Determinants of ICT Adoption: Evidence from Firm-Level Data

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Motivation

ICT at the core of the knowledge-based ("new") economy

- ICT-linked knowledge, innovation and ongoing technological change are strong determinants of productivity, growth differentials, the ability to benefit from globalisation
- ICT perceived as enabling technology
  - facilitates creation of new products and services
  - can help to improve product design, marketing, production, finance and organisation of firms
  - increases the productivity of R&D in downstream sectors

Questions:

What factors explain ICT adoption and diffusion across firms?

How much does the local availability of xDSL services matter?

Models of New Technology Adoption

Main Prediction: Preferred adoption dates vary across potential adopters of a new technology (Geroski, 2000; Karshenas and Stoneman, 1993)

Reasons:

- returns from adoption differ across firms (David, 1969; Davies, 1979, Ireland and Stoneman, 1986)
- spread of information about the technology (Mansfield, 1968)
- benefits to the marginal adopter decrease with the number of previous adopters (Reinganum, 1981)
- benefits from adoption depend on firm's position in the order of adoption (Ireland and Stoneman, 1985; Fudenberg and Tirole, 1985)

Two types of technolgy diffusion (Stoneman, 2002)

- **Inter-firm Diffusion, i.e. Adoption:** First-time use of a new technology
- **Intra-firm Diffusion:** Increasing intensity of technology use

Empirical Evidence
Determinants of ICT Adoption and Diffusion

- Fabiani et al. (2005) for Italy
- Hollenstein (2004) for Switzerland
- Bayo-Moriones and Lera-López (2007) for Spain

important determinants:

firm size, human capital, industry, foreign ownership, ability to absorb knowledge from other firms and institutions, workplace organisation, changes in organisational structures, information spillovers between firms

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Data

Merge Survey of E-Commerce and ICT

use of computers, degree of internet usage, sales and purchases via the internet, type of connection

with

Enterprise data from Census of Industrial Production

ownership, turnover, employment, exports, age

to obtain

Unbalanced panel of NACE Rev. 1.1 sectors 15-36 (excl. 16, 23) for period (2001) 2002-2004/5

Indicators of ICT Adoption

Indicators of inter-firm ICT diffusion (discrete):

1) Does the enterprise have a website?
2) Has the enterprise received online orders?
3) What type of technology does the firm use in-house?

Indicators of intra-firm ICT diffusion (continuous):

1) Share of employees using computers
2) Share of turnover due to online transactions

Indicators of ICT Adoption: Summary Statistics

	Indicators of inter-firm ICT adoption				Indicators of intra-firm ICT diffusion					
	Obs	% of firms with website	Obs	% of firms that accept orders online	Obs	% of employees using computers		Obs	% of turnover due to online transactions	
						Mean	StdDev		Mean	StdDev
Year										
2002	1,687	42.44	2,143	10.78	1,687	31.6	29.2	2,143	1.19	6.72
2003	2,169	47.44	1,636	14.06	2,050	33.9	29.6	1,636	1.83	8.71
2004	1,444	60.39	1,236	15.13	1,444	35.9	29.1	1,236	2.08	9.25
Size										
<20	2,922	36.82	2,572	12.33	2,871	30.8	29.5	2,572	1.44	7.35
20-49	1,235	56.84	1,253	13.73	1,202	33.3	27.8	1,253	1.19	5.11
50-249	933	70.53	946	13.64	905	39.2	28.9	946	2.13	9.90
250-499	135	84.44	154	10.39	131	52.0	28.9	154	3.71	16.59
500+	75	89.33	90	15.56	72	53.4	27.1	90	3.74	14.71
Ownership										
domestic	4,475	45.23	4,141	12.97	4,381	30.9	28.3	4,141	1.39	6.90
foreign	825	71.88	874	12.70	800	49.1	30.5	874	2.70	12.14
NUTS3 region										
border	726	46.97	670	12.54	709	25.5	24.9	670	2.22	9.80
midlands	308	44.81	289	9.34	302	26.0	22.6	289	0.72	4.25
west	476	50.21	436	15.14	469	34.5	30.0	436	1.35	6.39
dublin	1,370	54.01	1,259	17.55	1,331	42.6	32.7	1,259	1.86	7.45
mideast	538	49.26	539	12.24	530	33.0	28.3	539	1.80	9.44
midwest	443	48.53	449	11.80	432	33.3	29.2	449	1.26	5.23
southeast	692	44.80	687	8.73	680	28.6	26.0	687	1.19	8.44
southwest	747	49.40	686	10.35	728	33.6	28.7	686	1.67	9.38
Total	**5,300**	**49.38**	**5,015**	**12.92**	**5,181**	**33.7**	**29.4**	**5,015**	**1.62**	**8.08**

