THE MULTIFACETED NATURE OF ICT

Final Report of the ESSnet on Linking of Microdata to Analyse ICT Impact

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Special thanks

Three phases of ICT impacts projects have now passed, and unbelievable eight years since everything started. A lot of things have changed during this period of time, especially within the rapidly developing field of ICT, but also at the statistical offices. Some team members have been along since the first project, while others have joined later, but the constant has been a high professional quality.

Not only have our analyses and outputs expanded, but also our comradeship. I would like to thank the whole team for excellent inputs to both project work and after work gatherings (food, culture and exercises).

Warm thanks also go to our external collaborators, without whom our insights of the usefulness of the dataset at hand would have been far more limited.

Once again, I would like to direct my gratitude to Eurostat, who allowed us to expand and fine-tune our earlier work.

Stockholm 26 December 2013

Eva Hagsten
Project Leader
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Introduction

ICT continues to be an important factor of growth, although its features and the channels through which it transforms into firm performance have undoubtedly changed over time from the sole investments in computers to a multi-dimensional palette of advanced ICT systems and interactions. This development has also been clearly visible throughout the three different waves of the Eurostat ICT Impacts projects.[1] Besides investigating the feasibility of large scale microdata-linking of the business register, extended production as well as ICT usage and innovation surveys and the build-up of a micro-aggregated dataset (the Micro Moments Database, MMD), these projects have also analysed the impacts of ICT in 14 European countries. In addition, the work has led to the development of a novel firm-level ICT intensity indicator (ICTi), created with the purpose of being resistant to changes in technology and industry structure over time. From earlier phases of the project we know that when saturation is approaching, the effect on firm performance diminishes and the basic ICT tools may have to give way for more advanced systems or complementary investments in order to render an effect on output.

Some strands of ICT impacts, or relationships with other phenomena, have been more easily detected than others during the course of analysis, for instance the influence on firm performance of ICT usage and ICT schooled employees. Similarly, the effects on exports behaviour have been traced as well as the importance of broadband internet-enabled employees (BROADpct) for the adoption and effectiveness of more advanced ICT system. However, the role of ICT in employment growth and how ICT, innovations and firm performance are connected have been more difficult to disentangle.

Thus, this final report of the ESSNet on Linking of Microdata to Analyse ICT Impact (ESSLait), aims at presenting and then weaving together the empirical results on the impact of ICT with possible policy indications. Subsequently, there is a discussion of durable ICT indicators and finally some suggestions for future work. In Annex 1 there is a technical exposition of the project deliverables. All other outputs from the project will be presented as standalone reports (on metadata, input and output quality, ICT and productivity patterns as well as on the Micro Moments Database) and are listed in Annex 2. After end of project, the MMD will be made available to researchers at the Eurostat safe centre.

ICT intensity and firm performance

According to Eurostat (2008), the manufacturing firms were the ones that most easily gained from increases in the proportion of employees with broadband internet in the early 2000s, but this effect changes over time, visible already in Eurostat (2012) and is now more widespread among services firms, as can be seen in Table 1.[2] Services firms in ten and manufacturers in eight out of 14 countries exhibit a significant relationship between broadband employees and labour productivity (*Impact*). The estimates illustrate the effect on productivity from a unit

[1] ESSNet on Linking of Microdata to analyse ICT Impact (ESSLait), Grant Number 50721.2013.001-2013.082, ESSnet on Linking of Microdata on ICT Usage (ESSLimit), Grant number 50701.2010.001-2010.578 and ICT Impacts, Grant number 49102.2005.017-2006.128. ESSLait participating countries, institutes and national project leaders are listed in Annex 3.

[2] Eurostat (2008) "Final Report, Information Society: ICT Impacts Assessment by Linking Data from Different Sources" and (2012) "Final Report, ESSNet on Linking of Microdata on ICT Usage".

increase in the proportion of broadband internet-enabled employees. Table 1 also reports on the ranking of countries in their intensity of usage of the same ICT tool (*Intensity*). Typically, in countries where firms are already intensive ICT users, productivity gains are less apparent. The index column shows that larger estimates are illustrated by deeper shades.

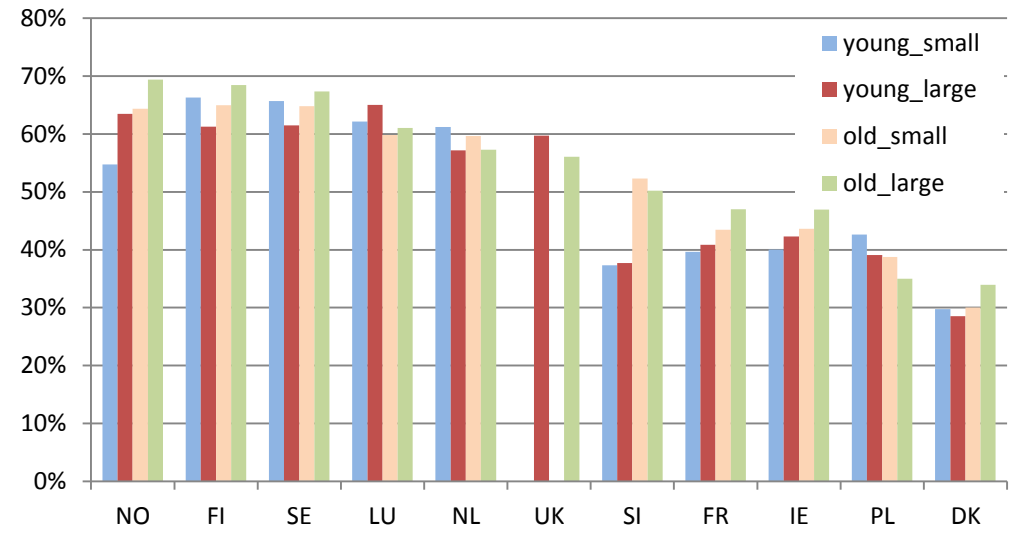
Table 1. Intensity and Impact of broadband internet-enabled employees in firms

	Services 50t74		Manufacturing 15t37		
Country	Impact	Intensity	Impact	Intensity	Index
DE	0.222	8	*0.258*	6	1
PL	0.218	13	0.507	14	2
UK	0.154	6	0.225	4	3
IE	0.099	10	0.352	9	4
IT	0.092	12	0.113	12	5
LU	0.081	5	0.181	7	6
AT	0.073	11	*0.016*	10	7
FI	0.055	1	*-0.026*	3	8
NL	0.052	3	0.071	5	9
FR	0.044	9	0.056	8	10
SI	*0.026*	7	-0.146	11	11
DK	*-0.002*	13	*-0.012*	13	12
NO	*-0.002*	2	*-0.009*	2	13
SE	*-0.005*	4	*0.004*	1	14

Note: The intensity shows the ranking of countries according to the proportion of broadband internet-enabled employees in firms during 2010 and the impact represents the effect on labour productivity from a units increase of the same variable based on pooled firm-level regressions for the period 2001-2010. Shaded estimates are significant at the five per cent level as a minimum. Deeper colour means larger estimate. White cell implies insignificant estimate.
Source: ESSLait Micro Moments Database and own calculations

Large scale microdata linking also gives vast opportunities to present data in dimensions not earlier explored. An example of this can be found in Diagrams 1 and 2 where the two different measures of ICT intensity, BROADpct and ICTi, are presented by firm age and size. BROADpct is measured as the proportion of broadband internet-enabled employees in firms and ICTi is a composite indicator derived from the estimated propensities of adopting various kinds of ICT (e-commerce, automated data exchange, sharing of information between business functions and mobile internet access). The comparison shows that the employee internet access varies only marginally across firm size and age in most countries, with the old and large firms having a slightly higher degree of intensity than other firms. Instead, the results reflect the major and already well-known disparity across European countries in the firm uptake of ICT.

