Broadband Connected Employees and Labour Productivity

A Comparative Analysis of 14 European Countries Based on Distributed Microdata Access

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Abstract

In this study the association between ICT intensity in firms and labour productivity is explored across 14 European countries for the years 2001-2010. ICT intensity is approximated by the proportion of broadband internet-enabled employees, a novel indicator measuring not only adoption but also diffusion within and among firms. Data have been retrieved by means of the Distributed Microdata Approach (DMD) from registers on business, trade and education as well as from surveys on production, ICT usage and innovation activities held at the national statistical offices. This pioneering approach allows access to otherwise confidential linked firm-level and micro-aggregated (Micro Moments Database, MMD) information in dimensions not earlier available. Pooled OLS estimations based on approximately 400,000 observations in harmonised and representative datasets show that in a majority of countries there is a significant and positive relationship between the proportion of broadband internet-enabled employees and labour productivity in firms. However, the strength and width of the relationship varies across countries and industries. Manufacturing firms receive 50 per cent larger estimates than the services firms, where the positive association appears more frequently. A lower ICT intensity in firms seems to coincide with a potentially larger link to labour productivity.

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Introduction

Early uncertainties about both measurement and impacts of Information and Communications Technology (ICT) (Solow, 1987) have been fended off by strong evidence that ICT is indeed an enabler of growth. This finding have been made available thanks not least to pioneering statistical and analytical work by the OECD, UNCTAD and the European Commission (Eurostat and EUKLEMS), among others. Now, data on ICT is both vast and multi-facetted, as is the literature. Initial research focussing on the aggregates and investments in hardware (Jorgenson and Stiroh, 1999; Chou et al. 2014) has spread to disaggregated studies on selected groups of firms and different kinds of ICT, in isolation as well as in conjunction with other factors such as skills and organisational structure (Black and Lynch, 2001; Brynjolfsson and Hitt, 2003; Van Reenen et al., 2010, Cardona et al., 2013). In general, ICT is considered to potentially improve the quality of the production factors. The more productive these factors are the greater the return to investments. However, analyses of the association between specific ICT usages such as broadband and productivity are less common, especially at the level of the firm.

In this study the relationship between the level of ICT intensity and labour productivity in firms is investigated based on firm-level data from fourteen European countries. ICT intensity is illustrated by a novel broadband connected employee variable and the data are retrieved by the Distributed Microdata approach (DMD) (Bartelsman 2004; Eurostat 2008). This approach provides not only (micro-aggregated) data in new dimensions created by multiple linking of surveys, but also a way to perform comparative analyses.

The major contribution of this study is twofold: First, the introduction of the new specific quantitative ICT intensity variable: the proportion of internet-enabled employees in firms (BROADpct). This variable is superior to many other commonly used broadband measures because it indicates not only adoption but also the diffusion within and across firms. Second, the study is based on internationally comparable and representative firm-level datasets for 14 European countries.

In a literature review, Holt and Jamison (2009) conclude that there seems to be a positive relationship between broadband deployment and economic growth, although the subject is also surrounded by

methodological difficulties including access to data, implying that precise conclusions about mode and extent of impact are difficult to draw. Czernich et al. (2011) reveal that an increase in broadband penetration raises per capita growth for a panel of OECD countries and Gruber et al. (2014) calculate that a fast development of broadband infrastructures across the European Union would lead to benefits larger than costs. According to Majumdar et al. (2010) there is a relationship between firm productivity and broadband deployment in the US communication technology industries during the years 1995-2000 and Grimes et al (2012) show that broadband is of importance for productivity in a large group of New Zealand firms, although exact speed matters less. On the other hand, Bertschek et al. (2013) and Haller and Lyons (2012) find no clear relationship between firm productivity and broadband penetration in Germany 2001-2003 or in Ireland 2002-2009. These contradictory results emphasise the discussion held by Howell and Grimes (2010), on the level of analyses and the many nuances of broadband: how it is measured, intensity in usage, how it interacts with other important factors such as skills and organisational structure, whether there is a one-off or continuous effect and when in time possible gains appear.

Broadband internet-enabled employees are found by Eurostat (2008, 2012, 2013) to clearly associate with firm productivity in a larger group of European countries, although the general level of ICT intensity seems to affect the strength of the relationship. Bartelsman (2010) illustrates that the same variable also affects productivity at the micro-aggregated (industry-level); even when adoption is taken into account.

