PAPERS PRESENTED AT THE
SALTSJÖBADEN CONFERENCE OCTOBER 2012

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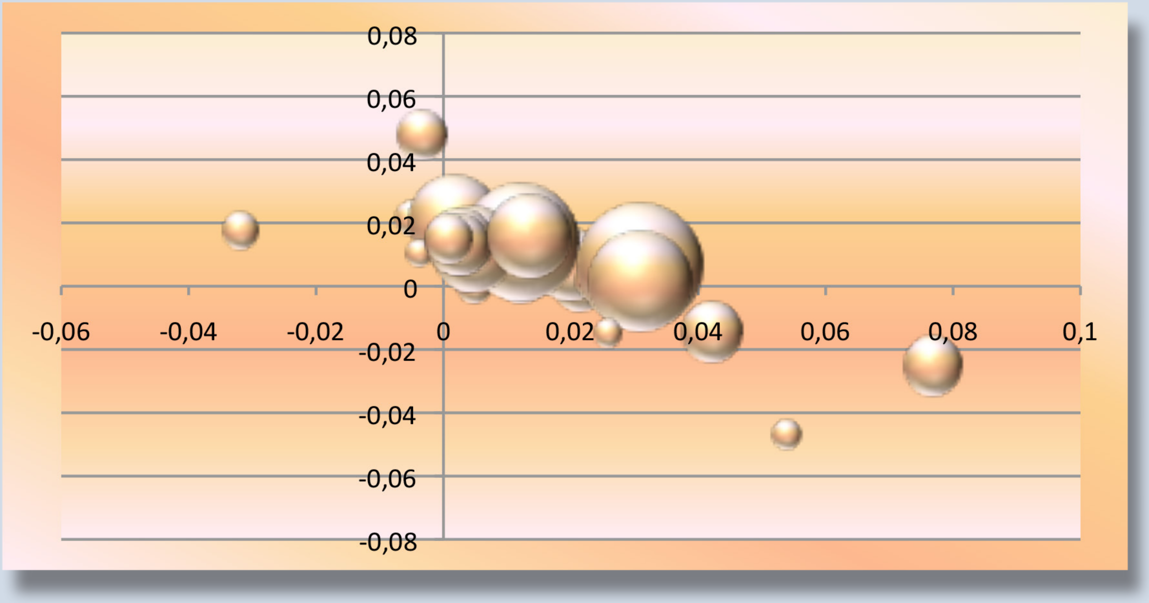

Yearbook on Productivity 2012

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Previous publication	Yearbook on Productivity 2011
Producer	Statistics Sweden, National Accounts Department Economic Analysis Box 24300, SE-104 51 Stockholm +46 8 506 940 00
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Cover: Ateljén, SCB

ISSN 1654-0506 (Online)
URN:NBN:SE:SCB-2012-X76BR1201_pdf

This publication is only available in electronic form on www.scb.se

Foreword

Growth is important. Today's growth is what we have to live on tomorrow. The importance of growth is always important and not least today in a world of economic crises and low or negative growth this is apparent. This is why we have focused on productivity and growth, and this is why Statistics Sweden has decided to create a yearbook on productivity. The yearbook is also an important part of our work on improving the economic statistics in Sweden. The objectives and priorities for this work were outlined by the Commission on the Review of Economic Statistics and this conference; the yearbook is part of this program. This yearbook also contains a number of productivity studies. The articles have been written by colleagues outside Statistics Sweden as well as by people from our own organisation. This year's yearbook is the eighth one and was presented at our yearly conference in Saltsjöbaden.

We want to especially thank Elif Köksal-Oudot at the Economic Analysis and Statistics Division at OECD Directorate for Science, Technology and Industry (STI), Graham Vickery at the Information Economics formerly OECD, Aoife Hanley, Kiel Institute for the World Economy (IfW), Marina Rybalka, Statistics Norway, Benjamin Engelstätter, Centre for European Economic Research Mannheim. Our own contributions this time were presentations of ongoing projects on developing innovation indicators by Emma Luukka and Matthew Carter, on a time series of Input-Output by Mårten Berglund and Andreas Poldahl and a finalised project on multifactor productivity by Hans-Olof Hagén.

Statistics Sweden, December 2012

Monica Nelson Edberg	Hans-Olof Hagén
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Contents

Global value chains within an input and output framework - the case of Sweden

Andreas C. Poldahl[*]

Final version: 2012-11-27[ϕ]

Abstract

We analyse the global value chains in a Swedish perspective using the trade flows embedded in the input and output systems. The results in this paper suggest that the international dependency of the Swedish economy had increased both in terms of exports, imports and offshoring. Our analysis indicates that domestic manufacturing production processes are shifted towards developed countries but at a decreasing rate. Offshoring of manufacturing activities towards growth economies had seen a dramatic increase but from low levels. Finally, our econometric results reporting significant employment effects are linked to the imports of intermediate manufacturing goods and services from the US.

Keywords: input and output tables, MNF employment and bilateral trade of intermediate goods and services.

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[ϕ] A previous version of this paper was presented at a conference held at Saltsjöbaden in Stockholm October 2012. The author would like to thank for valuable comments from Gaaitzen de Vries, Tore Melin and other participants at the conference.

Introduction

Input and output (IO) analysis has received renewed attention in recent years as IO tables are increasingly used in the empirical analysis of different topics, such as material flows, environmental issues, sustainable development, embodied technology etc. The increasing availability of national IO tables is partly due to the improved IT capabilities and improved availability and quality of national IO systems. This process results in more complex input and output analysis. As stated in Backer and Yamano (OECD 2007), less attention has been toward the globalisation issues since published national IO tables do not have the same dimension of product- and industry groups and therefore lack international comparability.

The growth in trade of goods and services has since 1980 accelerated and to some extent exceeds the growth in countries' GDP. One particular determinant of the rapid increase in the globalisation is the increase in FDI during the 1990s. The growth in the world economy is no longer restricted to a few but large countries, but less developed countries as China, India, Poland and Brazil also contribute.

Furthermore, current globalisation displays some distinctive features (OECD, 2007; Grossman and Rossi-Hanberg, 2006 Baldwin, 2006) as production processes are more fragmented geographically, resulting in the emergence of global value chains. A classic example is the mining industry, where extraction, production and processing previously had to be carried out in the same location in order to keep track of the cost. Since the ongoing globalisation enables firms to operate in different countries in order to reduce costs, some of the mining activities are exported within the same firm abroad. Important restructuring has taken place within firms, resulting in what called offshoring or outsourcing depending on which activities are performed within or outside the firm. The process of splitting the production into different geographic areas results in increased trade of final goods and intermediate goods and services.

In general, firm level data may provide the most complete information on the globalisation of value chains. Those data are more volatile since firms are more reluctant to provide precise information on offshoring plans. Input and output tables provide complementary information of the globalisation of value chains as they provide information on the value of intermediate goods and services that have been imported from outside the country. A key advantage of IO tables is the classification of goods and services according to their use. Another key advantage of IO tables is that they enable information on imported and domestic usage of intermediate products.

This chapter brings together some empirical evidence on the importance of global value chains regarding the Swedish business sector. Parallel with the ongoing quality process of national account system in Sweden, the focus in that chapter is to evaluate global value chains within available input and output systems. Furthermore, this paper also presents econometric analysis on the statistical relationship between employment by Swedish MNF (multinational firms) abroad and imports of intermediates. The statistical analysis is performed for important Swedish trade partners.

The remaining part of the paper is organised as follows: the next section presents different indicators of global value chains; thereafter we discuss offshoring for different countries. The chapter concludes with a regression analysis concerning MNF employment and imports of intermediates.

Data

In this paper, we use the input and output tables for Sweden in 1995, 2000, 2005 and 2008 to quantify and measure global value chains and offshoring. The input and output tables show transactions, wherever possible, product-by-product symmetric tables at basic prices under the assumption of industry technology.[1] We use information of the import of intermediate goods and services which are available every fifth year.[2]

The available matrices for years from 1995 to 2005 follow the standard international classification scheme, i.e. the industry and product code is ISIC Rev1.1 and CPA2002. In 2008 the industry and product groups were changed to ISIC Rev 2 and CPA2008. [3] All in all, we have data from older versions of IO tables on 55 products and 55 industries. The matrix from 2008 consists of 58 products and 58 industries.