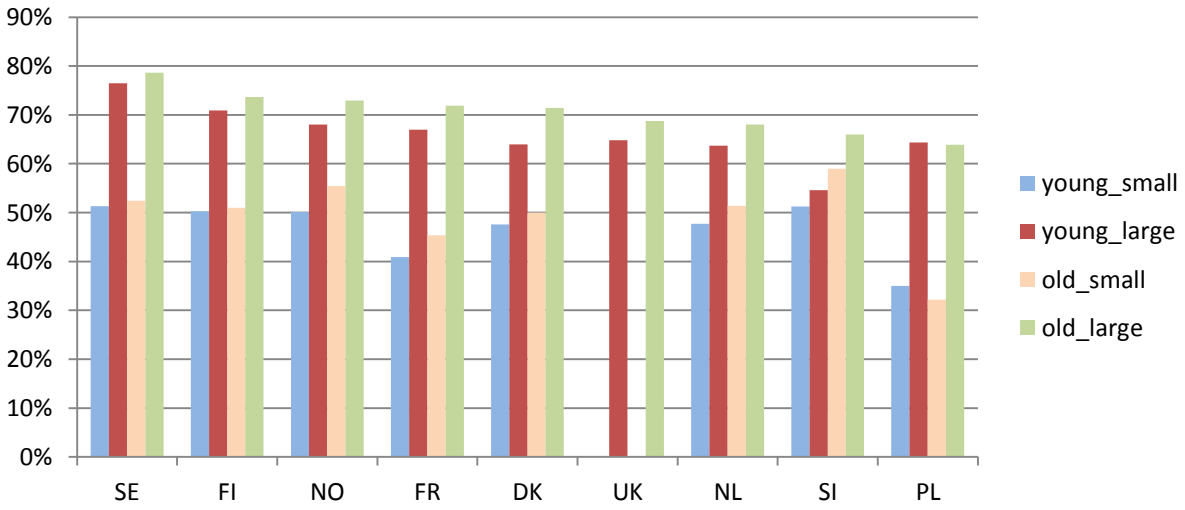
Diagram 1. Broadband internet-enabled employees by age and size in 2010



Note: Young means less than five years old and large is 50 or more employees. Countries excluded lack information on age.
Source: ESSLait Micro Moments Database

On the other hand, when the composite ICTi indicator is investigated, the pattern changes and reveals that the variation across countries is now far less visible than among firm types. The old and large firms are the most ICT-intensive ones and firm size seems to be of greater importance than age in this context, which is particularly clear in Poland. Apparently, the adoption of specific new technologies, as indicated by the ICTi variable, captures the differences in firm characteristics, whereas the BROADpct seems to indicate the usage of a general infrastructure at the national level.

Diagram 2. ICT-intensity in firms (ICTi) by age and size in 2010



Note: Young means less than five years old and large is 50 or more employees. Countries excluded lack information on age or data required for the computation of the ICTi indicator.
Source: ESSLait Micro Moments Database

In Table 2, the analysis of the relationship between firm performance and ICT intensity (BROADpct from Table 1) is expanded by the ICTi variable. On the whole this variable follows the same pattern as the employee internet access, where a high level of ICT usage to a certain extent has already depleted the possibility to gain from further ICTs. Overall, the ICTi receives higher estimates. Moreover, another interpretation of the results might be that there is a lower impact threshold for ICT intensity in general, which the firm needs to pass before it can benefit. Certainly, the different time spans available for the two variables need to be taken into account as well as the construction of the measures investigated when these results are interpreted; a sole proportion versus a geometric mean.

Table 2. Impact of alternative ICT intensities

	ICTi 2007-10		BROADpct 2001-10	
Country	50t74	15t37	50t74	15t37
UK	1.283	2.238	0.154	0.225
DE	1.027	*1.407*	0.222	*0.258*
PL	0.541	0.787	0.218	0.507
LU	0.379	*0.503*	0.081	0.181
AT	0.317	*-0.232*	0.073	0.016
FI	0.268	-0.293	0.055	*-0.026*
NL	*0.228*	*0.215*	0.052	0.071
SE	0.099	*0.179*	*-0.005*	*0.004*
FR	*0.089*	0.192	0.044	0.056
DK	*-0.041*	*-0.122*	*-0.002*	*-0.012*
NO	-0.191	*-0.086*	*-0.002*	*-0.009*
SI	*-0.280*	-0.743	*0.026*	-0.146
Mean	0.518	0.436	0.112	0.064
Min	-0.191	-0.743	0.044	-0.146
Max	1.283	2.238	0.222	0.225

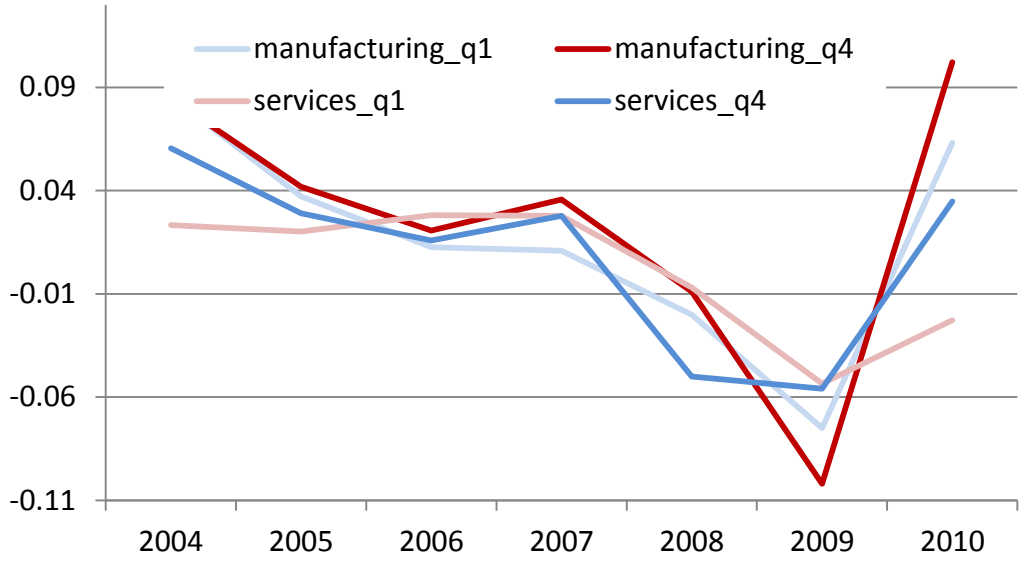
Note: The table shows the estimated impact on labour productivity from a unit increase of the ICT intensity variable in question. Shaded estimates are significant at the five per cent level as a minimum. Deeper colour means larger estimate. White cell implies insignificant estimate. The services firms are denoted 50t74 and the manufacturers 15t37.
Source: ESSLait Micro Moments Database and own calculations

Besides assessing the impact of ICT on firm performance in each country using the linked firm-level datasets, we can also estimate the average ICT impact using the country-industry-time panel of the MMD. For this purpose we use a specification where value added per worker, in a country, industry, and time panel is regressed on broadband enabled employees and fixed effects for country, industry and year are included. In this specification, the percentage of employees with access to broadband is seen to remain significantly related to value added per worker (unreported, available upon request). Of course, the significant regression coefficient should not be confused with a test for a causal relationship.

