Human Capital, Information Technology and Productivity

or

The role played by IT intensive human capital in firm productivity

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1. Summary

In this paper the effect on firm productivity from the information technology intensive human capital is investigated for a sample of three Nordic countries (Finland, Norway and Sweden). The results show that skilled human capital measured as the firm proportion of employees with post upper secondary formal education affects productivity both directly and to a certain degree indirectly. For the labour productivity the type of human capital seems to be of greater weight, in this case with stronger effects from IT intensive human capital than for the total factor productivity where general high skills are almost more or equally important. Services firms do generally have more to gain from improvements in the level than manufacturers and the magnitude of the gains are also larger than from the degree of IT usage in the firms. When using wages as an alternative proxy for human capital, the picture gets complicated since these estimates do not coincide fully with the real human capital either in significance, size or direction.

2. Introduction

When studying the effects on firm productivity from information technology (IT) the subject can be approached from at least two angles. The one angle considers the intensity of IT in the factor inputs of the firm production, the other the dissemination and the ability to use the technology.

In a production function approach, including the inputs capital, labour and intermediates each could be considered to have certain IT intensity through the share of IT capital, proportion of IT intensive higher educated employees and the kind of intermediate goods or services used. Even though information on IT capital and details on intermediates are scarce, the productivity effects from the former have been investigated to some extent, but analyses on the effects on productivity from investments in IT human capital are rare, partly due to a lack of data in many countries.

The purpose of this paper is to shed additional light on the effects on productivity from the quality and type of the human capital input to the firm production for a selection of countries and industries. The effects will be investigated both on their own and together with the firm IT usage on the matched production survey datasets in Finland, Norway and Sweden. Firstly some literature references will be briefly described together with the expected firm behaviour. Thereafter follow the results from the regressions run on the national firm level datasets. These results will be presented for different productivity measures and datasets. Finally there is a comparison between the use of real human capital and the wage bill as proxy in the regressions, followed by some concluding remarks.

3. Literature

Draca et al (2006) have summed up a wide range of literature on productivity effects from information technology and find out that the Solow paradox no longer holds, if it ever did. They found evidence of an important role for IT in accounting productivity both from growth accounting and econometrics. They also discuss the investments in organisations as something that needs to be further investigated, just like Abramovsky and Griffith (2005) touch upon the issue of the slower or lower uptake of IT in Europe compared with the United States. These differences may be referred to fewer investments in the organisational changes needed to allow the IT investments full blown effects. Crespi et al (2007) find evidence of an interaction between organisational changes and IT in their effects on productivity.

Doms et al (1997) conclude that plants using a considerable amount of new technology employ more educated workers and pay higher wages. Those firms high in capital seem to pay high wages both before and after adopting new technologies, as well as being high productivity plants. Galindo-Rueda and Haskel (2005) find evidence that firms high in college educated staff tend to be more productive and according to Ilmakunnas and Maliranta (2005) non-technical higher education affected productivity positively, and stronger than technical ones in Finland during the period 1988 to 1998. Rao et al (2002) show that the firm share of university graduates in particular boosts Canadian productivity. According to Bartel et al (2007) there is not only a relationship between IT and productivity but IT also leads to a change in the skills demand of the firm.

Gunnarsson et al (2001, 2004) show that an upgrade in the skills level with given IT affected productivity more than an upgrade in IT with given level of skills in Sweden during the period 1986-1995. They also found that human capital is complementary to IT capital; when IT was included in the regressions the direct effects on productivity were substituted by indirect ones over human capital. Acemoglu (1998) reasons that technological change in general and IT technology in particular complements rather than substitutes skills. This would also be boosted by a high proportion of skilled workers in the labour force. Romer (1996) concludes that not only higher education in itself but the right type of education is important for productivity. Similar conclusions are drawn by Iranzo et al (2006), who find that skills are positively related to productivity in the Italian traditional manufacturing industry. However, this is only true if the firms use the right mix of human capital. In this sense the skills are both complements and substitutes.