Complementary statistical information was collected from the OECD databases: *Bilateral trade in intermediate goods and services* and *Bilateral trade database by industry and end-use category*. The selected trade partners are US, UK and France and the less developed countries are Poland, China and India. Data on the number of employees in Swedish Multinationals at industry level has been provided by the Growth Analysis surveys of Swedish MNF.

[1] The reported values in the import use tables may possess some measurement errors which are related to corporations' application of transfer pricing which is not captured in the statistics.
[2] The official published import use tables are based on a survey of a subset of imported final products as well as intermediate products. In order to construct complete import use tables, Statistics Sweden applies the import proportionality assumption as auxiliary information.
[3] Since 2011, Statistics Sweden performed a major revision of the national account systems, which results in more product and industry groups. The change in classification implies a significant change in allocation between industries and products. Compared with the earlier classification, the service industries/products have become more disaggregated at the expense of the manufacturing industries/products. The production value of services has also increased, while the production value of goods has decreased.

Indicators on global linkages

Classical indicators of international linkages between countries are the export share of production and import penetration. The former measures the share of production of goods and services that are on sale abroad, the latter measures the extent of domestic demand that is served by imports from other countries. The mathematical formulas are presented in the appendix and therefore not presented in the text.

Table 1: Import penetration

	1995	2000	2005	2008*
ICT industries	44.0	58.7	55.4	53.0
High tech industries	40.2	40.4	40.4	40.5
Low tech industries	19.9	22.2	26.6	33.5
Manufacturing	29.5	31.0	31.6	36.3
Services	3.9	5.5	5.8	6.3
Total economy	14.5	16.5	16.9	18.4

Source: Statistics Sweden Input and Output Database. * indicates that a different product/industry classification code is available for IO system in year 2008.

Table 2: Export share

	1995	2000	2005	2008*
ICT industries	43.4	30.7	34.5	52.7
High tech industries	42.9	47.3	48.5	49.2
Low tech industries	28.9	32. 0	33.3	23.5
Manufacturing	36.8	39.7	40.6	42.1
Services	6.4	8.3	9.7	10.7
Total economy	18.1	20.1	20.8	21.6

Source: see comment for table 1

Table 1 and 2 above reveal that both import penetration and export share have increased in terms of goods and services. The international exposure in sectors such as *High tech industries* and *ICT industries* can be explained by the Swedish comparative advantage in production of high skilled products (ITPS 2007). During the period, the service sector became more important as an integral part of the economy and more oriented toward global markets, which also could be verified in the growth rates of exports and imports. The previous measures are aggregate indicators which involve trade in final goods. Aside the above measure, the foreign dependency among different countries can be better described only in terms of intermediates (Backer and Yamano 2007).

Table 3: Imported intermediates in relation to domestic intermediates

	1995	2000	2005	2008*
ICT industries	98.1	103.0	97.8	121.5
High tech industries	94.3	98.5	99.5	100.0
Low tech industries	25.8	49.3	58.3	39.0
Manufacturing	50.2	63.4	68.6	76.2
Services	19.5	22.5	23.5	25.4
Total economy	32.7	38.9	40.4	42.8

Source: see comment for table 1

The same storyline as in table 1 and 2 appears whenever using the ratio of imported intermediates to the domestic intermediates presented in table 3. At the aggregated level, we have seen an increased share of imported intermediates in relation to domestic intermediates. Even although the ratio of imported intermediates had increased over time, nearly all sectors had seen an upward trend in the imported intermediates; the low technology sector (i.e. less skilled intensive industries) had experienced the fastest growth. As expected, many of the older low skilled intensive activities in Sweden (textile, shipbuilding etc) have been offshored and replaced by increased import substitution.

Higher order effects linked to imports of intermediates

Confining our attention to tables 1-3 above, we discussed the direct consequences of the growing international dependency linked to trade of goods and services. For example, the purchase of intermediate products from domestic producers which in turn may import themselves a given fraction of the inputs means that there may be higher order effects related to the trade. Hence, imports of intermediates not only have direct impact on national economies but also to some extent indirect induced effects. Total direct and indirect imports are well known as "embodied imports" and are calculated as:

$$ICP = \mathbf{UA}^{m}_{direct}\,(\mathbf{1\text{-}A}^{d}_{direct})^{-1}\mathbf{y} \qquad (1)$$

$$ICE = \mathbf{UA}^{m}_{direct}\,(\mathbf{1\text{-}A}^{d}_{direct})^{-1}\mathbf{ex} \qquad (2)$$

where **U** denotes a 1 x n vector each of whose component is unity. $\mathbf{A}^m$ and $\mathbf{A}^d$ are n x k input and output coefficients for imported and domestic transactions respectively. Matrices **y** and **ex** are n x 1 vectors of output- and export share.

Table 4: Import content of production (ICP)

	1995	2000	2005	2008*
ICT industries	37.5	38.0	34.3	48.2
High tech industries	33.4	39.3	37.6	46.3
Low tech industries	25.8	32.0	36.9	30.6
Manufacturing	31.3	35.9	38.8	42.3
Services	12.0	13.9	14.4	16.0
Total economy	18.2	20.8	21.6	23.0

Source: see comment for table 1

Table 5: Import content of exports (ICE)

	1995	2000	2005	2008*
ICT industries	37.7	37.9	34.7	48.2
High tech industries	33.6	40.0	38.0	46.3
Low tech industries	27.1	35.1	43.1	32.2
Manufacturing	33.2	38.3	41.1	45.0
Services	19.1	18.6	19.3	21.7
Total economy	30.2	33.4	34.7	37.2

Source: see comment for table 1

Table 4 shows that the embodied imports in production have increased over time in all sectors except *in ICT industries*. The picture remains the same as compared to previous tables, the dramatic increase in the embodied import attributes foremost to the low skilled sectors. As frequently commented in the literature (see Ekholm and Hakkala) a large proportion of production of low tech products in Sweden have been substituted by imports or outsourced to other low wage countries. The import content of production in the *Low tech industries* increase on average by 3.6 percent yearly, which means that 37 percent of the total value of production in 2005 are imports. The embodied imports in manufacturing and services had also increased but at the slower rate.

IO links can also be used to estimate the effective contribution imports make in the production of goods and service for export markets. The emergence of global value chains means that imports and exports increasingly move together since the production processes of companies is increasingly characterised by fragmentised geographic production, i.e. vertical specialisation (see Hummels et.al 1998, 2001). Firms in different countries or locations imports intermediate products and re-export within the MNF. The pattern of import content of exports, although reported at aggregated level, reveal the same pattern as for the embodied imports for production.

Offshoring and outsourcing

The last indicator of global linkage is offshoring. The measure of offshoring stems from Feenstra and Hansson (1996, 1999) who relating the value of imports of intermediates to the production value. Following the terminology adapted by Ekholm and Hakkala (2006), we distinguish between narrow and broad measure of offshoring. Narrow offshoring refers to imports from the individual industry itself abroad and broad measure of offshoring refers to imports from all industries abroad.

$$z_i^N = \frac{m_{ii}}{Y_i} \qquad z_i^B = \frac{\sum_{j=1}^{N} m_{ij}}{Y_i}$$

where m_{ij} is industry i´s use of imported intermediate input from sector j abroad. Y_i is the i´s sector of production.

Table 6: Offshoring in 1995, 2000 and 2005, imported inputs as a percentage of output

Share in output		1995	2000	2005	Yearly average change in per	Change '05/'95 in percent
Total economy	Narrow	3.3	3.7	3.7	1.1	12.1
	Broad	11.7	13.6	14.1	1.9	20.5
Manufacturing	Narrow	9.1	9.8	10.5	1.4	15.4
	Broad	22.1	26.0	28.3	2.5	28.1
Services	Narrow	0.6	0.9	0.9	4.1	50
	Broad	6.7	7.8	8.1	1.9	20.9

Source: Statistics Sweden Input and Output Database.

Table 7: Offshoring in 1995, 2000 and 2005, imported inputs as a percentage of total domestic input usage

Share in input		1995	2000	2005	Yearly average change in per	Change '05/'95 in percent
Total economy	Narrow	35.5	38.6	37.6	0.6	5.9
	Broad	23.9	27.1	28.0	1.6	17.2
Manufacturing	Narrow	46.7	54.5	53.2	1.3	13.9
	Broad	33.4	38.8	40.7	2.0	21.9
Services	Narrow	13.7	14.3	15.4	1.2	12.4
	Broad	16.3	18.4	19.1	1.6	17.2

Source: Statistics Sweden Input and Output Database.