The length of the panels made available within the ESSLait project also allows us to study how firms performed during the financial crisis. In Diagram 3, the growth of labour productivity is illustrated for firms in the lowest and the highest quartiles of ICT intensity. Consistent with the general view, manufacturers were more strongly hit than services firms in the deepest period of the downturn (2008-09). However, ICT-intensive firms seemed to pick

up again after the crisis faster than the less intensive ones and most clearly so in manufacturing. Low ICT-intensive services firms experienced larger difficulties than other firms to recover after the crisis.

Diagram 3. Labour productivity growth by industry and ICT intensity of firms



Note: The quartile distribution shows weighted averages across 12 countries of the lagged BROADpct variable. Firms with lower ICT usage are found in quartile 1 (q1).
Source: ESSLait Micro Moments Database and own calculations

Furthermore, firms intensive in ICT have shown to be more volatile, although the causality is not completely clear. Either firms willing to take larger risks may be more prone to invest also in advanced ICT systems, or firms facing a more volatile environment may invest in ICTs to reduce adjustment costs. We have explored how volatility of firm output, productivity and employment growth vary with ICT usage by using 'long-panels' of firm-level production statistics for the period 1995-2010, where we classify firms as high or low in ICT, depending on their estimated ICT intensity (see above) in the period 2001-2010 and then we look at the time series and cross-sectional distribution of employment and output growth for these two groups of firms.

As seen in Table 3, the dispersion measures are higher for ICT intensive firms (ICT=1), except in France. In the first two columns the average standard deviation of the firm-level time series of labour productivity growth is presented. This is measured at the firm-level using a 5-year moving window. The firm-level dispersion is averaged into an industry series, using firm-size weights. Finally, the industry dispersion is averaged over the period 2003-2007 (thus using underlying firm-level data from 2001-2009).

The columns denoted ICT=0 use data from those firms that we label non-ICT intensive. Both for output growth and productivity growth the dispersion is larger for ICT intensive firms. We also have dispersion measures from the firm-level cross sectional distribution, both for productivity growth and output growth. In computing the dispersion, observations are weighted by firm size. In this exercise, the ESSLait project did not collect the measure for non-ICT intensive firms, only for ICT-intensive firms and the industry as a whole. In all

countries, except France, the ICT intensive firms have a higher standard deviation of the cross-sectional distribution of firm-level output and productivity growth.

Table 3. Output and productivity growth dispersion by ICT intensity

	Time series				Cross section			
	Productivity growth		Output growth		Productivity growth		Output growth	
Country	ICT=0	ICT=1	ICT=0	ICT=1	ALL	ICT=1	ALL	ICT=1
DK	0.19	0.21	0.24	0.26	0.23	0.24	0.29	0.32
FI	0.19	0.28	0.21	0.31	0.25	0.27	0.3	0.33
FR	0.2	0.18	0.22	0.18	0.21	0.18	0.21	0.19
NL	0.13	0.14	0.11	0.13	0.22	0.24	0.2	0.21
NO	0.18	0.26	0.21	0.29	0.32	0.35	0.33	0.35
SE	0.2	0.26	0.32	0.38	0.33	0.37	0.49	0.52

Note: The table shows the averaged standard deviation of labour productivity and output growth. In the time series columns, the standard deviation of growth is measured at the firm level for a 5-year moving window and averaged across ICT intensive and non-intensive firms in the industry (ICT=1 and ICT=0). The industry and time dispersion measures are then averaged over time and across industries with fixed industry weights. In the columns labelled cross section, the standard deviation of growth for the cross-section of firms in an industry is computed, for ICT intensive firms (ICTi=1) and for all firms (ALL). The industry and time dispersion measures are then averaged over time and across industries with fixed industry weights.
Source: ESSLait Micro Moments Database and own calculations

Similarly, in an industry-country-time panel dataset, there is a positive correlation between the standard deviation of the productivity distribution and ICT intensity, both in levels and first differences. In Table 4 we show the results of a regression of the standard deviation of the cross sectional productivity distribution in the MMD panel dataset on the average broadband intensity as well as on country, industry, and time fixed effects. The results reveal that higher ICT usage is associated with increased productivity dispersion.

Table 4. Standard deviation of firm-level productivity distribution regressed on broadband intensity

	Levels	First-differences
γ	0.47	0.28
t-stat	(5.02)	(2.59)
R^2	0.52	0.03
D.F.	1180	1021
Fixed effects	country, industry, time	country, industry, time

Note: Coefficients γ from a regression: $\sigma_{c,i,t} = \alpha + \gamma BBI_{c,i,t} + FE + \varepsilon_{c,i,t}$, with country, industry, time fixed effects, where σ is the standard deviation of the cross-sectional distribution of labour productivity in country c, industry i and time t, and BBI is the broadband intensity. The regression is run in levels and in first differences. D.F. is short for degrees of freedom.
Source: ESSLait Micro Moments Database and own calculations

Firm behaviour and alternative ICT intensities

Beyond the different ICT intensities and their effect on firm performance, a blend of analyses including ICT has been performed within the ESSLait project.

Infrastructure to more advanced ICT usages

The discussion above shows that the simple effect on firm productivity may be declining when a certain ICT variable reaches saturation. This could imply a need to substitute such a variable for a less mature one. Still, there is a possibility that a saturated variable remains valuable. For instance, it has been shown that the degree of broadband internet-enabled employees indeed has an effect on the choice to adopt systems for enterprise resource planning or customer relationships. Supposedly, this could indicate that the variable in question is a pre-requisite or an infrastructure for more advanced ICT usages. In addition, this same variable has also appeared as approximation of ICT investments, informal skills and firm structure.

ICT intensity, employment and wages

In general, we find no evidence to support the view that ICT is associated with negative consequences for employment growth at the firm-level, nor do we find clear evidence of benefits on firm-level employment from higher usage of ICT. A positive relation with ICT intensity could only be found for manufacturing firms. Turning to the industry-level analyses, the link between ICT and employment growth remains weak, but there are some intriguing findings. For each country, industry, and year, we have aggregates of employment, as well as other variables, split by ICT intensity of firms, or by age, size or age-by-size groups of firms. We have run regressions using the panel dataset of employment growth on a dummy variable for the firm-group as well as on fixed effects for country, industry and size. These results are presented in Table 5.