4. Expectations

The literature presented tells that there is a relationship between the quality of the human capital (skills) and productivity. There is also a link between IT and productivity. IT can affect productivity either directly or through the human capital. If assumed that these relationships hold, human capital is expected to affect productivity at least to some extent. However this does not necessarily encompass all types of higher skills.

Another series of literature found links between the IT effects on productivity over the organisational changes. This gives further fuel to the importance not only of human capital, but of the right type of human capital for the organisation and productivity. There also seems to be a link between the firm investments in human capital on the one hand and wages and productivity on the other. This means that firms high in IT investments or IT use are also likely to be high in skilled human capital, although the causality is not completely clear.

5. Descriptive data

The data used in this analysis originate from the cross-country dataset built up within the frame of the *Eurostat ICT impacts project*.[1] This dataset in turn mainly consists of aggregated data from the production surveys, the EU-harmonised firm ICT usage surveys and to some extent the education registers. In countries other than the Nordic ones, these types of education data are either not matched at all to the production surveys or are not available at the firm level. When data on human capital are not available the wage bill is often used as a proxy. Wages as a variable is a much more encompassing measure than real human capital and does not only include education but also industry, experience, bargaining strength, firm compensation policies et cetera. Educational attainment on the other hand is strictly formally based and less influenced by the production values.

Table 1: Employees with access to PCs or fast broadband connections at work

2005		Finland	Norway	Sweden
		%	%	%
Proportion of employees with PC access	All firms	70	60	66
	Services	76	68	73
	Manufacturing	56	51	60
Proportion of employees with fast broadband access	All firms	62	54	55
	Services	66	62	64
	Manufacturing	43	46	43

Source: Statistics Finland, Statistics Norway and Statistics Sweden

Finland is the country with the highest proportion of employees with access to a PC or to fast Internet connections at work. Norway is lagging behind somewhat and Sweden has the highest

[1] Eurostat Grant 49102.2005.017-2006.128

share of manufacturers with PC access. In general, the services firms have a stronger use of these IT tools in all countries.

In this study IT intensive human capital (or skills) is equalised with post upper secondary education in mathematics, physics or information technology. The proportion of employees with this education differs among the countries studied, and seems to be lowest for Sweden. That can partly be explained by the propensity of the public sector to attract large numbers of university graduates. Moreover the intensively IT skilled employees are far smaller groups in both Finland and Sweden but not in Norway.

While there is a difference among industries, those firms intensive in skills, IT or general, on average and independently of country do have more employees with access at work to computers or fast broadband. These same firms are also most often high in capital, wages and productivity, just like the findings by Doms et al (1997) and Galindo-Rueda and Haskel (2005). However, the causality of the links is still unclear.

Table 2: Average proportion of employees with post upper secondary education in 2005

2005		Finland*	Norway	Sweden
		%	%	%
Proportion of employees with IT intensive post upper secondary education	All firms	10	17	4
	Services	11	19	5
	Manufacturing	11	15	4
Proportion of employees with general post upper secondary education	All firms	17	6	11
	Services	22	7	11
	Manufacturing	10	4	10

*Education data for Finland are available up to the year of 2004.
Sources: Statistics Finland, Statistics Norway and Statistics Sweden

Despite many similarities, the industry structure in the countries investigated also show some differences. Norway is heavy on oil production while Sweden and Finland both have their shares of activities in traditional manufacturing as well as in the high technology communication industry. This may explain the somewhat lower IT use in Norwegian firms.

Table 3: Number of firms in production survey and matched dataset

Datasets	FIN	SWE	NOR
Exhaustive	**59635**	**776737**	**38491**
15t37	15832	101646	8718
50t74	31716	478297	23949
Matched	**7746**	**11398**	**663**
15t37	3395	4091	190
50t74	3831	5805	419

Source: Statistics Finland, Statistics Norway and Statistics Sweden

In all countries there are far more services than manufacturing firms. Included in the total are also the financial firms although these will not be reported separately due to their slight share of the matched dataset. This latter dataset does not represent the firms in numbers, but otherwise fully at the aggregated level. However, it is important to bear in mind that the matched dataset is biased towards larger firms.