The offshoring had increased over time, both expressed as in relation to the industries output as well as in relation to industries' total use of input. As explained in Ekholm and Hakkala (2006), the narrow measure of outsourcing shows that the Swedish service sector had the most dramatic increase, but at low levels. Measured in absolute terms, the manufacturing sector had an increase of offshoring by approximately 1.3 percentage points. Although the service sector is increasing its importance for the total economy, the manufacturing sector perhaps continues to be the most important driver of structural change. All these facts in turn may indicate an increasing vertical specialisation within firms.

Table 6 only reports the sum of imports of intermediates from the rest of the world. Therefore, the next table aims to point out which country groups explain the upward trend in the Swedish imports of intermediates goods and services. According to the standard international trade literature (see Feenstra, 1998), the distribution of imports may differ among supplying countries. For example, it seems more reasonable to assume that skill-intensive products more likely are imported from advanced countries than from less developed countries. The country groups selected for analysis is based on IMF country ranking list, where the IMF had grouped countries into developed economies, emerging markets and developing economies (more details of the list, see www.imf.org).

Table 8: Offshoring in 1995, 2000 and 2005, imported inputs as a percentage of output from different regions.

Import of primary products:	1995	2000	2005	05'/00'	05'/95
World	0.9	1.3	1.5	14.4	76.7
Developed countries	0.5	0.9	0.9	-5.9	81.3
Emerging markets	0.2	0.3	0.6	124.5	194.2
Developing countries	0.2	0.1	0.0	-66.0	-76.2
Import of industry products:					
World	6.8	7.0	6.8	-2.7	-1.0
Developed countries	6.2	6.4	6.0	-6.2	-3.6
Emerging markets	0.3	0.4	0.7	66.0	167.7
Developing countries	0.3	0.1	0.0	-76.2	-92.8
Import of service products:					
World	3.2	4.5	4.3	-3.5	34.8
Developed countries	n.a	3.5	3.8	9.3	.
Emerging markets	n.a	0.2	0.3	96.0	.
Developing countries	n.a	0.9	0.2	-73.6	.

Source: OECD bilateral trade in intermediate goods and services.

Table 8 reveals that main part of imports of intermediate products and services stem from manufacturing sectors in developed countries. The developed countries even seem to be more important for imports of service intermediate products into the Swedish economy. The broad measure of offshoring indicate an somewhat dampening growth of imports from developed countries during later years, the figures indicate that imports of intermediates more likely shifted toward the less developed countries. The conclusion stated above is well in line with Ekholm and Hakkala (2006); they argue for the fact that offshoring to Asia and Central and Eastern Europe had increased over time using employment as proxies of offshoring.

Empirical analysis

This section explores the statistical relationship of employment abroad by Swedish MNF and the Swedish imports of intermediate products and services. The imports are in turn divided into country specific supplying sectors. The selected countries for this empirical exercise is based on the fact that they are both important for Swedish MNF activities abroad and also important as trade partners (for more details on Swedish affiliates' activities abroad see the Swedish Agency for Growth Analysis report; "*Svenska koncerner med dotterbolag i utlandet*"[4]). The selected countries also aim to illustrate the systematic difference between MNF employment in a sample of important emerging countries as well as developed countries. The regression analysis is based on a pooled cross section analysis containing industry level data for each country over time. The dataset contains all 2-digit Swedish industries (ISIC rev. 2.1); primary sector (01-05), manufacturing sectors (15-37) and the service sectors (45-99). The regression specification is as follows:

$$ln(e_{itc})\alpha + \beta_1 ln(p_{itc}) + \beta_2 ln(p_{itc})D_c + \beta_3 ln(m_{itc}) + \beta_4 ln(m_{itc})D_c$$
$$+\beta_5 ln(s_{itc}) + \beta_6 ln(s_{itc})D_c + \beta_7 ln(size_{it}) + dummies$$

where subscript *i* and *t* refer to industry (0-99), time (1995, 2000 and 2005) and *c* denotes country (Poland, China, France and US). More details on variables and their definitions are provided in the appendix. The regression coefficients are estimated by the LSDV approach with robust standard errors.

[4] The above selected countries amount to 31.6 percent of the total of Swedish MNF employment abroad in year 2010.

Table 9: Regression results, the effect of imports of intermediates from supplying sectors in China, Poland, France and US

Supplying sectors abroad:	(1)	(2)	(3)
p	0.313***	-	-
	[0.11]	-	-
[p][China]	-0.377**	-	-
	[0.18]	-	-
[p][Poland]	0.00713	-	-
	[0.19]	-	-
[p][US]	0.0765	-	-
	[0.12]	-	-
m	-	0.595***	-
	-	[0.14]	-
[m][China]	-	-0.107	-
	-	[0.22]	-
[m][Poland]	-	-0.251	-
	-	[0.26]	-
[m][US]	-	0.530***	-
	-	[0.19]	-
s	-	-	0.460***
	-	-	[0.14]
[s][China]	-	-	-0.165
	-	-	[0.21]
[s][Poland]	-	-	0.0646
	-	-	[0.29]
[s][US]	-	-	-0.0723
	-	-	[0.15]
size	2.203***	2.068***	2.228***
	[0.40]	[0.40]	[0.44]
Year dummy: 1995	-	-	-
	-	-	-
Year dummy: 2000	0.346	0.24	0.0698
	[0.25]	[0.23]	[0.25]
Year dummy: 2005	0.598**	0.312	0.0813
	[0.25]	[0.25]	[0.31]
Industry dummies	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes
Observations	165	165	165
R-squared	0.65	0.70	0.64

Adjusted standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01. The reference country dummy is France.

Table 10: the total marginal effect of imports of intermediates

Supplying sectors abroad:	(1)	(2)	(3)
p + [p][China]	-0.063	-	-
	[0.21]	-	-
p + [p][Poland]	0.321	-	-
	[0.23]	-	-
p + [p][US	0.389**	-	-
	[0.17]	-	-
m + [m][China]	-	0.488**	-
	-	[0.21]	-
m + [m][Poland]	-	0.344	-
	-	[0.24]	-
m + [m][US]	-	1.124***	-
	-	[0.18]	-
s + [s][China]	-	-	0.295
	-	-	[0.20]
s + [s][Poland]	-	-	0.525*
	-	-	[0.31]
s + [s][US]	-	-	0.388***
	-	-	[0.14]

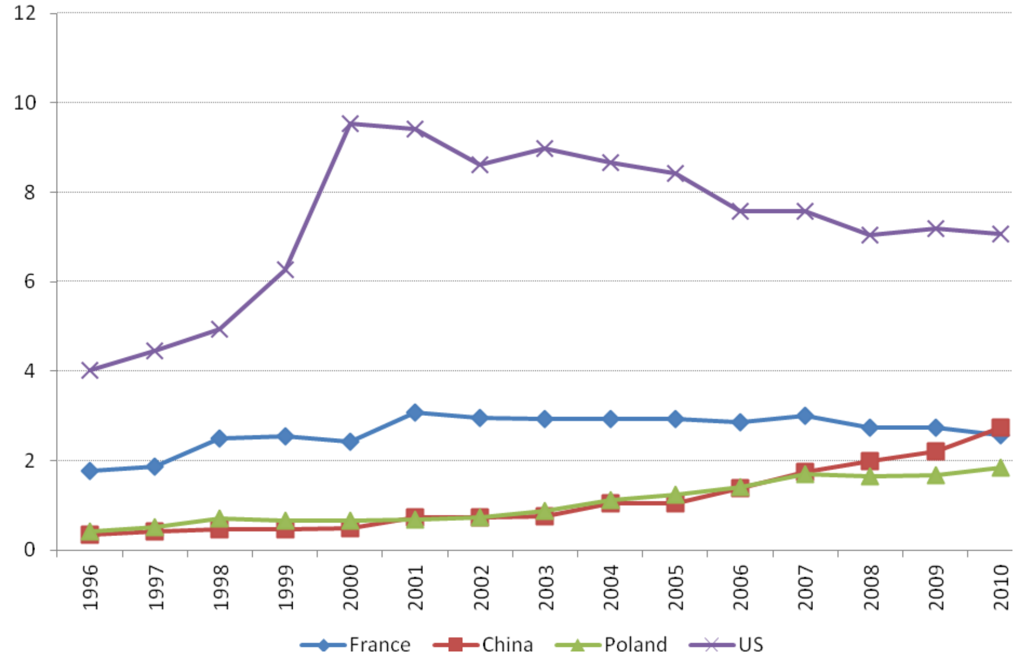
Adjusted standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01. The reference country is France. The linear combinations are based on regression output in table 9.