Note: The number of firms per year differs for the different indicators because all turnover related information is collected for the year prior to the year when the Survey on E-commerce and ICT was conducted (see Section 3 for more details on data from the Survey on E-commerce and ICT).

Empirical Methodology

Regression analysis controlling for:

- Firm size
- Output growth
- Firm age
- Multi-plant dummy variable
- Human capital:
  - Wages per employee
  - Share of managerial & technical staff in total employees
  - Share of clerical staff in total employees
- Export intensity
- Industry concentration
- Industry, region and time fixed effects
- DSL availability indicator for relevant county

Results: Website

	all firms		domestic firms	
Size (3-19)	-0.376 (0.114)	***	-0.327 (0.173)	*
Size (20-49)	-0.236 (0.119)	**	-0.180 (0.173)	
Size (50-249)	-0.154 (0.122)		-0.076 (0.181)	
Size (250-499)	-0.113 (0.135)		-0.059 (0.209)	
Size (500+)	*reference category*			
dlnTurnover	0.058 (0.027)	**	0.060 (0.028)	**
Age	-0.004 (0.002)	**	-0.003 (0.002)	
Age^2	0.000 (0.000)	*	0.000 (0.000)	
Multi-plant	0.067 (0.072)		0.076 (0.081)	
lnWage per employee	0.160 (0.033)	***	0.140 (0.035)	***
%Managerial/technical	0.355 (0.096)	***	0.387 (0.105)	***
%Clerical	0.498 (0.091)	***	0.484 (0.095)	***
Export Intensity	0.993 (0.143)	***	0.957 (0.157)	***
Export Intensity^2	-0.972 (0.149)	***	-0.903 (0.174)	***
HHI	0.047 (0.145)		-0.030 (0.167)	
epid_indreg_web	0.710 (0.064)	***	0.734 (0.074)	***
epid_ind_web	-0.127 (0.102)		-0.117 (0.111)	
dublin	*reference category*			
border	0.035 (0.038)		0.015 (0.042)	
midlands	0.009 (0.055)		-0.010 (0.058)	
west	0.059 (0.042)		0.048 (0.045)	
mideast	0.006 (0.042)		-0.011 (0.045)	
midwest	0.028 (0.045)		0.035 (0.050)	
southeast	0.001 (0.038)		-0.016 (0.041)	
southwest	0.016 (0.038)		0.035 (0.041)	
Year dummy variables	*Yes*		*Yes*	
Industry dummy variable	*Yes*		*Yes*	
Obs/Firms	4859 2625		4098 2234	
LogL	-2695.7		-2310.7	

Marginal effects results, with standard errors in parentheses. ***, **, * indicate significance at 1%, 5%, 10%, respectively. All explanatory variables are lagged by one year with respect to the dependent variable.