Table 5. Variables of importance for employment growth

	BROADpct	Process innovator	Age	Product innovator	Multinational	Foreign-owned	Exporter
Employment growth		**+**	**+**	**+**	**-**	**-**	

Note: A "+" means positive significant relationship at the 1 per cent level, "-" negative and a blank cell insignificant result.

Source: ESSLait Micro Moments Database and own calculations.

By size, we find that, on average, firm growth declines with firm age, but there are no significant differences between firm groups. Indeed, when looking at employment growth split by the 4 groups of firms (smaller or larger than 50 employees and younger or older than five years), we find that size does not matter, while young firms grow rapidly.

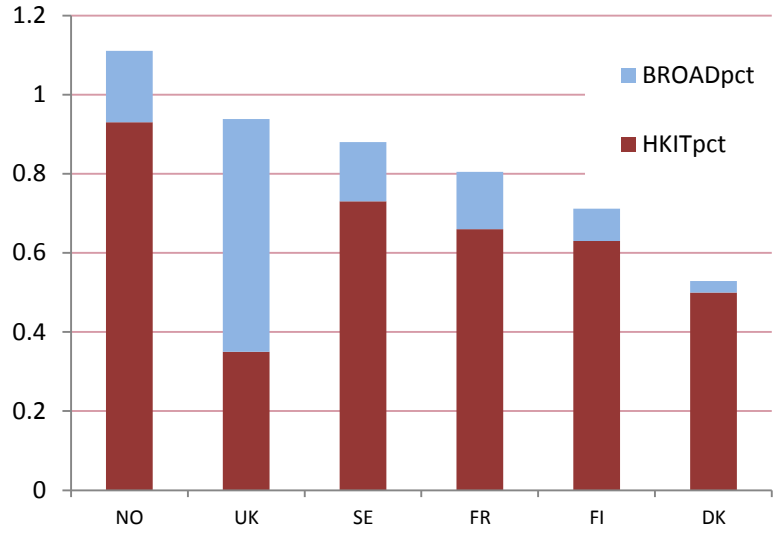
Industry aggregates split by whether firms are broadband intensive or use various ICT configurations, show that these do not relate significantly to employment growth. Interestingly, firms that affirm having process innovation, product innovation and organizational innovation all grow faster than firms that are not innovators. Finally, we find that multinational corporations and foreign-owned firms shed more workers on average than purely domestic firms.

Turning back to the firm-level analysis, although the overall link between ICT usage and employment growth seems to be absent, there is a significant relationship between ICT and pay per employee (Wages). Large and ICT intensive firms pay more, but innovativeness and international experience also matter. The relationship between ICT use and wages continues

to hold, even when controlling for the intensity of high skilled labour input in the country/industry.

ICT and intangibles
When the effect of formal ICT skills are studied, in this case defined as post upper secondary education in ICT-intensive fields (HKITpct), the results reveal a clear and positive connection to firm performance measured as output growth. This link is also stronger than for the informal skills provided by the broadband internet enabled employees. These results hold true in all countries studied except the United Kingdom, as is visible from Diagram 4.[3]

Diagram 4. Impact on firm performance of formal and informal ICT skills



Source: ESSLait Micro Moments Database and own calculations

The total effect of ICT-intensive human capital and usage follows a similar pattern across all countries studied except the United Kingdom. Tentatively, this could be related to the degree of labour protection, which is much less pronounced in the United Kingdom than in the other countries. Assumingly, this may also lead to a more liberal perspective on the importance of how the skills have been achieved, formally or informally.

Observing the differences in performance between firms using ICT-support or not, we find that the former group is the higher productive. Nevertheless, there seems to be no clear variation between the firms outsourcing or the ones using in-house ICT support.

Looking at software, we find from the MMD that the prevailing level of ICT in a firm positively affects the adoption of systems for enterprise resource planning (ERP), customer relationship management (CRM), and supply chain management (SCM). The adoption of these systems leads to higher productivity, although the systems may appear either as complements or substitutes.

An exploratory analysis on the funding of innovative activities shows that this matters for innovation success, specifically so if both national and international support is available, and

[3] Information on formal educational achievement is only available in a sub-set of countries.

regardless whether a firm is ICT-intensive or not. This suggests the scope for policy to stimulate the rate of innovation.

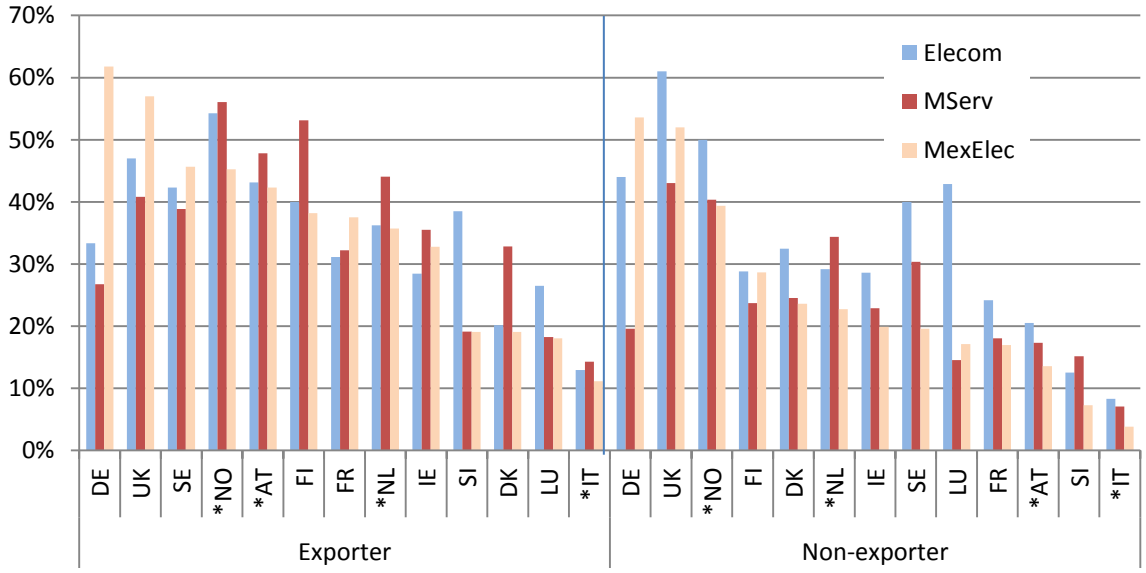
Intuitively it seems reasonable to assume links between ICT, innovations and firm performance. Indeed, by using reweighted variables to capture representativeness, we have been able to link ICT use to innovative activities and innovations to productivity at the country and industry levels. We find that internet-enabled employees, mobile internet and electronic sales intensity of an industry all are associated with an increased propensity to engage in product innovations. In a typical production function, regressing labour productivity on the capital-labour ratio, and human capital intensity, we find a positive significant effect of the predicted propensity to have product innovations. In short, it seems that ICT enables innovation and that innovation, as known, improves productivity.