The study is organised as follows: In the next section there is a brief description of the methods used. Then the data underlying the analysis is presented, ensued by a discussion of the results. Finally, the paper ends with some concluding remarks.

Method

To investigate the relationship between broadband internet-enabled employees and labour productivity, a Cobb-Douglas production function is used, where firm output *(Y)* is specified as a function of capital (*K*) and labour (*L*). Coefficients (α) and (β) are the output elasticities of each input with a given technology *(A).*

$$Y = f(A, K, L) = AK^{\alpha}L^{\beta} \quad (1)$$

The production function can be transformed into log-linear form for convenience in estimation:

$$lnY_{it} = lnA + \alpha \ln K_{it} + \beta lnL_{it} + \varepsilon_{it} \quad (2)$$

for each firm *i* at time *t* and where ε_{it} is the stochastic error term.

Similar to other firm-level studies (Black and Lynch, 2001, and Brynjolfsson and Hitt, 2003, for instance), ICT is expected to potentially improve the quality of the production factors and to allow larger returns to investments. In addition, broadband may facilitate higher speed in business transactions and streamline the production activities (Haller and Lyon, 2012). By assuming that the broadband internet-enabled employee intensity of firms (*BROADpct*) is the technology parameter, the specification may be augmented as follows:

$$lnVA_{it} = lnA + \alpha lnK_{it} + \beta \ln E_{it} + \gamma_1 lnW_{it} + \gamma_2 BROADpct_{it} + \gamma_3 \boldsymbol{Z_{it}} + \gamma_4 \boldsymbol{D}^{c} + \gamma_5 \boldsymbol{D}^{f} + \varepsilon_{it}$$

where firm output is denoted by value added (*VA*) in constant prices and (*E*) is the number of employees representing labour. The quality of labour (*W*) is approximated by labour costs (pay per employee) in constant prices and (*Z*) represents age and age squared. Information about firm characteristics such as size-class, international experience (*Exporter*) and affiliation (Multinational, *MNC*) are captured by the dummy variable (D^c) while time and industry effects are held fixed (D^f). The production function can be estimated by pooled Ordinary Least Squares (OLS) for each country separately. Note that the fixed effects estimator makes little sense given the rotating design of the ICT usage survey.[6] Not accounting for unobserved firm-level heterogeneity may lead to an overstatement of the impact of ICT variables.

[6] Using fixed effects models reduce the sample size by more than 50 percent.

Data sources and stylised facts

Data for this analysis originate from the ESSLait project national bases and from the Micro Moments Database (MMD).[7] These datasets hold linked and harmonised (in the case of the MMD: micro-aggregated) information on firms sourced from the national statistical offices in 14 European countries. Information is available from registers on business, trade and education as well as from surveys on production, ICT usage and innovation activities for the years 2001-2010. The Distributed Microdata Approach (Bartelsman, 2004; Eurostat, 2008) is employed to build the datasets with descriptive statistics, moments in different dimensions and to perform firm-level analyses. Data is held nationally at the level of the firm. The pooled MMD is deposited at Eurostat Safe Centre and includes data at the NACE rev 1.1 two-digit industry level as well as for the EUKLEMS alternative hierarchy and in several other dimensions such as size class, age class, ICT intensity, innovation activity, ownership, affiliation and international experience.

Value added is defined as gross output minus intermediate purchases of services and goods while capital is based on either the capital stock or on the book value. Wages reflects the labour costs and is calculated as pay per employee. Information on these three variables is sourced from the production statistics. Number of employees, age and NACE rev 1.1 two-digit industry classification originate from the business register. Data on exporters stem from registers on VAT or trade and information about international affiliation is derived from either the production or foreign affiliate statistics. The composite ICT intensity variable *proportion of broadband internet-enabled employee*s builds on information from the survey on ICT usage in firms. The variable includes information both on broadband adoption and on the proportion of employees with internet access. To protect firms from a high form-filling burden, panels rotating over time are favoured for sample surveys such as the ICT usage in enterprises. This causes high attrition in the