6. IT intensive human capital and productivity

For the three countries some ordinary least square production function regressions in the natural logarithm (ln) have been set. The purpose more in detail is to shed some further light on the link between productivity and IT intensive human capital by studying the effect on firm productivity from a change in the proportion of highly IT skilled employees. Another line is to illustrate whether there is a link between IT usage and improvements of the skills level in the firm.

Several measures of productivity can be calculated, both single and multifactor ones. Pointing out what is most relevant for the impacts regression including real human capital is not uncomplicated. Earlier studies by for instance Hagsten et al (2007) on Swedish industry subsets reported that there are no major differences between using value added and gross production, but Bartelsman and Doms (2000) favour the gross values on the basis that the shift in the use of intermediate inputs relative to capital and labour over time may otherwise create bias in the productivity measure. This is also emphasised by Bailey (1986). Despite this, the attention here is focussed on the value added based productivity metrics. The decision to do so is more practical than theoretical and follows from the fact that intermediate inputs are available only in the form of goods, leaving out the services inputs which could easily be IT intensive.

The Ordinary Least Squares regressions are performed on the unbalanced pooled panels of firms including the years 2001 to 2005 (for Finland skills data are only available up to the year of 2004). Beginning with the two skills variables (Hkitpct) and (Hknitpct), meaning the share of employees with IT intensive and general (non IT intensive) human capital in the form of post upper secondary education, the effects on productivity can be observed as well as whether the addition of new variables and changes of the datasets affect single estimates. Included are also dummies controlling for fluctuations in productivity over time, differences among firms, size and affiliation as well as an outlier control, cutting off the 1.5 per cent highest and lowest values of each dataset. The latter measure is undertaken in order to avoid the regressions getting disturbed by extreme values. Labour productivity (Lpv) is calculated as value added per person and total factor productivity (TFP) also includes capital in the denominator. The proportion of employees with access to fast broadband (DSLpct) and the firm share of E-commerce (ECpct), which is the sum of the firm shares of buying and selling over the Internet, are the two IT variables meant to capture different phases of IT maturity from the user side.

Table 4: Effects on firm labour productivity from IT intensive human capital
Ordinary Least Squares estimations on pooled and unbalanced panels of firms 2001-2005

LnLpv	FIN* 1	2	3	SWE 1	2	3	NOR 1	3
Hkitpct	0.767	0.734	0.766	0.127	0.129	0.262	0.454	0.749
	(0.014)***	(0.014)***	(0.039)***	(0.006)***	(0.006)***	(0.045)***	(0.001)***	(0.137)***
Hknitpct	0.596	0.581	0.610	0.118	0.117	0.217	0.111	0.190
	(0.011)***	(0.011)***	(0.038)***	(0.004)***	(0.004)***	(0.036)***	(0.021)***	(0.238)
Age		0.004	0.002		0.052	0.020		
		(0.000)***	(0.001)*		(0.001)***	(0.003)***		
Age2		0.000	0.000		-0.002	-0.001		
		(0.000)***	(0.000)		(0.000)***	(0.000)***		
DSLpct			0.085			0.194		0.255
			(0.018)***			(0.014)***		(0.064)***
ECpct			0.012			-0.001		-0.080
			(0.023)			(0.000)		(0.067)
R-squared	0.21	0.22	0.27	0.14	0.16	0.28	0.27	0.43
Observations	59635	59617	7746	776737	775778	11398	38491	663

*Skills data for Finland are available up to the year 2004.
Robust standard errors are shown within brackets with ***, ** and * meaning significant at the one, five and ten per cent level.
Unreported time, industry, size and affiliation dummies are used to control for firm specifics and changes over time.
Sources: Statistics Finland, Statistics Sweden and Statistics Norway