Results: Online orders

	all firms	domestic firms
Size (3-19)	0.038 (0.051)	-0.039 (0.081)
Size (20-49)	0.032 (0.054)	-0.037 (0.069)
Size (50-249)	0.018 (0.051)	-0.047 (0.060)
Size (250-499)	-0.019 (0.054)	-0.085 (0.035) **
Size (500+)	*reference category*	
dlnTurnover	0.015 (0.017)	0.021 (0.020)
Age	-0.001 (0.001)	-0.002 (0.001) *
Age^2	0.000 (0.000) *	0.000 (0.000) **
Multi-plant	0.033 (0.041)	0.009 (0.039)
lnWage per employee	0.002 (0.019)	0.005 (0.020)
%Managerial/technical	0.058 (0.048)	0.027 (0.058)
%Clerical	0.068 (0.043)	0.046 (0.047)
Export Intensity	0.278 (0.075) ***	0.316 (0.085) ***
Export Intensity^2	-0.239 (0.077) ***	-0.274 (0.094) ***
HHI	-0.026 (0.077)	-0.040 (0.089)
epid_indreg_ns	0.275 (0.038) ***	0.248 (0.042) ***
epid_ind_ns	0.109 (0.072)	0.151 (0.084) *
dublin	*reference category*	
border	-0.038 (0.017) **	-0.053 (0.017) ***
midlands	-0.060 (0.018) ***	-0.063 (0.019) ***
west	-0.016 (0.021)	-0.003 (0.025)
mideast	-0.038 (0.019) **	-0.035 (0.022)
midwest	-0.029 (0.021)	-0.045 (0.022) **
southeast	-0.056 (0.016) ***	-0.054 (0.018) ***
southwest	-0.050 (0.016) ***	-0.053 (0.017) ***
Year dummy variables	*Yes*	*Yes*
Industry dummy variable	*Yes*	*Yes*
Obs/Firms	3993 2298	3319 1937
LogL	-1433.0	-1193.5

Marginal effects results, with standard errors in parentheses. ***, **, * indicate significance at 1%, 5%, 10%, respectively. All explanatory variables are lagged by one year with respect to the dependent variable.

Results: Share of employees using computers

	all firms		domestic firms	
Size (3-19)	-0.038 (0.037)		0.005 (0.044)	
Size (20-49)	-0.053 (0.034)		-0.010 (0.044)	
Size (50-249)	-0.050 (0.033)		-0.024 (0.041)	
Size (250-499)	-0.001 (0.038)		-0.032 (0.045)	
Size (500+)	*reference category*			
dlnTurnover	-0.013 (0.014)		-0.011 (0.014)	
Age	-0.003 (0.001)	***	-0.002 (0.001)	***
Age^2	0.000 (0.000)	***	0.000 (0.000)	***
Multi-plant	-0.006 (0.023)		0.044 (0.029)	
lnWage per employee	0.127 (0.017)	***	0.109 (0.017)	***
%Managerial/technical	0.382 (0.050)	***	0.321 (0.056)	***
%Clerical	0.490 (0.042)	***	0.458 (0.043)	***
Export Intensity	0.098 (0.061)		0.203 (0.065)	***
Export Intensity^2	-0.035 (0.062)		-0.208 (0.071)	***
HHI	-0.021 (0.057)		-0.010 (0.068)	
epid_indreg_web	0.110 (0.027)	***	0.108 (0.029)	***
epid_ind_web	0.284 (0.047)	***	0.275 (0.050)	***
dublin	*reference category*			
border	-0.052 (0.016)	***	-0.051 (0.016)	***
midlands	-0.042 (0.020)	**	-0.032 (0.021)	
west	0.010 (0.021)		0.014 (0.021)	
mideast	-0.015 (0.019)		-0.016 (0.019)	
midwest	-0.012 (0.019)		-0.012 (0.020)	
southeast	-0.037 (0.017)	**	-0.026 (0.017)	
southwest	-0.020 (0.016)		-0.015 (0.017)	
Year dummy variables	*Yes*		*Yes*	
Industry dummy variables	*Yes*		*Yes*	
Obs/Firms	4742 2625		4006 2234	
LogL	-2030.9		-1674.9	

Marginal effects results, with standard errors in parentheses. ***, **, * indicate significance at 1%, 5%, 10%, respectively. All explanatory variables are lagged by one year with respect to the dependent variable.