However, at the firm-level, we have not been able to find similar strong connections between ICT intensity, innovations and firm performance, although ICT use and various types of innovative behaviour seem to be complementary. Possibly, the time lags along the various causal paths between ICT, innovation and performance effect make it difficult to find systematic results that hold across countries. Another possible worry is that the small linked dataset needed to study these interactions at the firm level is too biased towards larger firms and thus renders no significant results. Moreover, the fact that a link is found in the aggregated data suggests that the aggregation may filter noise that otherwise hampers the identification at the firm-level.

ICT and internationalisation of firms

Exporting behaviour of firms has been investigated in connection with the usage of three ICT tools, representing different areas of complexity; using a website (WEB), engaging in online sales (AESELL) or benefitting from complementary ICT skills through broadband internet-enable employees. Firms selling on the international market are generally also higher users of ICT, as in the example of internet sales, illustrated in Diagram 5.

Diagram 5. Intensity of internet sales among exporters in 2009



Note: An asterisk "*" implies exports of goods only.

Source: ESSLait Micro Moments Database

The estimations of a probability model, based on information about whether the firm is an exporter or not, show that ICT do indeed relate to exports behaviour in a majority of countries, but the type of tool most useful varies, most likely because of different levels of adoption. These results are summarised in Table 6.

Table 6. ICT and decision to export

	AT*	DK	IE	FI	IT*	FR	LU	NL*	NO*	SI	SE	UK
WEB	+		+		+				+	+		
AESELL										+	+	+
BROADPCT		+			+				+		+	+

Note: A "+" means positive and significant estimate at minimum 10 per cent level, regressions on pooled samples of firms, years 2001-10, except Italy (2001-2009).
Source: ESSLait Dataset and own calculations

Accompanying the firm-level analysis on exports, the link to e-commerce in the shape of the degree of buying and selling on the internet has also been studied. Exploring the exports behaviour from a European vantage points reveals that these activities are indeed important for the export intensity (exports over sales) and more strongly so for the smaller countries.

Turning again to the analysis of the MMD, we have explored both the determinants of the decision of firms to export as well as the drivers of export intensity at the industry level. We find that in industries with more human capital, product and organisational innovation, as well as industries with better resource allocation, the propensity to export is higher. Conditional on exporting, the intensity of export in an industry is correlated with the percentage of broadband enabled employees. Further, significant coefficients are found for human capital and productivity, which coincides with earlier findings in the literature on exporting.

The multi-dimensionality of ICT and the policy environment

In the wider perspective, the ESSLait analytical results as well as the microdata linking procedure and quality work may touch upon several policy issues related to the EU 2020 strategies, the Digital Agenda or to policy in the broader sense. In this section an attempt is made to extract policy signals from the ESSLait results. Because of its specific nature the Micro Moments Database allows multi-country analyses beyond the common industry level classifications, and should prove to be an excellent tool for further policy related research.

The ESSLait project is financed under the MEETS programme, aiming at improving general data quality and increasing secondary usages of business statistics, among other. These goals are partly contradicted by the prevailing macro perspective on sample surveys and the strong national emphasis on easing the response burden of firms. Unfortunately, this is something that leads to reduced representativeness of linked firm-level datasets because of small overlaps of samples. Further, a low overlap will most likely cause difficulties in presenting estimates on drivers and impacts in the economy, information often sought by researchers and policy makers. Additionally, changes in questionnaire design and sampling methodology, may lead to discontinuity of variables and information needed to analyse the development of firm behaviour, which thus becomes more difficult to explore.

Policy signal 1: Meeting the increased demand for information about drivers and impacts in the economy is impeded by the strict focus on macro-perspective and response burden issues in the sampling design.

Table 7. ESSLait analytical themes and pillars of the Digital Agenda for Europe

Analytical themes / Pillar of the digital agenda	E-business	Firm dynamics/Resilience	ICT and human capital	ICT and innovation	ICT, outsourcing and skills	ICT and exports	ICT and employment	ICT and productivity
Digital single market	x					X		
Interoperability & standards	x					X		
Trust and security						X		
Fast and ultra-fast internet access	x	X						x
Research and innovation				x				
Enhancing digital literacy, skills and inclusion			x		x		x	
ICT-enabled benefits for EU-society		X				X	x	x

Note: An "x" shows fields where analyses have been pursued and a red shade indicates areas where also impacts of ICT have been found. More information about the Digital Agenda for Europe is available on http://ec.europa.eu/digital-agenda.

In Table 7 each ESSLait analytical theme has been listed together with the seven pillars of the Digital Agenda for Europe. It should be noted that, the matching of different purposes is not perfect, but despite this each analytical theme can, with some good will, be related to at least one of the pillars. This is illustrated by an "x" in Table 7. Additionally, if the cell is shaded, it means that the analytical work has also succeeded in unfolding certain impacts of ICT.

Digital single market

Possibly, the ESSLait connection to the digital single market might be represented by the analyses within the field of ICT and exports. Our results indicate a link between ICT and international sales, although the specific ICT tool most useful seems to differ. This deviation may be explained by differences in the industry structures, but also by variations in the provision and quality of certain ICTs, such as system for on-line transactions, something that most likely also affects the demand for these services.

Policy signal 2: Diverse or unstable system for online transactions may affect international trade and then also the digital single market. Analyses of ICT as a determinant of exports may inform on this issue.

Interoperability and standards

Regarding interoperability of software systems, the Micro Moments Database incorporates a large amount of ICT indicators, of which some could be used as indicators for a certain level of standardisation. One of these variables is BUSORG, which classifies firms into eight different categories, depending on the specific combinations of internal and external ICT systems in firms. Likewise, the database also includes indicators for joint adoption of different ICTs, (JOINTS). Roughly speaking, a concentration of combinations may indicate complementarity, which in turn can be related to the level of ICT standardisation.

Policy signal 3: Variables from the Micro Moments Database may be used as indicators of interoperability of ICT systems.

Trust and security

Regrettably, the trust and security pillar does not allow a strong connection to ESSLait issues, although the deviations in results of exports behaviour may be thought to partly relate to the availability of secure systems for online transactions.

Policy signal 4: An absence of e-sales as determinants of total international sales may indicate a deficit of secure systems for online transactions, both nationally and internationally.

Fast and ultra fast internet access

Typically, the internet pillar of the Digital Agenda is by far the one strongest related to ESSLait work. From the project perspective, broadband internet enabled employees have been a key impact variable, showing clear and positive relationship with firm performance. Moreover, it is also obvious that this variable is approaching saturation in some countries and consequently opportunities to gain from it in economic terms diminish. However, other strands of project research have indicated that the broadband employees might also be a pre-requisite for the adoption of and ability to benefit from more advanced ICT systems. In this case, and besides the fact that broadband offers the crucial infrastructure to make various ICT systems work properly, the broadband employees would provide the necessary skills needed to access or operate the more advances systems. Project work has also concluded that the broadband employee variable is not only a possible proxy for (ICT) skills, but also for investments in ICT and firm structure. A shortcoming of the project is that the underlying data have not allowed us to discriminate between impacts of different qualities of broadband, but only beyond a certain speed.

