Modelling the adoption of new technologies
  - What drives adoption?
  - Are there (anticipated) complementarities in the adoption phase?

What's driving this?

- Why simultaneous adoption (and why not?)
- Why cross-country/cross-industry differences?
- Two competing theories:
  - Complementarities in the production process (Milgrom and Roberts)
  - Cost advantages in simultaneous adoption (adjustment cost, see e.g. Shapiro, 1986, Asphjell et al 2010)

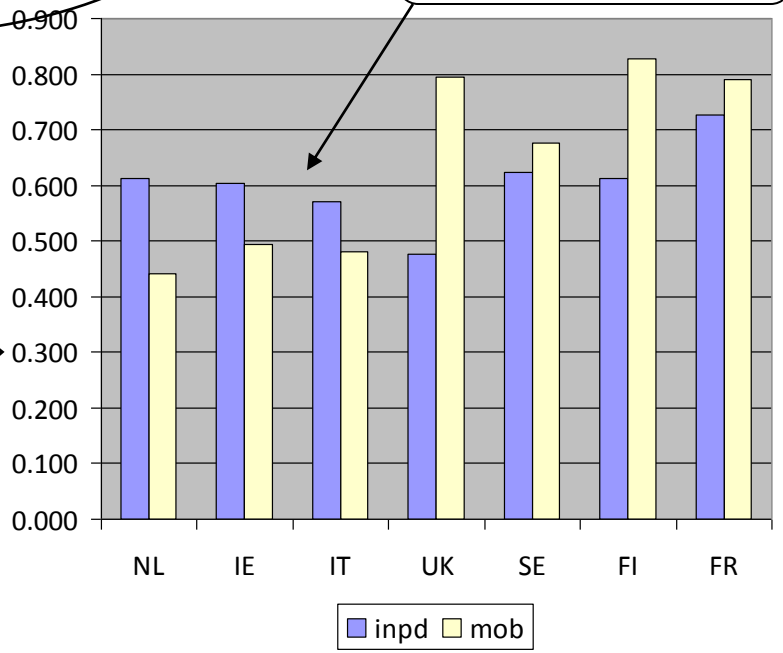
Adoption phase: joint probabilities

an example:
Mobile internet vs innovation (EleCom, 2008)



Joint probabilities

Eg. IE has more MOB and PROD than IT



… but joint adoption is higher in IT

Marginal probabilities

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

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) x Pr(B)

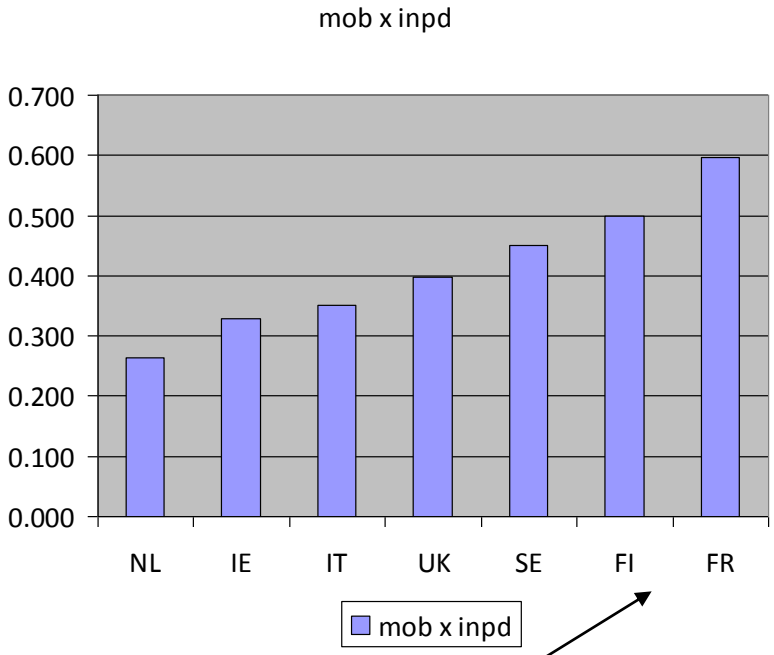
Expected differences in joint adoption under independence:

$Pr(A)_i \times Pr(B)_i - Pr(A)_j \times Pr(B)_j$ for country *i* and *j*

Compare to observed $Pr(A \cap B)_i - Pr(A \cap B)_j$ to assess difference in simultaneous adoption.