[7] See www.cros-portal.eu. The Micro Moments Database includes micro-aggregated firm-level information for Austria, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Sweden, Slovenia and United Kingdom. It is important to note that these datasets may not, due to the merging and harmonisation procedures, fully match official statistics.

linked datasets. Nominal prices (value added, capital and wages) have been deflated by EUKLEMS or WIOD two-digit price indexes.[8]

Table 1. Average firms across countries in 2010

Variable	AT	DE	DK	FI	FR	IE	IT	LU
BROADpct	44	51	32	67	46	44	39	61
LPV € (000)								
mean	53	75	61	57	70	76	47	56
10pctl BROADpct	89	n.a.	76	95	108	198	95	165
Wage € (000)	44	46	49	45	52	37	36	48
Size,ē	44	136	49	49	196	105	42	51
XI (pct)	19	n.a.	35	n.a.	21	186	14	72
Observations*	2685	3277	2834	2586	7398	1438	11547	1742

Variable	NL	NO	PL	SE	SI	UK	Mean
BROADpct	59	66	37	66	50	57	51
LPV € (000)							
mean	77	47	36	60	26	73	58
10pctl BROADpct	185	85	78	113	52	n.a	112
Wage € (000)	43	47	17	54	22	39	41
Size,ē	103	37	75	42	37	444	101
XI (pct)	22	16	33	44	56	10	44
Observations*	4913	3182	9996	2643	1296	2236	57773

Note: LPV means value added-based labour productivity in nominal prices, BROADpct broadband internet-enabled employees, Wages pay per employee in nominal prices, size average firm size in number of employees and XI proportion of exports over total sales in firms. With the UK excluded the average size of firms is 74 employees. For AT, NL and NO only exports of goods are included. Information on BROADpct in AT refers to 2009 as does all information for IT. In column "Mean" number of observations refers to the total coverage in 2010.

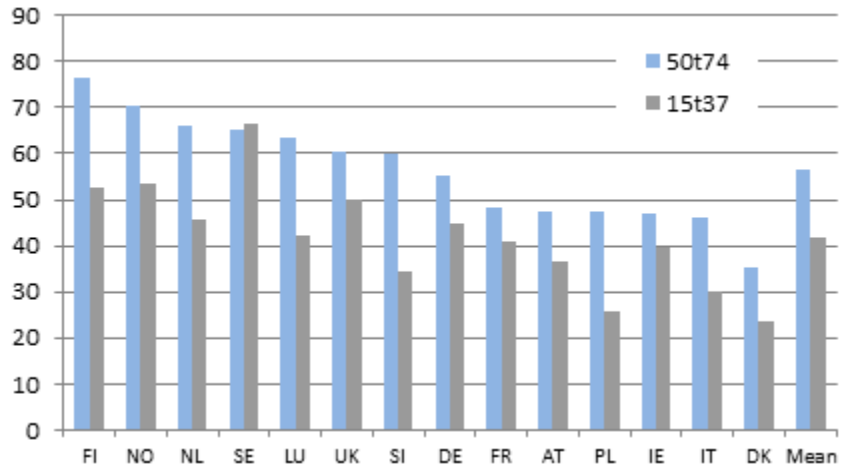
Source: ESSLait Micro Moments Database

There is a certain spread in the ICT intensity across countries, indicating a pattern where firms in northern Europe are the most frequent users (Table 1). Finland, Norway and Sweden are the countries with the highest ICT intensity in firms measured as broadband internet-enabled employees. In all countries except Sweden, where no clear differences between industries can be detected, the intensity of this ICT usage is higher in services than in manufacturing firms (Diagram 1).

[8] See www.euklems.net and www.wiod.org.

Diagram 1: Broadband internet-enabled employees by industry in 2010

Chart 1: Per cent



Note: 15t37 refers to manufacturing firms and 50t74 to services in accordance with NACE rev 1.1 industry classifications. Information for Austria and Italy relates to 2009.
Source: ESSLait Micro Moments Database

A similar pattern across countries as for the broadband internet-enabled employees is found for the level of labour productivity. Firms at the top end of broadband internet-enabled employees exhibit much higher labour productivity than on average. The average value of wages in firms arrives at Euro 41,000 with Sweden and France reaching above 50,000 and PL below 20,000. Norway, Slovenia, Sweden and Italy exhibit the smallest average number of employees in firms and the United Kingdom by far the largest. In small countries firms export more extensively than in larger countries, revealing a higher dependency on international trade. The merged datasets uncover close to 60,000 observations for the single year 2010 and approximately 400,000 observations for the whole unbalanced panel of firms.