All three countries receive labour productivity (Lpv) bonuses from an increase in the firm share of IT intensive human capital. The Finnish coefficient estimates are clearly higher than those for Norway and Sweden, coming close to an elasticity of one and are stable over the different datasets, implying than Finnish firms gain the most in productivity with Norwegian ones coming close but leaving Swedish ones far behind. When adding further variables like firm age (Age) and age squared (Age2), the latter controlling for non-linearity, the Swedish and Finnish estimates are kept almost untouched, that is, significant and positive with stronger effects from IT intensive than from high general human capital. The final matching of the E-commerce survey to the production data set, presented in column 3, leaves the major part of firms behind and also affects the estimates for Sweden and Norway in particular. In Sweden the effects on labour productivity from

all kinds of higher education become stronger while IT intensive human capital is still the most important one. However, Norwegian labour productivity is not affected at all by improvements in higher general human capital in the smaller sample of firms, while the effects from IT intensive human capital improve strongly.

Firms in all three countries were positively affected in labour productivity by an improvement in the share of employees with access to fast broadband. The most visible effect appears in Norway and the weakest in Finland, although these effects are smaller than those from the improved skills level of the employees. This follows quite logically from Finland being the country with the highest access rates to PCs and fast broadband at work and therefore may already have depleted possible productivity gains, while Norway, lagging behind somewhat, still has bonuses to pick up. Buying and selling over the Internet was found to be of no importance at all for firm labour productivity in the group of countries.

Table 5: Effects on firm total factor productivity from IT intensive human capital
Ordinary Least Squares estimations on pooled and unbalanced panels of firms 2001-2005

LnTfp	FIN* 1	2	3	SWE...1	2	3	NOR...1	3
Lnkl	-0.386	-0.387	-0.378	-0.169	-0.169	-0.221	-0.280	-0.260
	(0.003)***	(0.003)***	(0.008)***	(0.001)***	(0.001)***	(0.004)***	(0.002)***	(0.013)***
Hkitpct	1.095	1.081	1.034	0.279	0.282	0.253	0.535	0.881
	(0.028)***	(0.028)***	(0.089)***	(0.007)***	(0.007)***	(0.056)***	(0.014)***	(0.140)***
Hknitpct	1.110	1.107	1.027	0.234	0.231	0.289	0.194	0.334
	(0.023)***	(0.023)***	(0.087)***	(0.005)***	(0.005)***	(0.045)***	(0.021)***	(0.244)
Age		-0.002	-0.005		0.059	0.022		
		(0.001)**	(0.002)*		(0.001)***	(0.004)***		
Age2		0.000	0.000		-0.003	-0.001		
		(0.000)***	(0.000)**		(0.000)***	(0.000)***		
DSLpct			0.238			0.316		0.249
			(0.041)***			(0.018)***		(0.066)***
ECpct			-0.060			0.001		0.034
			(0.052)			(0.001)*		(0.069)
R-squared	0.63	0.63	0.58	0.61	0.61	0.77	0.68	0.61
Observations	59634	59616	7745	776675	775716	11397	38490	662

*Skills data for Finland are available up to the year 2004.
Robust standard errors are shown within brackets with ***, ** and * meaning significant at the one, five and ten per cent level.
Unreported time, industry, size and affiliation dummies are used to control for firm specifics and changes over time.
Sources: Statistics Finland, Statistics Sweden and Statistics Norway

While on the aggregate level both IT intensive and general higher human capital are of importance for labour productivity, a closer look reveals that this is only true to a certain degree. When focussing instead on manufacturing and services firms, it becomes obvious that the adaptation of the model is poorer for the manufacturers since for those there are fewer significant estimates and the determination coefficients are very low, meaning that several factors affecting firm productivity are left unexplained (results reported in Appendix 1). Both Swedish and Finnish manufacturing firms now show results similar to those for overall Norway, meaning that no relationship between productivity and higher general skills could be traced, meanwhile the effects from IT intensive human capital are somewhat higher than for firms in general. The matched datasets, where the intensity in the firm IT usage is taken into account, do not show signs of any effects on productivity from buying and selling over the Internet. However, the firm proportion of employees with high speed access to the Internet affects productivity in most cases, but less pronounced than the intensive human capital and somewhat more for services firms.