Results: Share of turnover from online orders

	all firms		domestic firms	
Size (3-19)	-0.008 (0.009)		-0.008 (0.010)	
Size (20-49)	-0.010 (0.005)	*	-0.009 (0.006)	
Size (50-249)	-0.006 (0.006)		-0.006 (0.005)	
Size (250-499)	-0.005 (0.006)		-0.009 (0.001)	***
Size (500+)	*reference category*			
dlnTurnover	0.003 (0.004)		0.005 (0.005)	
Age	0.000 (0.000)		0.000 (0.000)	
Age^2	0.000 (0.000)		0.000 (0.000)	
Multi-plant	-0.007 (0.003)	***	-0.006 (0.002)	***
lnWage per employee	0.001 (0.003)		0.000 (0.003)	
%Managerial/technical	0.013 (0.008)		0.002 (0.009)	
%Clerical	0.000 (0.007)		-0.005 (0.005)	
Export Intensity	0.025 (0.014)	*	0.037 (0.014)	***
Export Intensity^2	-0.013 (0.015)		-0.032 (0.015)	**
HHI	-0.003 (0.014)		0.003 (0.013)	
epid_indreg_ns	0.044 (0.007)	***	0.033 (0.008)	***
epid_ind_ns	0.011 (0.012)		0.025 (0.012)	**
Year dummy variables	*yes*		*yes*	
County dummy variables	*yes*		*yes*	
Industry dummy variables	*yes*		*yes*	
Obs/Firms	3993 2298		3334 1946	
LogL	-266.7		-198.1	

Marginal effects results, with standard errors in parentheses. ***, **, * indicate significance at 1%, 5%, 10%, respectively. All explanatory variables are lagged by one year with respect to the dependent variable.

Modelling local DSL service availability

- Merge all business addresses from An Post's Geodirectory
- With a map of eircom exchange areas, which tells you the

⟶ Exchange to which each business address is likely to be connected

- Add info on when each exchange was enabled for DSL
- and County/Electoral District in which each firm is located

⟶ Yearly average DSL availability in each County/ED

	% of firms using				
	Modem	Isdn	Dsl	Dsl>2MB	Wireless
2002	40.8	39.3	7.1	3.4	3.7
2005	23.9	32.2	13.7	12.3	8.1

% of Business Premises Within the Catchment Area of DSL-Enabled Exchanges

NAME	2001	2002	2003	2004	2005
CARLOW	0.0%	0.0%	27.2%	60.5%	80.2%
CAVAN	0.0%	0.0%	7.0%	32.0%	51.0%
CLARE	0.0%	0.0%	37.6%	52.6%	59.9%
CORK	0.0%	7.5%	47.3%	76.2%	85.0%
DONEGAL	0.0%	0.0%	15.6%	37.6%	61.3%
DUBLIN	24.4%	81.6%	90.3%	97.0%	99.3%
GALWAY	0.0%	2.2%	43.1%	62.2%	70.2%
KERRY	0.0%	12.3%	43.1%	50.0%	68.2%
KILDARE	0.3%	5.3%	43.5%	80.7%	89.0%
KILKENNY	0.0%	0.0%	25.9%	51.7%	62.4%
LAOIS	0.0%	0.0%	33.6%	46.8%	65.9%
LEITRIM	0.0%	0.0%	2.8%	33.8%	36.9%
LIMERICK	0.0%	7.8%	49.0%	58.3%	72.5%
LONGFORD	0.0%	0.0%	4.5%	55.2%	69.5%
LOUTH	0.0%	0.0%	61.9%	77.3%	85.5%
MAYO	0.0%	6.1%	39.9%	50.0%	64.9%
MEATH	0.0%	0.2%	15.4%	64.1%	77.7%
MONAGHAN	0.0%	0.0%	7.1%	36.9%	68.6%
OFFALY	0.0%	0.0%	10.5%	55.0%	74.8%
ROSCOMMON	0.0%	0.0%	5.6%	44.7%	66.3%
SLIGO	0.0%	8.4%	43.1%	59.7%	60.6%
TIPPERARY	0.0%	0.0%	7.9%	48.5%	72.9%
WATERFORD	0.0%	0.0%	37.8%	64.9%	79.9%
WESTMEATH	0.0%	4.7%	44.2%	62.4%	70.6%
WEXFORD	0.0%	0.0%	42.9%	60.6%	61.7%
WICKLOW	9.1%	27.5%	58.2%	68.2%	80.7%