Estimation results and discussion

To account for differences in the production technology across industries, the relationship between value added in constant prices and broadband internet-enabled employees is estimated on data for manufacturing and services industries separately. Given that labour (number of employees) is controlled for in the specification,

significant regression estimates of the variables can be interpreted as associations with labour productivity.

Table 2: Relationship between broadband internet-enabled employees and labour productivity in manufacturing firms across Europe

Table 2: Pooled OLS estimations, unbalanced panel of firms 2001-10

A 15t37		BROADpct	lnE	lnW	AGE	AGE2	MNC	EXPOR-TER	Inter-cept	EDF	RSQ
AT	coef	0.016	1.032***	0.945***				-0.112***	0.201	7970	0.94
	't	0.02	0.02	0.02				0.01	0.13		
DK	coef	-0.012	1.025***	1.024***	0.000	0.000	0.009	-0.070***	-0.090	4715	0.93
	't	0.71	53.5	33.2	0.34	0.60	0.62	4.130	0.40		
FI	coef	-0.027*	0.941	0.967***	0.004***	0.000***		-0.092***	0.953***	10839	0.93
	't	1.67	77.07	48.51	5.84	6.52		8.47	8.42		
FR	coef	0.056***	0.985***	1.129***	0.001***	0.000***		-0.038***	-0.175***	18730	0.95
	't	5.39	160.40	110.01	4.17	2.42		5.09	2.82		
IE	coef	0.352***	0.967***	0.742***	-0.004***	0.000***		-0.034**	2.071***	11040	0.84
	't	10.94	58.27	43.23	3.90	5.10		2.24	15.03		
IT	coef	0.113***	0.999***	1.050***	0.002***	0.000***			-0.030	43073	0.91
	't	9.51	127.67	139.33	6.32	5.73			0.48		
LU	coef	0.181***	0.946***	0.928***	0.004*	0.000	0.046	0.045	0.961**	1219	0.89
	't	3.16	19.41	13.98	1.95	0.55	1.02	1.03	2.33		
NL	coef	0.081***	1.039***	0.903***	0.007***	0.000***	0.000	-0.020*	0.257***	12247	0.90
	't	4.92	107.90	68.54	5.47	5.26		1.74	2.74		
NO	coef	-0.009	0.983***	1.094***	0.004***	0.000**		-0.047***	-0.380**	7668	0.93
	't	0.53	62.43	62.03	3.47	2.28		3.50	2.45		
PL	coef	0.507***	1.003***	1.031***	0.004***	0.000***	0.018	-0.135***	0.492***	26056	0.87
	't	23.68	77.14	88.09	3.79	10.79	0.44	13.63	4.61		
SI	coef	-0.146**	0.953***	1.467***	-0.010**	0.000***	0.000	-0.087	-0.836***	1183	0.91
	't	2.094	43.52	24.55	2.06	2.71		1.51	3.48		
SE	coef	0.004	1.000***	1.019***	0.007***	0.000***	-0.039***	-0.057***	0.072	8781	0.95
	't	0.28	86.82	47.48	4.22	2.66	3.13	4.15	0.47		
UK	coef	0.225***	0.993***	1.032***	0.011***	0.000***	-0.076***	-0.040***	0.209*	9100	0.86
	't	9.13	76.28	64.22	4.75	4.86	4.98	2.67	1.86		

Note: The OLS estimations are based on heteroscedasticity consistent standard errors. Log value added (VA) in constant prices is the dependent variable. (E) means number of employees, (W) wages in constant prices, (AGE) firm age, (AGE2) firm age squared, (BROADpct) broadband internet-enabled employees, (EDF) degrees of freedom and (RSQ) R-squared. (MNC) and (Exporter) display lack of international affiliation or experience. Because of inconsistent measurement and uneven coverage across countries the regressions have been run assuming that capital (K) is constant (left out). Results for German manufacturers are withheld due to irate coverage over time. All regressions include dummy variables for size class, time and NACE rev 1.1 2-digit industry. Significance at the 1, 5 and 10 per cent levels are denoted ***, ** and *.