Policy signal 5: Even if the direct effect of (fast) broadband internet-enabled employees is declining, a policy focus could still be meaningful due to its possible indirect effects on firm performance and thus also growth.

Research and Innovation

At the country or industry level we find that internet enabled employees, mobile internet and electronic sales intensity of an industry all are associated with an increased propensity to engage in product innovations. It seems that ICT enables innovation and that innovation, as known, improves productivity.

Besides these results, the analysis of funding of technological innovations shows that these are indeed important for productivity, and particularly so if national and EU funding are combined. This suggests a scope for policy to stimulate the ratio of innovations.

Policy signal 6: ICT seems to enable innovations, which in turn improves productivity. However, exactly how these links unfold in single firms is difficult to disentangle. Innovation funding matters, especially when funding from different bodies is available.

Enhancing digital literacy, skills and inclusion

ESSLait research suggests that broadband employee intensity could be an indicator of digital literacy, or learning by doing ICT skills. Yet, the analysis shows a much stronger impact on firm performance of employees formally schooled in ICT. Possibly, this could be related to the fact that basic ICT skills are already widespread and something more advanced is needed to identify an effect on firm performance. A high level of broadband internet employees may also generate spillover effects from professional to private life and thus increase social inclusion.

Policy signal 7: Formal advanced ICT schooling, not only basic digital literacy, is important for growth. A high level of ICT usage at work may also spill over to private life and increase social inclusion.

ICT-enabled benefits for EU society

There is emerging evidence that the policy environment may impede or accelerate adoption of ICTs and thereby the ICT-enabled benefits for society. At the country, industry level, we find a strong correlation between ICT intensity and a summary measure of the efficient allocation of resources across firms in an industry. The latter measure has clear links to product and labour market regulations and other policy that levels the playing field for firms in an industry.

Clear relationships between ICT and employment growth at the firm-level have been difficult to find, nor has evidence of job-less growth. However, the worry that ICT and process innovation can harm employment is not substantiated by evidence at the country and industry level either.

Policy signal 8: No evidence is found that increased ICT usage leads to a decrease in employment, although the results indicates that ICT usage is beneficial for an efficient allocation of resources.

Core indicators from past to future

During the course of the three ICT impacts project, the Eurostat harmonised ICT usage survey, the key focus of our analysis, has been through several major revisions, including not only changes in questions and resulting variables but also new definitions of old indicators. Typically, the motivation behind these changes are often technical, for instance when a variable does not represent the firm characteristics sought after, or the ICT field in itself is very dynamic, implying that also survey questions need to have a high turnover. This works perfectly well as long as no attention is paid to development over time. However, most data make sense only in comparison with something else, over time or across countries. From an

analytical perspective a slightly wrong variable, but consistent over time, could well be better than a regularly fine-tuned indicator.

How then can these conflicting perspectives be over-bridged? A core set of indicators, which are not changed over time, together with a thematic module, seems to be the solution. This is in principal already the setup of the survey, but with policy pressure for certain modules even indicators that would normally be considered of core value have been left aside, in order not to exceed a fixed maximum number of modules and questions. (This does not only refer to the cost for firms, the response burden, but also to the costs for the statistical office issuing the survey). Similar recommendations have also been put through by Mairesse and Mohnen (2010). [4]

To allow for meaningful analysis of ICT impacts, the core indicators of a survey should not be substituted until they have reached saturation and their possible effects have worn off. Further, when definitions are changed, parallel series over a span of years would be optimal. Variables of interest include, but are not limited to ICT characteristics of the firm within the areas of:

i) the employee
ii) the external ICT systems and
iii) the internal ICT systems.

These variables could well be categorical, monetary or fractional.
Moreover the following recommendations would vastly improve the secondary usefulness of the survey results:

1. A re-considerations of the sampling strategies, to allow fewer firms to be quickly rotated out,
2. The introduction of common guidelines for how raw data should be coded. The different practices of how to code a missing value, a zero and sub-questions under filter questions creates unnecessary uncertainty about the comparability both over time and across countries and
3. The inclusion of micro-firms.

Finally, the lack of two types of information severely hampers the identification of the impact of ICT. Firstly, despite a recent pilot survey on ICT expenditures by Eurostat, there is no coherent information on capital stock or ICT capital. Obviously, the availability of such data would greatly improve the quality of both aggregate statistics on this matter as well as firm-level productivity analysis. Secondly, despite several attempts by among others the EUKLEMS and WIOD consortia and OECD, a huge gap in the statistical system seems to be the availability of a longitudinal cross-country industry-level dataset on price deflators. Again, it is evident that productivity analysis would hugely benefit from the existence of such a database.

[4]Mairesse, Jaques and Pierre Mohnen (2010) "Using Innovation Surveys for Econometric Analysis*" United Nations Working Paper Series*, UNU-Merit 2010-023.

Suggestions for future work

Continuation of the MMD infrastructure

Over the last eight years the ICT impact consortium has invested a tremendous amount of expertise, time and work in building an environment that allows data linking and exchange of results. The Distributed Microdata approach includes intensive metadata analysis and harmonisation exercises. Now when these products are realised, it would be a waste not to build further on the existing infrastructure and network and use it for further data linking and analytical exercises. Potential extensions include, but are not limited to:

- linking of additional sources, for example, trade statistics and social statistics on employer-employees (see also below),
- increasing the scope of countries: since the common code (programme) employed in the project that produces the national micro-aggregated dataset is generic, the effort of running this code is fairly low once the data assembly exercise has taken place. This allows new countries to join, making use of the available guidelines on data assembly, increasing the scope for further benchmarking analysis, especially with non-EU countries and
- extending the dataset in time when new waves of e-commerce, innovation and production surveys come up. This is particularly worthwhile for analysis of longer panels. Moreover, in the current economic circumstances, the analysis of firm behavior throughout the crisis would also greatly benefit from additional years. Finally, development in ICTs and pertinent new information from e-commerce survey may warrant the introduction of new variables to the dataset.

Further research and use of the data for policy evaluation

A large array of research topics has been pursued by the ICT Impacts consortium and collaborating partners. We feel that this is just the beginning of exploiting the potential of the data. Making the MMD available now to eligible external researchers should open up further avenues of research questions to be explored, and also, maybe spur the demand for additional data sources. Some avenues that spring to mind include the following:

An area where we have only begun to scratch the surface of is that of policy evaluation. Given the multi-country nature of the MMD and the level of detail available, it should prove an excellent tool for analysing the effect of national policies. A natural way to process is to use the MMD and subsequently link in data on changes in such policies and considering them as quasi-experiments.

Further, part of our research has also shown that by skilfully constructing moments from the microdata, the cross-country micro-aggregated data can be used to estimate ‘pseudo-micro-data’ regressions. DMD data even appears to be a feasible alternative for plain firm-level data when it comes to the estimation of more complex models that feature new directions in micro-econometrics. Besides the advantage of pooling country-data, this also has a major advantage because of the fact that (non-systematic) measurement errors are wiped out, so that estimates are expected to be less biased. Given that the ICT impacts projects have achieved the availability of a harmonised metadata structure over countries, it should be possible to easily gather these additional micro-moments in the future. We view this as an intriguing extension to the DMD approach as it exists today.