There is some empirical evidence in favour of Swedish firms which re-allocate some of their internal activities abroad, meaning that import intensive sectors are found to be positive correlated with employment share in Swedish multinationals abroad. The employment effects are found to be somewhat higher for domestic sectors that import manufacturing intermediate products than sectors that import intermediate products from primary sectors. The same story also holds whenever comparing the employment effects via imports of intermediate products from abroad service sector. Furthermore the employment effects also differ depending on trading partner; our results suggest that intermediate products imported from US manufacturing sectors had more effect on employment share than imports from Poland and China. Importing intermediates from the US service sector only matters for employment growth in Swedish MNF active in US. Otherwise, our result does not detect any further systematic differences among trading partners.

Perhaps our results support the idea that Swedish multinational firms more likely re-allocate manufacture activities than comparing to service activities toward other countries. Firms planning to locate the service activities abroad probably do not seek cheap substitutes abroad but instead replace exports by local service production. Otherwise, our results should be interpreted with some caution since analysis does not treat the causality issue, i.e. the statistical direction between employment abroad and imports of intermediate.

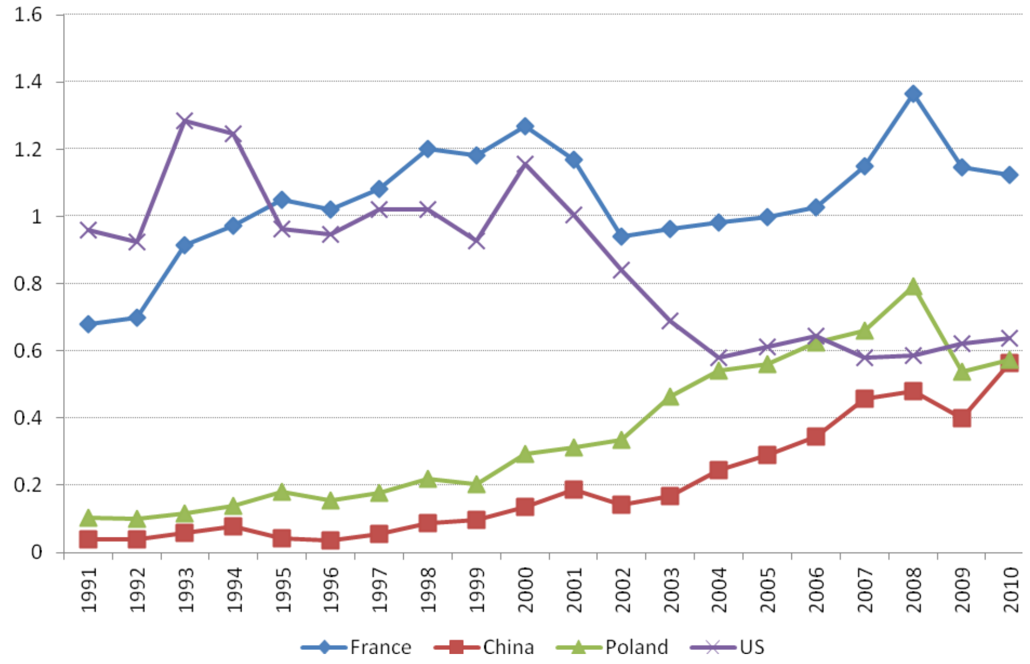
To complement and finish our previous discussion we present two figures: figure 1 illustrates the employment share abroad by country and figure 2 reports the imports of intermediate of goods. The largest share of employment of Swedish MNF is found in the US. The figures reveal that China and Poland had increase their shares of Swedish MNF employment, and this indicates that since beginning of 2000 the share of employment in the US had shifted toward an increased employment share in China and Poland. Comparing this to the trade statistics in figure 2, nearly same pattern holds. The importance of the US as a trading partner had decreased during the last decade. The sharp decrease in imports of US intermediates is compensated by increased imports from Poland and China.

Figure 1: The share of employment in Swedish affiliates abroad in relation to total domestic employment



Source: Growth Analysis surveys of Swedish MNF.

Figure 2: The percentages of import of intermediate goods in relation to value added



Source: OECD bilateral trade database by industry and end-use category.

Concluding remarks

This paper examines the global value chains from a Swedish perspective using the trade flows embedded in the input and output models. One striking feature of the world economy is the ongoing shift of activities of domestic production going global. Not only are the final goods traded internationally, but intermediate goods including both parts and components and in recent years services are also increasingly traded internationally. By using the trade statistics from input and output tables rather than traditional trade indicators reveal detailed information on the use of goods. The results in this paper indicate that Swedish international dependency had increased both in terms of direct measure of foreign dependency (exports and imports) and indirect via imported intermediates. Particularly, the evidence points at *High technology industries* using to a large extent international traded inputs in domestic production of final goods. In 2008, nearly a half of the production value consists of imported inputs. Finally, our econometric analysis reports the significant relationship between the Swedish MNF employment in the US and imports of manufacturing intermediate products from the US. Likewise, the statistical tests of imports of intermediate primary products as well as intermediate service products indicate a positive association with employment patterns within the Swedish MNF in the US.

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Appendix

Table 11: Industry classification

Isic rev1.1	Definition
1-5	Agriculture and fishing
10-14	Mining and quarrying
15-16	Food products
17-19	Textiles & wearing apparel
20-22	Wood, publishing & printing
23	Refined petroleum & other treatments
24	Chemical products
25	Rubber & plastic products
27-28	Metal products
29	Mechanical products
30	Office machinery & computers
32	Radio, TV, communication equipment
33	Medical & precision instruments
34	Motor vehicles
35	Other transport equipment
36-37	Other manufacturing.
40-41	Electricity, gas & water
45	Construction
50-52	Trade and repairs
55	Hotels and restaurants
60-63	Transport, storage & auxiliary activities
64	Post and telecommunications
65-67	Insurance & Finance
70	Real estate
71	Renting of machinery & equipment
72	Computer activities
73	Research & development
74	Other business activities
75-99	Other services

Table 12: Variable definitions

Variable	***Definition***
mne	Number of employed persons located abroad in Swedish MNF
p	Imports of intermediate primary products and services
m	Imports of intermediate manufacturing products and services
s	Imports of intermediate service products and services
size	Industry employment in relation to the average employment

Table 13: Summary statistics

	Observations	Mean	Standard Deviation	Min	Max
France					
mne	51	3196	4811	32	21831
p	73	192	354	0	1676
m	73	101501	91753	6400	435031
s	72	31759	39915	677	265924
China					
mne	24	1807	1928	34	5274
p	73	56	127	0	877
m	73	16026	23190	336	133076
s	72	4750	9898	32	67751
Poland					
mne	42	1217	1306	16	5226
p	73	1643	3053	2	15840
m	73	28175	37553	1086	219410
s	72	6978	9230	116	60492
US					
mne	48	10320	22720	36	110607
p	73	192	354	0	1676
m	73	78584	70900	5707	298099
s	77	107674	174377	363	1000000
Sweden					
size	73	1	2	0	10

Formulae

$$\text{Import penetration} = \frac{\sum M_i}{\sum D_i}$$

$$\text{Export share} = \frac{\sum EX_i}{\sum X}$$

where M, D, EX and X represent total imports of goods and services, total demand, total exports and total supply.

$$\text{Ratio of imported intermediates} = \frac{\sum_i \sum_j x_{ij}^m}{\sum_i \sum_j x_{ij}^d}$$

where x_{ij}^m and x_{ij}^d are respectively the imported and domestic transaction of intermediates from sector i to j.

Climate impact trends of Swedish consumption: building a time series of input–output tables for environmental applications

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Revision: 2012-10-02[†]

Abstract

In recent years, increased attention has been given to growth in consumption as being responsible for the increasing human global climate impact. In this study, the development of the global climate impact of the Swedish final demand is assessed using an environmentally extended input–output model. The environmental input–output model developed is done in a single regional framework where CO_2e emissions from imports have been estimated using emission intensities for the Swedish import countries. Included in the CO_2e emissions are CO_2, CH_4 and N_2O. To build the time series, a method for updating input–output tables has beenis developed based on the known domestic–imports shares from the official input–output tables published every five years. A sensitivity analysis is undertaken based on a variation of assumptions, e.g., the valuation of GDP based on purchasing power parity rates or market exchange rates.