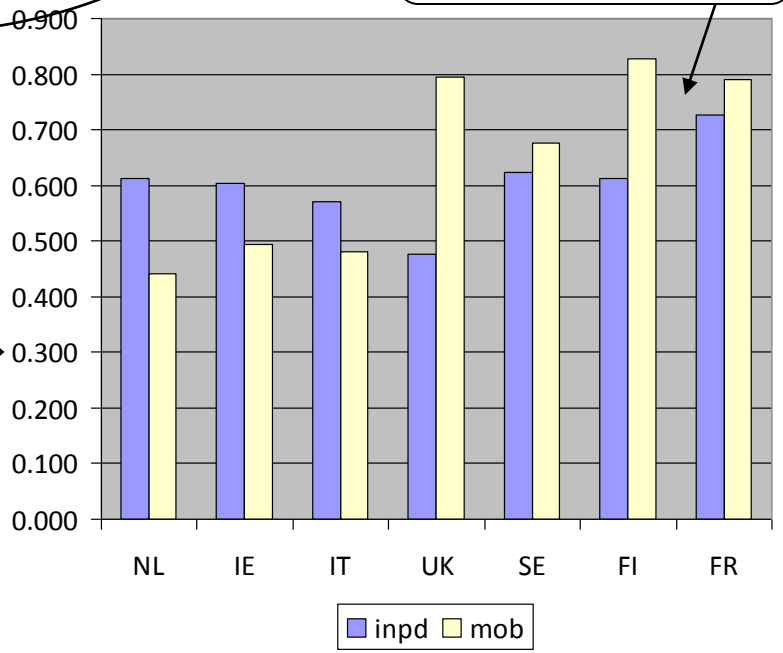
Adoption phase: joint probabilities

an example:
Mobile internet vs innovation (EleCom, 2008)



Joint probabilities

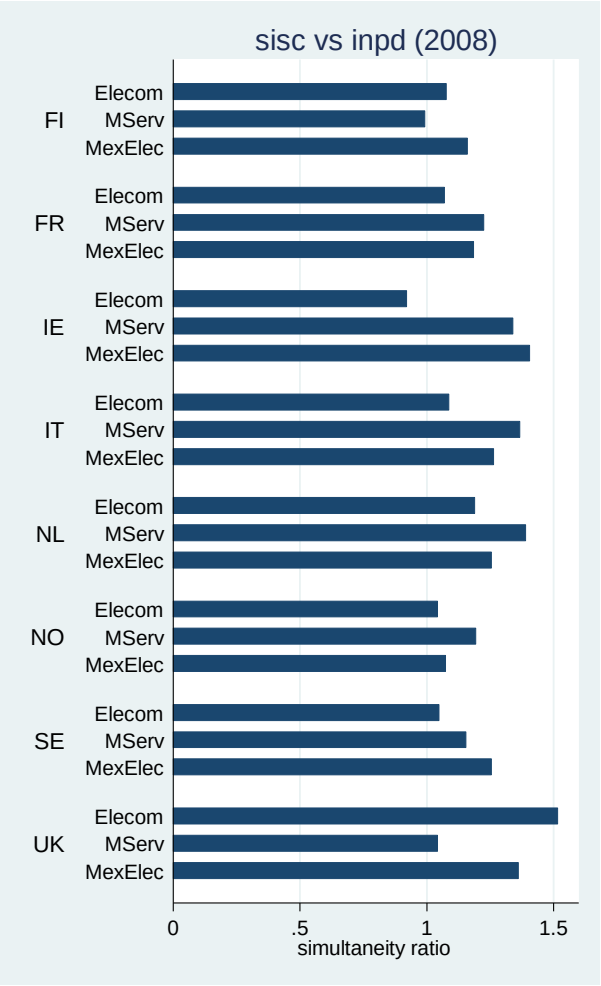
Expected difference FI and FR about 7%



… but actual difference is 10%

Marginal probabilities

Comparing joint and marginal probabilities



SCM vs Product innovation

- cross-country differences:

e.g. complementarity in services in almost all countries but not in UK or FI.

… and complementarity in manufacturing in all countries but not in NO

Testing simultaneity

Table 3: Sign test for the simultaneity ratio (Pr($R > 1$) > 50%))

combination	mean	std. dev.	*p*-value sign test	*N*
mob vs inpd	1.131	0.210	0.000	48
mob vs inps	1.076	0.204	0.003	48
mob vs orgin	1.069	0.214	0.040	33
mob vs mrkin	1.226	0.194	0.000	27
iterp vs inpd	1.176	0.177	0.000	42
iterp vs inps	1.140	0.180	0.000	42
iterp vs orgin	1.159	0.227	0.049	30
iterp vs mrkin	1.210	0.138	0.000	27
sisc vs inpd	1.164	0.153	0.000	30
sisc vs inps	1.186	0.180	0.000	30
sisc vs orgin	1.252	0.218	0.000	21
sisc vs mrkin	1.221	0.115	0.000	24

Table note: simultaneity ratio = $\Pr(A \cap B)/(\Pr(A)\times\Pr(B))$.
$\Pr(A \cap B)$: the observed probability of joint occurrence of A and B.
$\Pr(A)\times\Pr(B)$: the theoretical probability of joint occurrence if A and B are independent events.

Exploiting the country-industry dimension of the dataset, we can test for Pr($R > 1$).

… turns out to be significant for all cases considered (MOB, ERP, SCM vs innovations)

Econometric modelling of joint dependence

Estimation of adoption equations

$$\Pr(\text{tech}_1 = 1) = f(a_1\text{tech2}, B_1Z_1)$$
$$\Pr(\text{tech}_2 = 1) = f(a_2\text{tech1}, B_2Z_2)$$

where Z_k are drivers of adoption

- multivariate probit model
- (with simultaneous discrete dependent variables)
- Complementarity if $a_1 + a_2 > 0$ (Lewbel, 2007)

To be tested in other countries!

Testing simultaneity

Table 4: Estimates of cross-dependence between IT systems and innovations for the Netherlands (2008).

		product innovation		process innovation		organizational innovation	
		α	se	α	se	α	se
ICT	ERP	0.070**	0.032	-0.128***	0.035	0.021	0.032
	CRM	0.176***	0.032	-0.026	0.031	0.112***	0.031
	SCM	0.197***	0.046	0.098***	0.035	0.306***	0.038
N	2175						
draws	50						

In general we find positive cross-dependence of E-business systems with innovation

BUT

Negative cross-relation of ERP with process innovation, no relation with CRM

No relation between ERP and organizational innovation

Productivity effects from joint adoption (to do)

$$A_{it} = f(X_{it})$$

$$f(X_{it}) = \gamma_1 1[\text{profile}_1] + \gamma_2 1[\text{profile}_2] + \ldots + \gamma_N 1[\text{profile}_N]$$

Complementarity:

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

To be run in all countries

Adoption profiles

- Often observe only 0/1 variable for adoption
- For example: product, process, and organizational innovation
- 8 innovation profiles (2 x 2 x 2)

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

Productivity effects from joint adoption

$$f(X_{it}) = \gamma_1 1[\text{profile}_1] + \gamma_2 1[\text{profile}_2] + \ldots + \gamma_N 1[\text{profile}_N]$$

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)