The regressions with total factor productivity as the dependent variable give far higher R-squared values indicating that the variables included explain this productivity better than the labour productivity. All significant human capital estimates now become stronger than in the labour productivity regressions. The patterns also differ, giving less importance to type of capital, except for Norway, where a relationship between improvements in high general human capital and TFP,

just like for the labour productivity, does not exist in the matched dataset. Fast Internet access is slightly more important for total factor than for labour productivity. Changes in the pattern are not surprising since TFP is a much more complex measure capturing also spill over effects from human capital as well as many other things. If the total factor productivity could be considered to reflect even the organisational uptake of IT, discussed by Draca et al (2006) and Abramovsky and Griffith (2005), the estimates here indicate that the Finnish adoption of IT may be on another level than in Sweden and Norway.

Separate regressions by type of industry (results presented in Appendix 1) confirm that the effects are stronger on total factor productivity than on labour productivity, if there is a match that is. Although significant, the manufacturers gain less in productivity from IT intensive human capital than the services firms. While Norwegian groups of firms often seem to lack the link between productivity and high general skills, both Finland and Sweden show similar patterns where the effects from both high IT and high non IT human capital leave stronger marks on total factor productivity, stronger than for firms in general and particularly so for the services firms. Nevertheless, the exception to the rule appears in the form of Finnish manufacturers, who visibly gained from improvements of IT intensive human capital in the exhaustive data set but were not affected in the matched one. This partly coincides with earlier findings by Ilmakunnas and Maliranta (2005). An additional oddity appears among the Swedish manufacturing firms that are negatively affected by an increase in the level of IT skilled employees.

While the effects on labour productivity from high speed broadband connected employees were far stronger for the services firms than for the manufacturers, the opposite seems to be true for the total factor productivity. These effects are also in general larger, almost as strong as the effects from the improvements in the level of skilled human capital. This stresses the importance of the right mix of skills and technology in manufacturing. The buying and selling over the Internet led to losses in total factor productivity for the Finish manufacturing firms. Otherwise the overall lack of significant estimates for this variable may indicate that firms are not yet ready for these kind of activities (or the variable does not correctly capture the sought after activities).

Table 6: Interaction between skilled human capital and IT use
Ordinary Least Squares estimations on pooled and unbalanced panels of firms 2001-2005

Equation 4	LnLpv			LnTfp		
Variable	**FIN***	**SWE**	**NOR**	**FIN***	**SWE**	**NOR**
Lnkl				-0.383	-0.219	-0.249
				(0.008)***	(0.004)***	(0.005)***
Hkpct	0.712	0.116	0.932	1.129	-0.010	0.905
	(0.050)***	(0.052)*	(0.086)***	(0.109)***	(0.065)	(0.090)***
Age	0.002	0.020		-0.004	0.023	
	(0.001)	(0.003)***		(0.002)*	(0.004)***	
Age2	0.000	-0.001		0.000	-0.001	
	(0.000)	(0.000)***		(0.000)**	(0.000)***	
Dslpct	0.099	0.175	0.171	0.308	0.277	0.126
	(0.026)***	(0.016)***	(0.028)***	(0.056)***	(0.019)***	(0.030)***
Hkdsl	-0.047	0.196	-0.138	-0.188	0.449	0.047
	(0.064)	(0.068)**	(0.100)	(0.140)	(0.085)***	(0.105)
R-squared	0.26	0.27	0.37	0.60	0.76	0.63
Observations	8791	11685	5139	8790	11684	5138