The most conservative results show an increase in CO_2e emissions of 12 percent in the period studied, from 84 million Mtons in 1993 to 94 million Mtons in 2005. These results arego contrary to the Swedish official UNFCCC territorial emission statistics which show a decrease of 8 percent during the same period. The results suggest that Sweden has not yet decoupled economic growth from increasing global climate impact.

Keywords: Input–output analysis time series, updating input–output tables, emissions embodied in trade, consumption-based accounting, purchasing power parity, greenhouse gases, Sweden.

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[†] A previous version of this paper was presented at the 20th International Input–Output Conference in Bratislava, Slovakia, 2012.

Introduction

Consumption-based accounting and environmental applications of input–output analysis have gained wide-spread interest among sustainability researchers in recent years.[1] The rationale behind the growing interest can be interpreted as an urge to understand the discrepancy between the sometimes decreasing environmental pressure from typical Western countries with high and increasing standards of living, and ever increasing global environmental pressure. The question is whether the decreasing environmental pressure of some countries can be explained in terms of consumption being met by production in other countries.[2]

Although a lot of studies have been published world-wide the last decade in the area of environmental input–output analysis and consumption-based accounting,[3] but only a few have produced time series.[4] The same situation holds for Sweden,[5] but in the last year severala couple of time series studies have been published.[6] In a couple of the studies by Peters et al., a time series from 1990 to 2008[7] and to 2010,[8] covering 113 countries, is built by means of extrapolation based on single-year multiregional input–output tables for the years 1997, 2001 and 2004 from the GTAP database.[9] The studies by Peters et al. are multiregional analyses and therefore should be considered more robust, at least for the years 1997, 2001 and 2004. This present study of the consumption-based emissions in Sweden, although single-regional, contributes to the picture of the climate impact of the Swedish consumption, building on consistent time series of national accounts and environmental accounts data from a single source (Statistics Sweden). It is also the first continuous Swedish time series that includes all the three most important greenhouse gases (CO_2, CH_4, and N_2O), without using the more simple domestic technology assumption.[10]

In this paper, I will briefly present the main methodological findings and results from this ongoing research project[11] where the environmental pressure over time resulting from the Swedish final demand is estimated. Here, I will concentrate on the climate impact from the Swedish final demand, duringin the period 1993–2005, based on the emissions of CO_2, CH_4 and N_2O. A sensitivity analysis is performed by means of a variation of various methods and assumptions, resulting in a range of various emission curves.

This paper is also part of an ongoing effort at the Nnational Aaccounts Uunit at Statistics Sweden to compile and publish yearly input–output tables from 1993 and onwards in both the NACE 1.1 and NACE 2 revisions.

In the following section, I will describe the methodology of the environmental extension of input–output analysis and its foundation in the national accounts and

[1] Leontief, 1970 gives an early account. See Wiedmann, 2009 and Wiedmann et al., 2011, for two recent overviews.
[2] This is sometimes in a general sense called carbon leakage. For a discussion, see e.g. Peters & Solli, 2010, Davis & Caldeira, 2010, and Weber & Peters, 2009.
[3] See Wiedmann, 2009 for an overview.
[4] Notable exceptions are Weber & Matthews, 2007, Wiedmann et al., 2010, Peters et al., 2011, and Peters et al., 2012.
[5] Single-year studies include Statistics Sweden, 2000, Carlsson-Kanyama, 2007, and Swedish EPA, 2008. An overview of studies in the Nordic countries is performed in Peters & Solli, 2010.
[6] Peters et al., 2011, Peters et al., 2012, Berglund, 2011, and Swedish EPA, 2012.
[7] Peters et al., 2011.
[8] Peters et al., 2012.
[9] Global Trade Analysis Project.
[10] However, preliminary results from this research were first published in Berglund, 2011.
[11] Started as a master thesis at the Global Energy Systems group at Uppsala University, and now continued at the environmental accounts of Statistics Sweden. See Berglund, 2011.

environmental accounts system. I will also describe the updating method used to build a time series of input–output tables. Subsequently, a section follows presenting the results and the conclusions. The paper is concluded with a section of further questions to investigate and possible extensions of the research project.

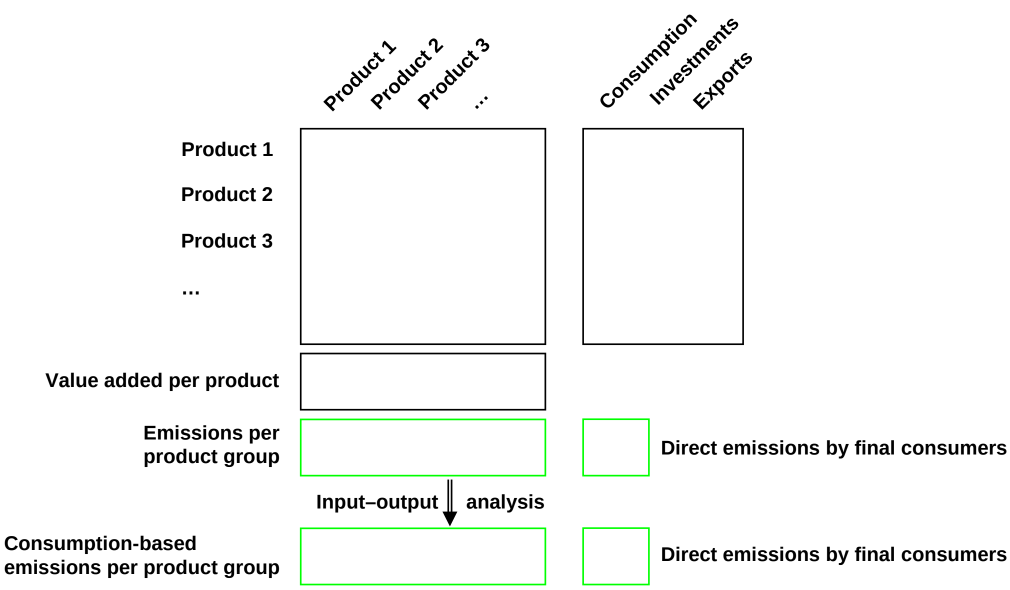
Methods and data

The general framework

Consumption-based emissions data can be regarded as one step inof a series of steps in collecting and compiling environmental data:[12]

1. The collection of emission statistics based on the territory of a country – *territorial emissions*.
2. The restructuring of emissions statistics data from the territory of a country to the production sectors of a country – *production-based emissions* and direct emissions by final consumers.
3. Transforming emissions per producing sector to emissions per final demanded product group, by means of input–output analysis, and adding the direct emissions by final consumers – *consumption-based emissions*.

This can be understood by organiszing national accounts data and environmental data into a single NAMEA-framework,[13] as depicted in Figure 1. The territorial emissions can there be regarded as the emissions on the second lowermost row in the figure. On that same row, the emissions have been divided ionto various product groups – these are the production-based emissions – and ionto direct emissions by final consumers. Through input–output analysis, the emissions per product group are transformed into emissions per final consumed product group, depicted to the left in the lowermost row in the figure. The entirewhole lowermost row, including the direct emissions by final consumers, arerow, including the direct emissions by final consumers, is the consumption-based emissions.



[12] See Peters & Hertwich, 2008, and Peters, 2008, for a similar approach.
[13] National Accounting Matrix with Environmental Accounts.

Figure 1. NAMEA-framework with an environmentally extended input–output table.

Workflow used in this study

In this study, data of consumption-based emissions are generated and subsequently a sensitivity analysis of these consumption-based emissions data,data is performed. The data compilation and the calculations done,done can be divided into the following steps:

- Obtaining national accounts data, and building time series of input–output tables.
- Obtaining environmental accounts data.
- Performing the environmental input–output analysis.
- Taking into account the emission intensities in the imports.
- Sensitivity analysis.

Building a time series of input–output tables[14]

Since Swedish input–output tables are only published every fifth year, only the 1995, 2000 and 2005 tables were available forin the period studied. In order to make a complete time series of input–output tables, the supply and use tables which are produced annually, are used to compile input–output tables.[15] However, the input–output tables thus obtained are in market prices and lack information of the division between domestic and imported inputs. The following paragraphs describe the method used in this study to build a time series of input–output tables including both domestic and imported inputs. See Figure 2, for a visual presentation of the procedure.