Finally, an estimation method that has gained a lot of popularity in recent econometric work is that of indirect inference[5]. This method involves finding the set of parameter values for a particular structural economic model that matches best a set of suitably chosen statistical moments of the data. For different sets of parameter values a dataset is simulated for which the moments are calculated. A search routine determines the set of parameter values that minimises the difference between the moments from the actual data and the moments from the simulated data, according to some distance measure. By its very nature, our MMD data are very appropriate to be used with such techniques and we expect that researchers from various fields can benefit greatly from these data, allowing for multi-country comparisons.

Supporting the release of the MMD

In accordance with the ESSLait contractual obligation, the MMD will be transferred to the Eurostat safe centre when the project accounts are finalised. Although a description of the dataset will also be released, we appreciate that some additional guidance would be required to access and use the dataset, especially initially. Thus we suggest that Eurostat contract the ESSLait project leader and analytical leader to aid in this process. Further, this task could also include an assessment of the resources needed to update the MMD.

[5] See *inter* alia Gourieroux and Monfort (1996), Simulation-based Econometric Methods. Oxford University Press, Oxford, United Kingdom.

Annex 1. Technical Report of the ESSLait Project

Introduction

Eva Hagsten Statistics Sweden and Michael Polder, Statistics Netherlands

This is the technical part of the final report on the ESSNet on Linking of Microdata to analyse ICT Impact (ESSLait), as required in the Grant Agreement for an Action with Multiple Beneficiaries, number 50721.2013.001-2013.082, with the main purpose to further expand the methodology for ICT impact analysis developed in the two earlier closely related projects (ICT Impacts and ESSLimit), extend the time series to include data from more recent years for a group of European countries, analyse how the economic environment influences the links between ICT and firm performance and ready an infrastructure for future cross-country distributed research.[6] Work within the Action has carefully been related to relevant policy areas such as the EU digital Agenda and the MEETS programme for improving business statistics.

The project has been organised in two workstreams (Administration and Impact Analysis) and consists of partners from 14 European statistical offices, supported by academic advisors.[7] Statistics Sweden is the project leader, with Statistics Netherlands and Statistics Norway in the steering group together with the sponsor Eurostat. As from May 2013, the Central Statistical Office of Poland was invited to join the steering group following a re-balance of tasks provided by Statistics Norway.

According to plan, there was a two-fold focus during the initial months of the project: on creating good conditions for the analytical work and on starting or restarting the exploratory or already ongoing analytical work. This meant that issues relating to harmonisation of data, data quality and development of code were high on the agenda, as was the forming of internal analytical sub-groups in the project.

Workstream (I) – Administration

Objectives

Workstream I dealt with general project management including data sharing and dissemination of information, as listed in Table 1.

Achievements

All Deliverables have been fulfilled except the financial report, which is due two months after end of term. The secure infrastructure, the project mailbox, website as well as the e-mail address were made available from 1 January 2013. In addition, the EU Cros-portal (www.cros-portal.eu) has been used for brief information of the project work and progress.

[6] ESSnet on Linking of Microdata on ICT Usage, Grant number 50701.2010.001-2010.578 and ICT Impacts Grant number 49102.2005.017-2006.128.

[7] The statistical offices of Austria, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Poland, Slovenia and the United Kingdom are all co-partners of the project. Academic advisors from the Free University of Amsterdam, University of Ljubljana, the Institute for Prospective Technological Studies (IPTS) in Seville and the Austrian Institute of Economic Research (WIFO) have contributed to project set up and output.

Table 1. Deliverables and Timing, Workstream I

Deliverables	Timing
Provision of a secure infrastructure for data transfer and storage	Lifetime of project
Provision of a website and project mailbox for internal and external exchange of information and communication of results	Lifetime of project esslait@scb.se, www.esslait.eu
Mid-term technical report	End of month 5
Dissemination of datasets with detailed results	End of project
Final report	End of project
Financial report in accordance with conditions described in the grant agreement	*60 days after end of project*

Note: *Italic* means remains to be done.

The project held its first steering meeting in Amsterdam on 7 February 2013, focussing on strategies. The launch workshop followed in Oslo on 21-22 March with an emphasis on data and code. The Oslo meeting also kicked off the data quality work by holding a special workshop on this theme.

The second steering meeting took place in Stockholm on 18-19 June highlighting the analytical themes of the project. Hans Lööf from The Royal College of Technology in Stockholm was invited to comment on the analytical work of the project. The Stockholm meeting was also combined with two separate workshops, one on quality in the linked dataset, another on ICT and employment together with representatives from the IPTS in Seville. Parallel to the steering meeting in Stockholm, a workshop was held in Vienna on input data quality. On 5-6 June a workshop was held in Ljubljana on the issue of ICT on exports.

The final conference took place in Rome on 15-16 October 2013. To this meeting representatives for the OECD (Andrea De Panizza), The Conference Board (Desiree van Welsum), WIFO Austria (Martin Falk), IPO United Kingdom (Tony Clayton) and the IPTS (Federico Biagi) were invited to comment on analytical results and possible policy links.

A final work meeting was held in Amsterdam on 4-5 December 2013, with the project lead and the academic advisors.

All meetings have been carefully documented and notes are available on demand from Statistics Sweden.

Risks and mitigation

Running a project the size of 14 countries, partly on remote control is a huge managerial task and if things are not working fully everywhere there are certain difficulties to deal with that. In the case of ESSLait, most things have been running smoothly with good support from the project team. However, one main risk, which was also clearly highlighted in the Interim report, is late delivery or non-delivery of outputs. The project has suffered from this to a certain extent, meaning that data from two project countries only have been included in the analytical work to a certain extent.

Further risks as mentioned in the Interim report relates to the quality of the data and to the dissemination of output. The description of the micro-aggregated output (Micro Moments

Database) and the work on both input and output data quality (available in separate reports) have been chosen as the approach to describe what the data holds for.

The quality of the analytical work has been safe guarded partly by the academic advisors and collaborators to the project, partly by repeatedly presenting the work to the academic society and policy sphere.

Workstream (II) – Impact Analysis

Objectives

The main task for this workstream was to update and further develop the project software (Common Code) and methodology for impact and descriptive analyses initiated by the ESSLimit and ICT Impacts projects. The undertaking also included an update of the metadata repository and the inclusion of more recent years to the project datasets. Furthermore, code development was undertaken to allow future use of the data infrastructure. Table 2 presents the planned and fulfilled deliverables from this workstream.

Table2. Deliverables and Timing, Workstream II

	Deliverables	Timing
A	Report on updated metadata repository	End of month 5
B	Common fixed code for reading, linking, output	End of project
C	Updated description of project methodology and output, including quality assessments (final report)	End of project
D	Report on analytical results (final report)	End of project
E	Release of output dataset	End of project
F	Set of cross country indicators for public use	End of project

Achievements

All deliverables have been fulfilled by the latest according to the timing presented in Table 2.

(A) A final version of the metadata report is available as separate document, Denisova (2013).