*Skills data for Finland are available up to the year 2004.
Robust standard errors are shown within brackets with ***, ** and * meaning significant at the one, five and ten per cent level.
Unreported time, industry, size and affiliation dummies are used to control for firm specifics and changes over time.
Sources: Statistics Finland, Statistics Sweden and Statistics Norway

In order to study if IT is more effective on its own or whether it works through the human capital in its effect on productivity, an interaction variable has been created. This variable (Hkdsl) is based on the firm share of employees with post upper secondary education multiplied with the firm share of employees with access to fast broadband. On average only the Swedish firms received

significant estimates for this variable, indicating that this complementarity or indirect effect is overrun by a direct effect on productivity both in Finland and Norway. The results also show that the effect is stronger on the total factor productivity and adding this variable weakens, or drains the direct effect on Swedish productivity from human capital. This mirrors the findings by Gunnarsson et al (2001, 2004) on the complementarity between human capital and IT investments. The broadband variable only suffers marginally from the operation. However, noticeable is the fact that the effect mainly originates from the services firms (and the financial firms that are not reported here). In Finland a significant estimate can be found for the manufacturing firms, but unfortunately one that indicates a productivity drawback if human capital and IT usage are interacted.

7. Alternative approximation of human capital

As commented on earlier, education data for creating human capital variables may be hard to find. This often leaves no other alternatives than using wages in some form as a proxy. However, when comparing wages (Lnw) with real human capital it becomes clear that these two variables differ in estimates in a non-systematic way, so unfortunately there is no quick fix available to control for differences in level or direction.

Table 7A: Comparison of regression estimates for skilled human capital in exhaustive dataset

	LnLpv			LnTfp		
Equation 1	**Lnw**	**Hkitpct**	**Hknitpct**	**Lnw**	**Hkitpct**	**Hknitpct**
FIN	0.172	0.767	0.596	0.175	1.095	1.110
	(0.001)***	(0.014)***	(0.011)***	(0.002)***	(0.028)***	(0.023)***
NOR	0.682	0.454	0.111	0.706	0.535	0.194
	(0.004)***	(0.001)***	(0.021)***	(0.005)***	(0.014)***	(0.021)***
SWE	0.626	0.127	0.118	0.649	0.279	0.234
	(0.001)***	(0.006)***	(0.004)***	(0.001)***	(0.007)***	(0.005)***

Sources: Statistics Finland, Statistics Norway and Statistics Sweden

Norwegian firms, which did not meet a link between general higher skills and productivity, can with the wages variable be considered to have a clear and reasonably strong positive effect on both labour and total factor productivity from skilled human capital. The estimates are even somewhat stronger than for the real human capital. In the case of Sweden the wages variable shows that this version of human capital affects productivity to a far higher degree than the ones based on formal education. The Finish results are partly contradictory both to Sweden and Norway and allow only a much smaller effect on productivity from wages in the exhaustive dataset. Meanwhile the pattern for the matched dataset is the same as for Norway and Sweden, with larger estimates for wages. However, it also seems that the difference in estimates between the labour and total factor productivity tends to be less with the wages variable than with the real human capital.

Table 7B: Comparison of regression estimates for skilled human capital in matched dataset

	LnLpv			LnTfp		
Equation 3	**Lnw**	**Hkitpct**	**Hknitpct**	**Lnw**	**Hkitpct**	**Hknitpct**
FIN	0.943	0.766	0.610	0.923	1.034	1.027
	(0.015)***	(0.039)***	(0.038)***	(0.039)***	(0.089)***	(0.087)***
NOR	0.965	0.749	0.190	1.019	0.881	0.334
	(0.084)***	(0.137)***	(0.238)	(0.104)***	(0.140)***	(0.244)
SWE	1.000	0.262	0.217	1.043	0.253	0.289
	(0.014)***	(0.045)***	(0.036)***	(0.019)***	(0.056)***	(0.045)***

Sources: Statistics Finland, Statistics Norway and Statistics Sweden

When taking a look at the results from the interaction regressions there are some further changes in the significances. While the Swedish firm IT usage seemed to operate through the real human capital in its effects on labour productivity, this is not the case for the proxy wages when interacted with the broadband variable (Lnwdsl). Nevertheless, there is a positive effect on total factor productivity, but a far smaller one than with the real human capital. Moreover, both Finnish and Norwegian firms are now affected indirectly by the IT usage working through the human capital (or the other way around) in its effects on labour productivity. However, contrary to the Swedish results these effects reduce firm productivity.