The calculations are done in three steps.[16]

1) For every year in the period 1993–2005, the intermediate matrix in the input–output table is calculated as

(*i*) $$\boldsymbol{F} = \boldsymbol{U}\,\boldsymbol{S}_c'$$

where $\boldsymbol{U}$ is the use matrix of the use table, and $\boldsymbol{S}$ is the make matrix of the supply table.[17] $\boldsymbol{S}_c$ is the coefficient matrix of the make matrix, i.e. a matrix describing the share of each product to the total output of an industry. In mathematical terms it means $\boldsymbol{S}_c = \boldsymbol{S}\,\hat{\boldsymbol{x}}_{ind}^{-1}$, where $\hat{\boldsymbol{x}}_{ind}$ should be interpreted as the vector of output from industries, diagonalized as a matrix. Through equation (*i*) the intermediate matrix of the input–output table has now been obtained in market prices for every year between 1993–2005. The final demand part of the input–output table is obtained from the final demand part of the use tables.

2) Taking the year 1995 as an example, a domestic–imports ratio input–output table is generated, based on the domestic–imports shares in the official input–output table for that year, and on the input–output table in market prices generated in step 1) above for

[14] This procedure is about to be improved and revised as part of an ongoing effort at the Nnational Aaccounts Uunit at Statistics Sweden to publish yearly input–output tables from 1993 and onwards. Data resulting from that project were not yet produced uponat the publication of this paper, and thereforethe reason why the revised procedure is not presented here.

[15] Official input–output tables and supply and use tables are from Statistics Sweden, 2006a, 2006b, 2008, 2009, and 2011a.

[16] See Berglund, 2011 for a more thorough description.

[17] This is the industry technology assumption. See Berglund, 2011, for a more detailed explanation.

that year. The domestic–imports ratio input–output table contains three layers. The lowermost layer, contains for every cell, the share of domestic input in that cell. The middle layer, contains, for every cell, the share of imported input in that cell. The uppermost layer contains, for every cell, the share of taxes less subsidies in that cell. The uppermost layer marks the difference between the input–output table in basic prices and in market prices. The domestic layer is obtained through dividing element-wise every cell in the domestic part of the official input–output table with the corresponding cell in the market-price input–output table generated in step 1) above. The corresponding procedure is done for the imports layer.

To obtain an input–output table for, say, year 1997, these shares are then, for each cell, multiplied element-wise by the cells in the market-price input–output table for year 1997, obtained through equation (*i*) above. Through this operation an input–output table is obtained in basic prices, with a division between domestic and imported inputs.

The same procedure is followed for the other official input–output tables from 2000 and 2005. From the official 1995 input–output table, input–output tables for the years 1993–1997 are generated. From the official 2000 input–output table, input–output tables for the year 1998–2003 are generated. From the official 2005 input–output table, input–output tables for the year 2004–2005 are generated.

3) As a final step, every input–output table for any given year generated in the preceding steps, isare then calibrated. This is done by making sure the domestic and imported part of the input–output table sums up to the total domestic output and the total imports respectively for that year.

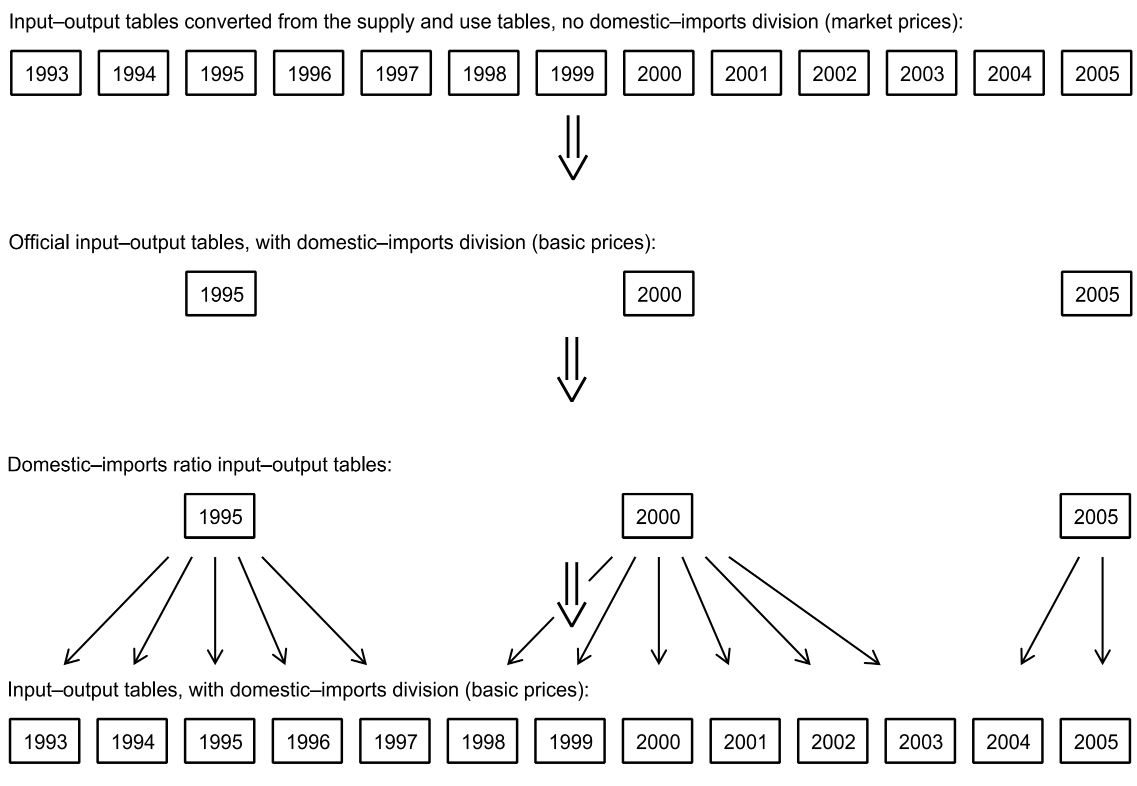


Figure 2. Outline of the procedure used for generating time series of input–output tables.

Environmental accounts data

Emissions data were obtained from the environmental accounts[18] as emissions per industry, $\boldsymbol{E}_{ind}$. These were transformed to emissions per product through[19]

(*ii*) $$\boldsymbol{E}_p = \boldsymbol{E}_{ind}\,\boldsymbol{S}'_c.$$

Emission intensities were then obtained through

(*iii*) $$\boldsymbol{E}_i = \boldsymbol{E}_p\,\hat{\boldsymbol{x}}_p^{-1}.$$

The environmental input–output analysis[20,21]

In order to proceed with the environmental input–output analysis, it is feasible to make a mathematical description of the input–output tables. These can be described as

(*iv*) $$(\boldsymbol{F}_d + \boldsymbol{F}_m)\boldsymbol{i} + (\boldsymbol{y}_d + \boldsymbol{y}_m) = \boldsymbol{x}_p + \boldsymbol{m}\ ,$$

where $\boldsymbol{F}_d$ and $\boldsymbol{F}_m$ are the domestic and imported part respectively of the intermediate matrix of the input–output table, $\boldsymbol{y}_d$ and $\boldsymbol{y}_m$ are the domestic and imported part respectively of the final demand matrix of the input–output table, $\boldsymbol{x}_p$ is the domestic output per product group, $\boldsymbol{m}$ is the imports, and $\boldsymbol{i}$ is the unit vector.

The corresponding technological matrices describing the amount of input needed in production per dollar's worth of output, are then

(*v*) $$\boldsymbol{A}_d = \boldsymbol{F}_d\,\hat{\boldsymbol{x}}_p^{-1}$$

and

(*vi*) $$\boldsymbol{A}_m = \boldsymbol{F}_m\,\hat{\boldsymbol{x}}_p^{-1}.$$

Through equation (*iv*), (*v*) and (*vi*) it is possible to describe the domestic output of the economy as

(*vii*) $$\boldsymbol{A}_d\,\boldsymbol{x}_p + \boldsymbol{y}_d = \boldsymbol{x}_p\ .$$

Rearranging gives us that

(*viii*) $$\boldsymbol{x}_p = (\boldsymbol{I} - \boldsymbol{A}_d)^{-1}\,\boldsymbol{y}_d,$$

meaning that the output is a function of the final demand, given a certain fixed industrial structure $\boldsymbol{A}_d$. $\boldsymbol{L}_d = (\boldsymbol{I} - \boldsymbol{A}_d)^{-1}$ is the Leontief inverse (domestic version). If the rest of the world were to have the same input–output table as the Swedish, it can be shown that the total output needed in the whole world due to Swedish final demand of Swedish and imported products, are $\boldsymbol{L}_{tot}\,\boldsymbol{y}_{tot}^{nexp}$, where $\boldsymbol{L}_{tot} = (\boldsymbol{I} - \boldsymbol{A}_d - \boldsymbol{A}_m)^{-1}$, and $\boldsymbol{y}_{tot}^{nexp}$

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[18] Statistics Sweden, 2011b.