Results: External Connection

	Modem	Isdn	Dsl	Dsl>2MB	Wireless
Size (3-19)	0.164 *	-0.027	-0.108 **	-0.062 **	-0.028 (*)
	(0.065)	(0.067)	(0.027)	(0.015)	(0.017)
Size (20-49)	0.122 (*)	0.167 *	-0.045 *	-0.031 **	-0.023 *
	(0.068)	(0.068)	(0.018)	(0.007)	(0.011)
Size (50-249)	0.046	0.178 **	-0.018	-0.021 **	-0.011
	(0.064)	(0.066)	(0.020)	(0.006)	(0.012)
Size (250-499)	0.032	0.034	0.009	-0.005	0.029
	(0.074)	(0.074)	(0.027)	(0.009)	(0.026)
Size (500+)	*reference category*				
dlnTurnover	-0.028	0.051 **	0.006	0.007	0.014 *
	(0.018)	(0.019)	(0.010)	(0.006)	(0.006)
Age	-0.001 *	0.000	-0.000	-0.000 *	-0.000
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Multi-plant	-0.022	0.011	0.004	-0.001	0.002
	(0.046)	(0.047)	(0.019)	(0.008)	(0.013)
lnWage per employee	-0.009	0.090 **	0.085 **	0.029 **	0.026 **
	(0.023)	(0.025)	(0.012)	(0.007)	(0.010)
%Managerial/technical	0.000	-0.034	0.077 **	0.029 *	0.025
	(0.065)	(0.070)	(0.026)	(0.014)	(0.022)
%Clerical	0.154 *	0.154 *	0.142 **	0.020	0.056 *
	(0.065)	(0.069)	(0.029)	(0.018)	(0.023)
Export Intensity	0.009	0.445 **	0.017	0.032	0.079 **
	(0.106)	(0.108)	(0.045)	(0.026)	(0.028)
Export Intensity^2	-0.062	-0.335 **	-0.017	-0.013	-0.071 *
	(0.112)	(0.112)	(0.045)	(0.025)	(0.029)
Foreign-owned	-0.058 *	-0.043	0.044 **	0.021 *	-0.010
	(0.028)	(0.030)	(0.015)	(0.009)	(0.007)
Exchange enabled	-0.043	-0.078 *	0.093 **	0.026 **	0.015
	(0.031)	(0.033)	(0.015)	(0.009)	(0.010)
Year dummy variables	yes				
Industry dummy variables	yes				
Obs	6215	6226	5994	5412	5861
Firms	2952	2958	2855	2608	2790
Pseudo R^2	0.06	0.09	0.2	0.24	0.13

Marginal effects results, with standard errors in parentheses. ***, **, * indicate significance at 1%, 5%, 10%, respectively. All explanatory variables are lagged by one year with respect to the dependent variable.

Summary of modelling results

- Proximity to firms that have adopted ICT positively associated with inter- and intra-firm diffusion of ICT
- Larger firms, firms with more skilled employees, firms located in the Dublin area more successful in ICT adoption
- Younger firms quicker in adopting ICT
- Patterns of ICT adoption differ for domestic and foreign-owned firms regarding size and export intensity
- DSL availability indicator has significant effects on choice of connection type

➢ delays and differences in ICT adoption & diffusion

Lessons for policy and further research

- Geographical clustering of firms' ICT adoption rates
- Firm size effects support theories that suggest that larger firms adopt new technologies earlier
- Evidence of interaction between firms' human capital and ICT adoption
- Domestic firms take active decision on ICT adoption, foreign firms implement headquarter decisions
- DSL availability has a significant effect on connection choice; in future, include it in models of business and residential ICT adoption
- Check robustness of clustering and availability effects at more disaggregated Electoral District level