Table 7C: Comparison of regression estimates for skilled human capital in matched dataset with interacted variables

	LnLpv				LnTfp			
Equation 4	**Lnw**	**Hk**	**Lnwdsl**	**Hkdls**	**Lnw**	**Hk**	**Lnwdsl**	**Hkdls**
FIN	0.983	0.712	-0.083	-0.047	0.917	1.129	-0.010	-0.188
	(0.023)***	(0.050)***	(0.032)**	(0.064)	(0.055)***	(0.109)***	(0.075)	(0.140)
NOR	1.054	0.932	-0.067	-0.138	0.929	0.905	0.021	0.047
	(0.023)***	(0.086)***	(0.030)**	(0.100)	(0.027)***	(0.090)***	(0.035)	(0.105)
SWE	0.998	0.116	0.008	0.196	0.983	-0.010	0.126	0.449
	(0.021)***	(0.052)*	(0.030)	(0.068)**	(0.028)***	(0.065)	(0.041)***	(0.085)***

Sources: Statistics Finland, Statistics Norway and Statistics Sweden

When investigating certain groups of industries, the wages estimate continues to deviate from the real human capital ones, emphasising the delicacy in using and interpreting human capital variables.

8. Conclusions

Being a Nordic country means having quite many things in common. This seems to also encompass the industry sphere and the effects on firm productivity from investments in IT human capital and IT usage. There are clear productivity bonuses to be found from IT intensive human capital in the firms of all three countries. With few exceptions, the effects on productivity differ more among industries than among the countries explored. Although the causality is not known, firms with many highly educated employees also tend to have high capital, high wages and a high proportion of employees with access to PCs and fast Internet connections. As expected, higher skills affect productivity both directly and to a certain degree indirectly. The effects are generally stronger than for the firm IT usage. For the labour productivity the type of human capital seems to be of greater importance, in this case with heavier effects from IT intensive human capital than for the total factor productivity where general high skills are almost more or equally important.

Finland is the country where the firms receive the largest direct effects on productivity, something that could indicate another level of IT adoption in the organisation than in Sweden and Norway. It could as well reflect the differences in industry structure. The services firms do generally have more to gain from improvements in human capital than the manufacturers. The latter also seem to be captured less well in the models leaving changes in productivity still unexplained to a less than negligible extent. However, this should not necessarily be interpreted as the manufacturing firms are lagging behind in technology; it could just as well mean that they use another type of IT that is not captured by the variables used here. Instead of the degree of employees connected to the Internet via high speed broadband, another variable may be needed to capture their degree of IT maturity.

The use of wages as a proxy for human capital has its obvious limitations from several perspectives. Compared with the human capital variable based on formal education no systematic spread between the two variables could be found, making it very difficult to decide on and interpret results from human capital variables in general. A broader access to matchable education data may ease some of this dilemma.