Source: ESSLait Micro Moments Database and own calculations

In a majority of the countries (7 out of 13 in manufacturing and 10 out of 14 in services firms), the OLS estimations show that an increase in the proportion of broadband internet-enabled employees

is significantly and positively related to labour productivity, as illustrated in Tables 2 and 3. The average estimate for the manufacturers is 0.149 and for the services firms 0.107. The strength of the significance differs across industries, ranging from -0.146 (Slovenia) to 0.507 (Poland) for the manufacturers and between 0.028 (Finland) and 0.222 (Germany) for the services firms. This shows that the presumptive gains from increases in broadband internet-enabled employees are larger for manufacturers but occurs more often in services firms across the group of countries studied.

Table 3: Relationship between broadband internet-enabled employees and labour productivity in services firms across Europe

Table 3: Pooled OLS estimations, unbalanced panels of firms 2001-10

A 15t37		BROADpct	lnE	lnW	AGE	AGE2	MNC	EXPOR-TER	Inter-cept	EDF	RSQ
AT	coef	0.073***	0.974***	0.969***				-0.125***	-0.122	11969	0.89
	't	4.40	58.02	70.92				8.91	0.85		
DE	coef	0.222***	0.869***	0.891***				-0.038***	2.064***	10407	0.90
	't	13.28	109.44	90.16				2.70	14.80		
DK	coef	-0.002	0.981***	0.967***	0.003***	0.000***	0.032***	-0.054***	0.203	9017	0.93
	't	0.16	67.73	60.50	4.70	3.93	2.88	5.71	1.32		
FI	coef	0.028***	0.915***	0.981***	0.003***	0.000***		-0.064***	0.499***	15907	0.94
	't	3.01	95.45	85.50	7.60	5.67		6.81	5.15		
FR	coef	0.044***	0.978***	0.991***	0.004***	0.000***		0.012*	0.157***	24838	0.95
	't	5.90	210.30	151.82	12.13	7.58		1.99	3.27		
IE	coef	0.099***	0.983***	1.010***	0.002*	0.000		0.010	0.428***	6091	0.80
	't	3.76	66.38	55.60	1.96	1.54		0.48	2.63		
IT	coef	0.093***	1.001***	1.043***	0.004***	0.000***			-0.115	43443	0.87
	't	12.23	121.58	163.57	7.85	5.78			1.50		
LU	coef	0.081***	1.013***	0.869***	0.015***	0.000***		0.121***	0.254	7048	0.77
	't	3.18	43.76	37.47	8.07	3.91		6.06	0.80		
NL	coef	0.059***	0.987***	0.887***	0.002*	0.000*		-0.035***	0.614***	12299	0.91
	't	4.67	134.45	96.04	1.83	2.17		3.43	7.74		
NO	coef	-0.002	1.019***	0.982***	0.007***	0.000***		-0.064***	-0.183***	20233	0.95
	't	0.25	142.56	154.54	9.61	7.95		8.90	2.70		
PL	coef	0.218***	0.995***	0.615***	0.002	0.000***	-0.154*	-0.087***	1.020***	31644	0.80
	't	14.28	72.49	60.88	1.50	9.70	1.94	7.64	7.16		
SI	coef	0.026	0.969***	1.105***	0.011*	0.000*		-0.069	-0.106	1056	0.89
	't	0.39	36.10	23.15	1.63	1.69		1.58	0.340		
SE	coef	-0.005	0.975***	0.969***	0.010***	0.000***	0.019**	-0.032***	0.254**	15091	0.95
	't	0.48	99.50	88.87	9.55	6.00	2.28	3.96	2.33		
UK	coef	0.154***	0.997***	0.940***	0.005*	0.000*	-0.074***	0.007	0.363***	15294	0.88
	't	9.96	143.43	110.52	1.91	2.14	6.66	0.50	4.63		

Note: The OLS estimations are based on heteroscedasticity consistent standard errors. Log value added (VA) in constant prices is the dependent variable. (E) means number of employees, (W) Wages in constant prices, (AGE) firm age, (AGE2) firm age squared, (BROADpct) broadband internet-enabled employees, (EDF) degrees of freedom and (RSQ) R-squared. (MNC) and (Exporter) display lack of international affiliation or experience. Because of inconsistent measurement and uneven coverage across countries the regressions have been run assuming that capital (K) is constant (left out). All regressions include dummy variables for size class, time and NACE rev 1.1 2-digit industry. Significance at the 1, 5 and 10 per cent levels are denoted ***, ** and *.