[19] Östblom, 1998, uses a similar approach.

[20] A general introduction to environmental input–output analysis is given in Miller & Blair, 2009 and in Peters & Hertwich, 2009.

[21] A detailed derivation of the following equations can be found in Berglund, 2011.

indicates that the final demand exclude exports. Thus the production occurring abroad due to Swedish final demand is $\boldsymbol{L}_{tot}\,\boldsymbol{y}_{tot}^{nexp} - \boldsymbol{L}_d\,\boldsymbol{y}_d^{nexp}$, and the production occurring domestically due to Swedish final demand is $\boldsymbol{L}_d\,\boldsymbol{y}_d^{nexp}$.[22]

Since the production needed to satisfy some final demand isare associated with some environmental pressure according to equation (*iii*), the total emissions due to the Swedish final demand can be expressed as

$$(ix) \qquad \boldsymbol{e}_{tot} = \boldsymbol{E}_i \boldsymbol{L}_d \boldsymbol{y}_d^{nexp} + \hat{\boldsymbol{k}}\, \boldsymbol{E}_i (\boldsymbol{L}_{tot}\boldsymbol{y}_{tot}^{nexp} - \boldsymbol{L}_d \boldsymbol{y}_d^{nexp}) + \boldsymbol{e}_{dir} \,,$$

where $\hat{\boldsymbol{k}}$ (diagonalized version of $\boldsymbol{k}$) indicates a scaling factor for the possibly bigger emission intensities which applies abroad, and $\boldsymbol{e}_{dir}$ is the direct emissionsare the direct emissions from final consumers.

Emissions intensities in imports

To estimate the emissions occurring abroad due to the Swedish final demand, the emission intensities areis scaled by a factor $\boldsymbol{k}$. In Berglund, 2011, this factor was derived by taking the emission intensity for the whole world divided by the Swedish emission intensity – a world average intensity approach. Another possibility is to use the following:

$$(x) \qquad k = k_1\, m_1 + k_2\, m_2 + \ldots + k_{20}\, m_{20} \,,$$

where m_i is the share of commodity imports from country *i* among Sweden's 20 biggest import countries in any year, and k_i is

$$(xi) \qquad k_i = \frac{emissions_i \,/\, GDP_i}{emissions_{Sweden} \,/\, GDP_{Sweden}} \,.$$

In this way the emission intensity of the production abroad is scaled by a factor which is a weighted average of the Swedish import countries' emission intensities in relation to the Swedish emission intensity. This is here called the import countries' intensities approach. The *k* factor is calculated for CO_2, CH_4 and N_2O, making up the vector $\boldsymbol{k}$.

Emissions data for the countries included in $\boldsymbol{k}$ come from the EDGAR emissions database.[23] GDP data come from the World Bank.[24]

Sensitivity analysis

A sensitivity analysis is performed through variation of methods used to calculate *k*. On the one hand, the world average intensity approach or the import countries' intensities approach is used. On the other hand, GDP can be valued according to market exchange rates (MER), or according to purchasing power parity rates (PPP). This gives us a total of four ways to generate the CO_2e emissions curve.

[22] A similar approach is used by Finnveden et al., 2007.
[23] EDGAR, 2010.
[24] World Bank, 2010.

The using of the MER or the PPP approach has in other studies been shown to generate considerable differences.[25] It may be that the PPP approach in the kind of calculation performed in this study is more accurate. The argument for this is that the exports share in the rest of the world isare valued too high when using the MER approach, since the MER approach really underestimates the value of the production occurring in the rest of the world, according to the PPP method of calculating GDP. Consequently, the MER approach overestimates the responsibility we have for generating emissions through the production of exports in the rest of the world going to us. Therefore, the MER approach will give us a bigger ***k*** than the PPP approach gives us.

Another argument for using the PPP approach, is that when comparing emission intensities between countries, emission intensities are normally measured as emissions per GDP PPP, in the same way as comparisons of GDP among countries preferably are done with GDP PPP.[26] Since equation (*xi*) is just a scale factor describing the intensity of a country compared with another, it could be argued emission intensities in studies as the one presented here, should be measured with the PPP method.

Results and discussion

The results from the calculations done, are presented in Figure 3 below. The most conservative results which come from the using of import countries' intensities with the PPP approach, show an increase in CO_2e emissions from 84 to 94 million Mtons CO_2e per year, during the period studied, an increase of about 12 %. With the same method using the MER approach the emissions increase from 97 to 130 million tonsMton CO_2e per year, an increase of about 34 %. The most extreme result comes from using the world average intensities approach with MER, which gives rise to emissions increasing from 122 to 159 MtonMillion tons CO_2e per year, an increase of about 30 %.

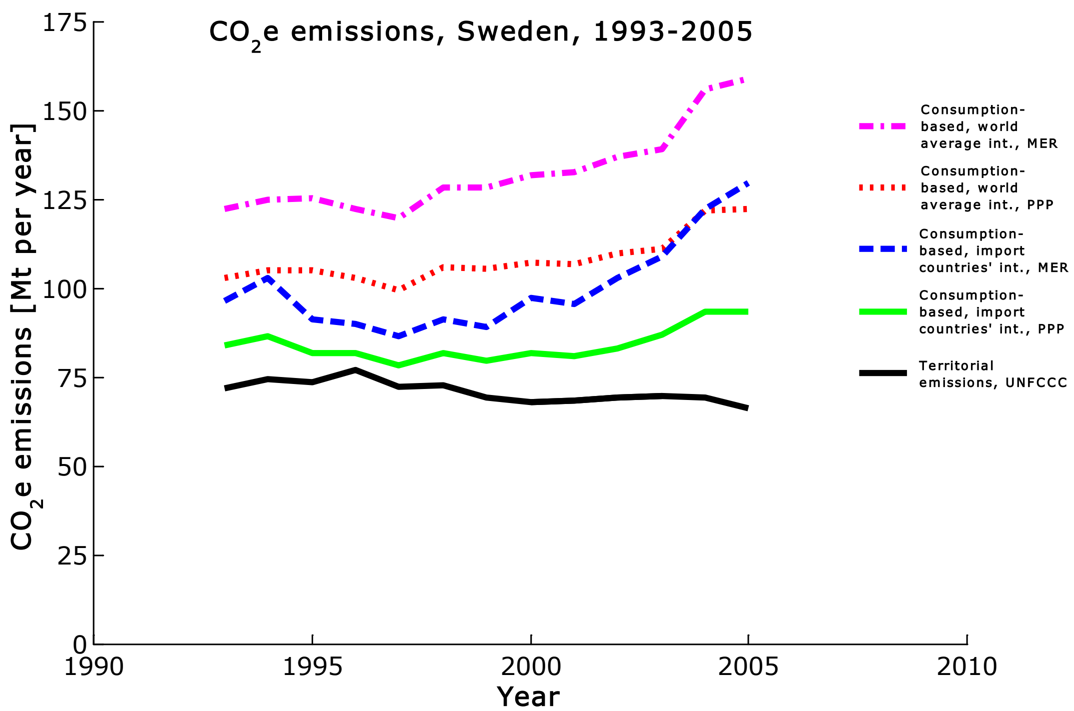

Figure 3. Consumption-based emissions of CO_2e in Sweden, 1993–2005.

[25] See e.g. Weber & Matthews, 2007.
[26] See e.g. Germanwatch, 2011.