9. References

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Appendix 1. Productivity effects from IT intensive human capital in manufacturing and services firms

Table A. Effects on firm labour productivity from IT intensive human capital
Ordinary Least Squares estimations on pooled and unbalanced panels of firms 2001-2005

	Manufacturing firms 15t37						Services firms 50t74					
LnLpv	**FIN* 1**	**3**	**SWE 1**	**3**	**NOR 1**	**3**	**FIN 1**	**3**	**SWE 1**	**3**	**NOR 1**	**3**
Hkitpct	0.617	0.896	0.060	0.219	0.547	1.322	0.827	0.730	0.149	0.291	0.491	0.585
	(0.035)***	(0.082)***	(0.021)***	(0.106)*	(0.038)***	(0.312)***	(0.016)***	(0.049)***	(0.007)***	(0.054)***	(0.017)***	(0.166)***
Hknitpct	0.198	0.043	0.026	0.070	-0.179	-0.359	0.712	0.653	0.123	0.282	0.169	0.286
	(0.037)***	(0.095)	(0.013)*	(0.064)	(0.061)***	(0.379)	(0.013)***	(0.045)***	(0.005)***	(0.046)***	(0.025)***	(0.317)
DSLpct		0.016		0.067		0.235		0.110		0.211		0.299
		(0.033)		(0.026)**		(0.120)*		(0.024)***		(0.018)***		(0.083)***
ECpct		0.059		-0.001		-0.094		-0.024		-0.001		-0.117
		(0.039)		(0.001)		(0.118)		(0.031)		(0.001)		(0.086)
R-squared	0.126	0.212	0.144	0.196	0.191	0.356	0.256	0.281	0.321	0.294	0.293	0.451
Observations	15832	3021	101646	4091	8718	190	31716	3831	478297	5805	23949	419

*Skills data for Finland are only available up to the year 2004.
Robust standard errors are shown within brackets with ***, ** and * meaning significant at the one, five and ten per cent level.
Unreported time, industry, size and affiliation dummies are used to control for firm specifics and changes over time.
Sources: Statistics Finland, Statistics Sweden and Statistics Norway

Table B Effects on firm total factor productivity from IT intensive human capital
Ordinary Least Squares estimations on pooled and unbalanced panels of firms 2001-2005

	Manufacturing firms 15t37						Services firms 50t74					
LnTfp	**FIN* 1**	**3**	**SWE 1**	**3**	**NOR 1**	**3**	**FIN 1**	**3**	**SWE 1**	**3**	**NOR 1**	**3**
Lnkl	-0.375	-0.431	-0.106	-0.173	-0.184	-0.250	-0.366	-0.366	-0.186	-0.219	-0.310	-0.252
	(0.004)***	(0.011)***	(0.001)***	(0.008)***	(0.004)***	(0.029)***	(0.004)***	(0.012)***	(0.001)***	(0.005)***	(0.002)***	(0.016)***
Hkitpct	0.259	0.038	0.082	-0.329	0.586	0.881	1.309	1.437	0.307	0.481	0.581	0.833
	(0.046)***	(0.124)	(0.023)***	(0.137)**	(0.042)***	(0.353)**	(0.036)***	(0.127)***	(0.008)***	(0.063)***	(0.017)***	(0.162)***
Hknitpct	0.633	0.770	0.113	0.358	0.077	0.194	1.176	1.065	0.228	0.223	0.226	0.315
	(0.048)***	(0.144)***	(0.015)***	(0.082)***	(0.068)	(0.442)	(0.029)***	(0.117)***	(0.005)***	(0.055)***	(0.026)***	(0.310)
DSLpct		0.353		0.415		0.697		0.099		0.219		0.140
		(0.050)***		(0.033)***		(0.136)***		(0.061)		(0.022)***		(0.082)*
ECpct		-0.175		-0.001		-0.102		0.002		0.001		0.076
		(0.059)***		(0.001)		(0.133)		(0.078)		(0.001)		(0.084)
R-squared	0.576	0.607	0.321	0.538	0.454	0.631	0.597	0.499	0.631	0.786	0.709	0.568
Observations	15831	3020	101643	4090	8717	189	31715	3830	478252	5804	23948	418

*Skills data for Finland are only available up to the year 2004.
Robust standard errors are shown within brackets with ***, ** and * meaning significant at the one, five and ten per cent level.
Unreported time, industry, size and affiliation dummies are used to control for firm specifics and changes over time.
Sources: Statistics Finland, Statistics Sweden and Statistics Norway