Source: ESSLait Micro Moments Database and own calculations

The appearance of significant and negative relationships of non-negligible sizes in manufacturing might, together with the sometimes larger estimates, indicate that manufacturers are more sensitive to the "right" ICT inputs than services firms. In a smaller group of countries (Denmark, Norway, Sweden and Slovenia, partly), no clear relationship between firm productivity and broadband employees is found. These countries are either on the higher end of ICT-intensity in firms, like Sweden and Norway or less intensive users such as Slovenia and Denmark, indicating that there might be both a critical level before the firm experiences a significant relationship between the proportion of broadband internet-enabled employees and labour productivity and an upper limit when the association subsides.

As expected of the control variables, increases in employment and changes in skills (wages) are significantly positively related to productivity. This holds true for age in firms across countries too, with an indication of a non-linear relationship. Being internationally experienced or affiliated also relates positively to productivity in a majority of cases. R-squared is close to or above 90 per cent on average in most countries, indicating a good fit of the model.

The results are well in line with certain findings (Majundar et al. 2010; Grimes et al. 2012), but contradict others. Haller and Lyon (2012) and Bertschek et al. (2013) find no association between firm productivity and broadband usage in Ireland or Germany. The disparate results uncover that i) the time dimension may be of importance, the study of Germany relates to early years of broadband usage and ii) the choice or definition of the broadband variables may be crucial. Supposedly, a firm level intensity variable (in this case the BROADpct) is more informative and durable over time than a mere binary one, giving information only about whether broadband exists and of what kind.

Several robustness controls have been performed. Due to irate coverage and measurement, capital has been treated as a constant (and left out of the regressions). This could possibly lead to an overestimation of the BROADpct variable. However, unreported results from total factor productivity regressions for a sub-group of countries show that this is necessarily not the case. Instead the estimates are sometimes even larger in magnitude.

It could be argued that a bundle of ICT usage variables rather than a single one should be used to illustrate the technology link to firm productivity. Because of this, several additional ICT usage variables have been tried, such as whether the firm engages in e-commerce or have mobile connections. Unreported results reveal that this does not affect the significance or magnitude of the BROADpct variable and that the additional ICT variables most often show no significant associations with labour productivity.

Further, as commonly suggested (Black and Lynch, 2001; Brynjolfsson and Hitt, 2003; Van Reenen et al., 2010, Cardona et al., 2013), ICT may not reach its full potential unless it is well-embedded. On account of this the indirect association between broadband internet-enabled employees and productivity is investigated by an interaction with skills. Unreported results show that the BROADpct in most cases remains significant and positive. Typically, there are also signs of complementarity. In some cases the original strength of the variable is drained and instead a clear indirect association appears. Estimates for firms in Denmark, Norway and Sweden, where no links between broadband internet-enabled employees and labour productivity could be established, turn significant and positive by the interaction.

Detailed information on educational achievement is seldom available for a merge with production statistics at the level of the firm. Because of this wages has been used as a proxy. Nevertheless, for a sub-group of eight countries, information on formal educational achievement of employees is available. By using an otherwise identical specification, but with wages substituted for the proportion of employees with post upper secondary education (ISCED 5+), there is still a clear and positively significant association between broadband internet-enabled employees and labour productivity in firms, as is reported in Table I, Appendix A. Further, these links are more frequently significant and the magnitude is larger than in the specification with wages.

According to literature, ICT or broadband do impact labour productivity. However, given the nature of the merged datasets used here, panel data methods that clearly establish causality cannot be used. This is due to the fact that sample surveys, such as the ICT usage in enterprises, are characterised by a high degree of attrition in order to ease the response burden of firms (see for instance Iancu et al. 2013). What is available though is the Micro Moments Database, where the relationship between broadband internet-enabled employees and labour productivity can be explored by the use of proper panel data methods at the level of industry or group of firms. Preliminary results, available upon request, show that BROADpct does indeed impact output for groups of firms.