(B) A final version of the code was released on November 22, including the infrastructure for docking new modules to the Common Code.

(C) An extensive output quality report is available as a separate document by Iancu, Hagsten and Kotnik (2013). The project methodology is part of a paper by Bartelsman, Hagsten and Polder (2013) intended to accompany the release of the Micro Moments Database, and informs potential external researchers on how the database is constructed and how to make use of it. The project is also presenting a report on the underlying input data by Airaksinen et al (2013) as well as a document on pattern on productivity and ICT by De Panizza et al (2013).

(E) A quality checked final version of the output dataset will be made available to external researchers through the Eurostat safe centre. This final version of output will be delivered when the project accounts have been audited and closed.

(F) A set of aggregated cross-country indicators will be released through the EU Cros-Portal.

During the process of gathering input data, it became clear that detailed deflators for gross output, intermediates and value added are either scarce or of low quality. This puts a certain burden on not only the ESSLait project, but on all other research projects in need of data below the aggregate level in pursuit of productivity measures. Because of this a separate note on deflators was issued together with the Interim Technical Report in May 2013.

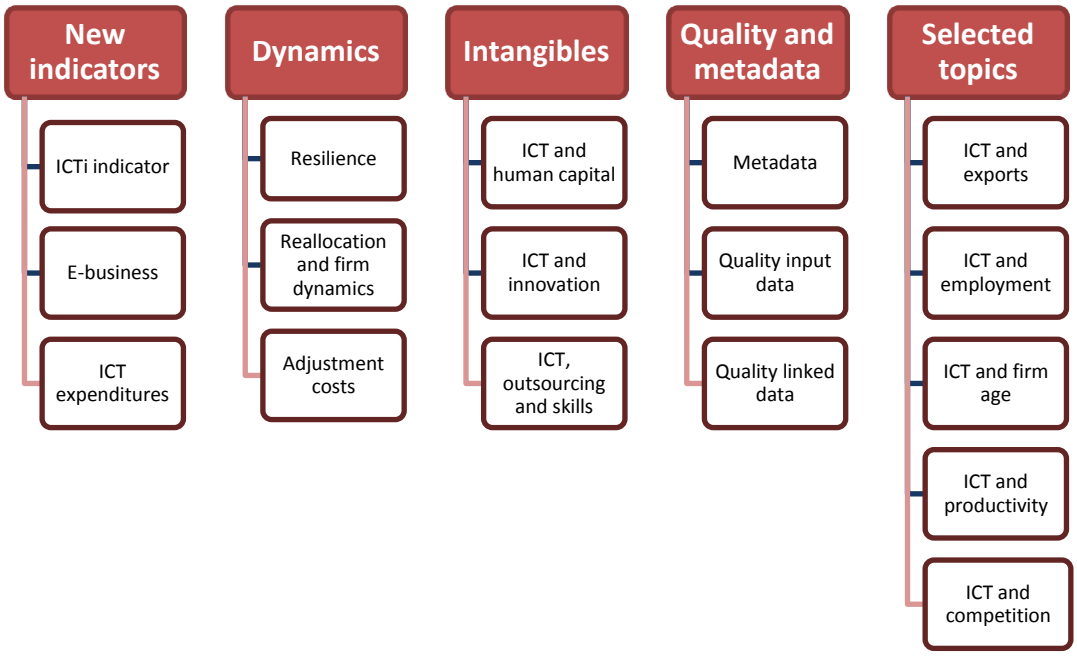
Code and data work

After a thorough metadata update it became clear that the most recent year with full information available for all datasets and across project countries is 2010. An old version of the Common Code was test run on these datasets including 2010 before a first revised version was released on 22 April 2013. An updated version of the code was then released on 16 August 12013. A final version 4.2 of the code was released on 22 November 2013. The purpose of this version was mainly to meet the needs of fine-tuning some of the analytical results.

Analytical themes

The analytical themes pursued are a mixture of already on-going work from the ESSLimit project and new ones. New tentative themes were presented and discussed at the steering meeting in Amsterdam and at the launch workshop in Oslo. Figure 1 illustrates all possible analytical topics, including presumptive new ones, grouped under five main headings, as discussed at the project meeting in Oslo.

Figure 1. Main Analytical Themes



Among the themes initially proposed, a couple were reconsidered and not pursued due to data or resource limitations. These include the research on ICT expenditures (data not available), adjustment costs, and ICT and firm age. Elements of the latter two topics are instead weaved into other themes, however, notably the research on reallocation (adjustment costs) and the replication of the OECD work on the Dynamics of Employment (DynEmp) project (ICT and firm age). The overall results from the analytical work is presented in the main body of this report, but will in most cases also be made available as separate papers.

Conferences and collaboration

Based on analytical work already started or ongoing from the previous round of the project, papers were accepted for the NOEG conference in Innsbruck (May 2013, human capital), ZEW ICT conference in Mannheim (June 2013, e-business) and the IARIW conference in Sydney (November 2013, human capital). Various papers from the project were also accepted for and presented at the CAED conference in September 2013 in Atlanta (Micro Moments Database, E-business, ICT and exports as well as ICT human capital). The e-business paper also re-occurred at the CMD workshop in London (December 2013). Project results have also been presented at the OECD WPIA special session on productivity in November 2013, as well as the OECD WPIIS in December, both meetings in Paris.

Furthermore, the project expertise has been sought by Framework 7 projects E-frame and Mapcompete and by the London School of Economics Network Economy Forum. The steering group has also engaged in an exchange of metadata experiences with the project leader of the ESSnet on Data Warehousing, who was invited to the Amsterdam steering meeting. The project leader has also reported the progress of the project to the Eurostat Working Group of Information Society in October 2013.

Some of the changes in variables and code have been undertaken with intensions to intensify collaboration with the OECD Dynemp research team. Additionally, the project is also cooperating with the ECB system project COMPNet. Together with ZEW in Mannheim a research proposal will be written for the upcoming round of its SEEK program.

Annex 2. ESSLait Reports

Airaksinen, Aarno, Justyna Berezowska, Nina Djahangiri, Edith Edelhofer, Matthias Redecker and Gregor Zupan (2013) "Study on ESSLait Input Data Quality"

Bartelsman, Eric, Eva Hagsten and Michael Polder (2013) "Cross-Country Analysis of ICT Impact Using Firm-level Data: Micro Moments Database and Research Infrastructure"

De Panizza, Andrea, Leila Peltier and Tristan Picard (2013) "ICT Patterns, Productivity and the Financial Crisis"

De Panizza, Andrea, Leila Peltier and Tristan Picard (2013) "ICT Impacts for Different Units of Observation"

Denisova, Ekaterina (2013) "Final Report on ESSLait Metadata Repository"

Iancu, Diana, Eva Hagsten and Patricia Kotnik *(2013 "*Quality of Linked Firm-Level and Micro-Aggregated Datasets: The Example of the ESSLait Micro Moments Database**"**

Annex 3. ESSLait Team and Collaborators

Project Lead		
Eva Hagsten	Statistics Sweden	SE
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Ekaterina Denisova	Statistics Norway	NO
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