Concluding remarks

This study provides first estimates of the relationship between broadband internet-enabled employees and labour productivity using linked and internationally comparable firm-level data from 14 European countries for the years 2001-2010. OLS results reveal that there is indeed a positive and significant relationship between these employees and labour productivity in most of the countries investigated. The association is more widespread in services firms with an average significant estimate of 0.107 as compared with the larger magnitude of 0.149 in manufacturing. Firms in countries already intensive in broadband internet-enabled employees exhibit to a lesser extent a link to labour productivity. The results partly coincide with earlier research and partly contradict them. In the case of contradictions the time dimension (early year of broadband usage) and specifics of the broadband variable itself is expected to play a role (quantitative variable here compared with more commonly used binary ones). The proportion of broadband internet-enabled employees has the advantage of not only indicating adoption but also the dissemination within and across firms. Further, the dissemination might as well reveal something about the level of (informal) ICT skills in firms.

Data have been retrieved by means of the Distributed Microdata Approach from registers on business, trade and education as well as from surveys on production, ICT usage and innovation activities, held at the national statistical offices. This pioneering work allows access to otherwise confidential linked firm-level and micro-aggregated (Micro Moments Database, MMD) information in

dimensions not earlier available. However, this approach still needs some fine-tuning. Analyses cannot be made more advanced than each dataset, local operator and IT system holds for. The providers of data may also put a restriction on how many times they accept to re-run analytical codes.

Unfortunately, distributed access does not automatically solve difficult data issues. Among these is the design of sample surveys at statistical offices. Generally, these surveys aim at producing accurate macro statistics without imposing too high a response burden on firms. This leads to small overlaps across surveys and within surveys over time. The latter is particularly difficult to deal with in impact analysis where more sophisticated econometric methods are needed to provide precise estimates and establish causality. Due to this, the results reported here should be interpreted as associations rather than causal effects.

An increased coordination of sample surveys could facilitate the use of panel data models. Alternatively, another avenue for imminent research is to move the analysis to a level (industry) where panels without attrition are available. Future studies might also benefit from more in-depth analyses of how different ICT tools in firms complement or substitute each other or other factors of production.

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Appendix A

Table I. Regressions estimates for BROADpct with alternative human capital variable

	Manufacturing firms 15t37		Services firms 50t74	
Country	Specification HK	Specification W	Specification HK	Specification W
DK	0.031 *	-0.012	0.035 ***	-0.002
FI	0.078 ***	-0.027 *	0.124 ***	0.028 ***
FR	0.200 ***	0.056 ***	0.231 ***	0.044 ***
NL	0.220 ***	0.081 ***	0.174 ***	0.059 ***
NO	0.190 ***	-0.009	0.181 ***	-0.002
SE	0.116 ***	0.004	0.120 ***	-0.005
SI	0.447 ***	-0.146 **	0.325 ***	0.026
UK	0.653 ***	0.225 ***	0.699 ***	0.154 ***

Note: BROADpct means proportion of broadband internet-enabled employees. Identical regressions (as in Tables 2 and 3) have been run except for the human capital variable which in one case is HKpct, degree of employees with post upper secondary education and in the other case W (wages, pay per employee).Capital (K) has been treated as a constant. All regressions include dummy variables for size class, time and 2-digit industry. Significance at the 1, 5 and 10 per cent levels are denoted ***, ** and *.

Source: ESSLait Micro Moments Database and own calculations

Specification Human capital (HK):

$$lnVA_{it} = lnA + \alpha lnK_{it} + \beta \ln E_{it} + \gamma_1 lnHK_{it} + \gamma_2 BROADpct_{it} + \gamma_3 \boldsymbol{Z_{it}} + \gamma_4 \boldsymbol{D}^c + \gamma_5 \boldsymbol{D}^f + \varepsilon_{it}$$

Specification Wages (W):

$$lnVA_{it} = lnA + \alpha lnK_{it} + \beta \ln E_{it} + \gamma_1 lnW_{it} + \gamma_2 BROADpct_{it} + \gamma_3 \boldsymbol{Z_{it}} + \gamma_4 \boldsymbol{D}^c + \gamma_5 \boldsymbol{D}^f + \varepsilon_{it}$$