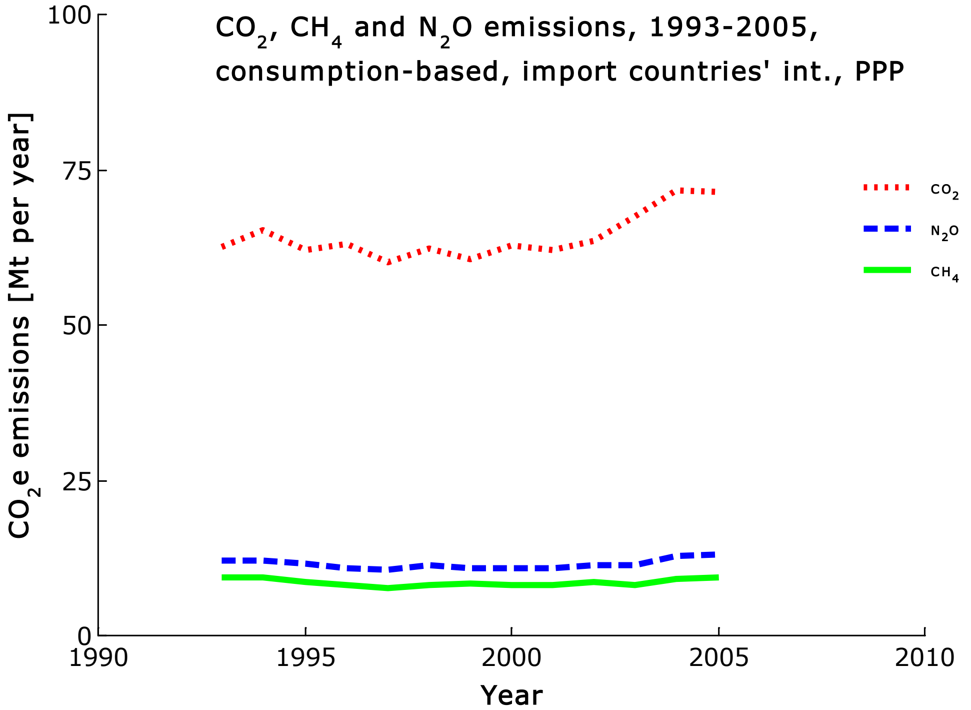

Figure 4. Consumption-based emissions of CO_2, CH_4 and N_2O measured as CO_2 equivalents, in the import countries' intensities approach, using the PPP method.

In Figure 4, the various components in CO_2e, i.e., CO_2, CH_4 and N_2O, are shown, suggesting CO_2 is the most important part in the rising trend. More analysis needs to be done however, since when using the MER approach, it can be seen in the data that CH_4 increases almost 30 % compared to almost no change in the PPP approach.

All these results differ substantially from the decreasing territorial emissions statistics reported to the UNFCCC, which decrease by 8 % during the period studied. These findings suggestsThese findings suggest that the climate impact of the Swedish society have not decreased with growing GDP and growing consumption, as is normally stated.

Sectoral results are shown in the Appendix, showing the production-based emissions generated directly in the industries per *produced* product group, versus the consumption-based emissions generated indirectly per *consumed* product group. Note that the latter emissions are not the same as the total carbon footprint per industry, as that would imply double counting of emissions.[27]

It is not necessarily so that the import countries' intensities approach gives the most accurate picture. ManyA lot of the imports to Sweden only displaysdisplay the dispatching country and not the producing country, meaning that some of the imports may in reality have been produced in China with higher emission intensities.[28] The real emissions may therefore be somewhere in between the world average intensities approach and the import countries' intensities approach.

Further on, earlier studies have shown that the import countries' intensities approach which uses the Swedish sector emission intensities scaled with the *k* factor, underestimates the emissions compared to when using the import countries' own sector emission intensities.[29]

[27] See Lenzen et al., 2007 for a discussion.
[28] Swedish EPA, 2008.
[29] Statistics Sweden, 2000, and Swedish EPA, 2008.

Further research

What to do more in this research project:

- Improve the input–output table updating method with domestic–imports divided into use tables in basic prices, and with more detailed balancing of row and column totals.
- Extend the time series to 2010 (if possible, also back to 1990).
- More in-depth sectoral analysis of the consumption-based emissions per consumed product group.
- Extend the sensitivity analysis by using other data sources for the calculation of emission intensities. E.g. data from UNFCCC (now only data from the EDGAR database are used).
- Investigate the arguments for the PPP approach further, with sample data on actual emissions from industries exporting to Sweden.

Acknowledgements

This research started as a master thesis project at the Global Energy Systems group at Uppsala University, Sweden, and has since then been supported both from the Global Energy Systems groups, and from the unit of Environmental Accounts at Statistics Sweden. I would like to thank professor Kjell Aleklett, head of the Global Energy Systems group, who showed interest in my research project and invited me to the group. Thanks also to Kristofer Jakobsson, my supervisor at the Global Energy Systems group, and to Viveka Palm, head of the unit of Environmental Accounts, both for helping me improve the text.

Appendix: Consumption-based versus production-based CO_2e emissions per product group (import countries' intensities approach, PPP)

		Production-based emissions			Consumption-based emissions		
NACE	Product group \ Year	1995	2000	2005	1995	2000	2005
01	Agriculture	10 426 874	9 803 678	9 610 529	3 910 310	4 226 194	6 230 147
02	Forestry	660 516	696 672	1 034 939	255 295	240 821	-46 133
05	Fishing	199 683	186 129	195 626	65 882	93 999	144 137
10-12	Extraction of energy resources	57 041	37 875	36 869	100 263	27 340	-91 303
13-14	Mining of metal ores, other mining and quarrying	661 289	661 149	643 598	37 933	31 263	-17 073
15-16	Food products, beverages and tobacco	1 057 957	934 405	743 683	11 508 699	10 001 872	12 247 777
17	Textiles industry	102 441	105 613	62 573	305 156	388 139	321 804
18	Textile products	9 137	6 991	4 563	726 198	694 189	673 273
19	Tanning and dressing of leather	4 774	5 164	3 318	256 035	320 454	330 286
20	Manufacture of wood and wood products	277 705	227 222	238 105	9 850	61 516	272 877
21	Pulp, paper and paper products	2 978 601	2 386 736	2 143 126	194 221	213 615	191 387
22	Publishing and printing	83 035	82 312	53 886	307 788	272 085	356 387
23	Coke, refined petroleum products and nuclear fuel	2 106 927	2 306 842	2 422 396	1 362 681	1 749 142	2 796 848
24	Chemicals and chemical products	1 868 048	1 795 177	1 825 706	1 266 894	1 189 827	1 591 802
25	Rubber and plastic products	181 883	198 337	128 640	95 616	122 373	155 623
26	Non-metallic mineral products	3 064 787	3 241 013	2 946 216	348 863	468 887	515 614
27	Basic metals	5 690 835	5 765 933	5 792 677	122 183	212 556	-176 464
28	Fabricated metal products	348 430	343 793	351 806	654 829	791 388	908 205
29	Machinery and equipment	296 817	222 102	238 531	1 842 266	1 889 608	2 601 640
30	Office machinery and computers	5 189	3 983	3 333	787 073	811 403	962 772
31	Electrical machinery and apparatus	46 695	43 901	39 594	445 765	1 182 988	719 076
32	Radio, television and communication equipment	26 778	0	0	548 369	0	0
33	Medical and optical instruments, watches and clocks	28 446	43 269	37 442	357 942	532 229	543 855
34	Motor vehicles, trailers and semi-trailers	308 915	200 072	245 771	1 448 257	2 110 322	3 090 216
35	Manufacturing of other transport equipment	92 384	58 043	105 201	102 158	461 558	330 713
36	Furniture and other manufacturing	62 603	53 630	67 468	765 699	872 305	1 144 306
37	Recycling/Samhall	50 090	109 874	112 339	0	0	0
40	Electricity, gas, steam and hot water	9 548 433	6 407 952	8 227 454	5 181 847	3 678 026	4 451 578
41	Water	712	55 725	66 401	0	0	0
45	Construction	2 469 044	2 318 984	2 775 255	4 860 882	4 760 244	6 273 264
50-52	Auto sales, wholesale trade, retail trade	1 819 464	2 065 357	2 192 117	3 572 188	4 295 673	5 459 840
55	Hotels and restaurants	234 033	257 313	262 729	1 619 063	2 132 791	2 414 323
60	Land transport, pipelines	3 120 328	3 064 203	3 604 753	1 149 296	1 287 504	1 724 694

61	Water transport	3 512 066	4 700 573	6 515 455	272 389	243 627	400 583
62	Air transport	1 951 788	2 369 593	2 007 916	438 514	661 007	718 356
63	Supporting transport activities	509 643	801 399	594 063	1 307 306	2 290 853	2 770 821
64	Post and telecommunications	140 702	181 576	171 937	285 766	452 540	670 732
65	Banking	55 661	25 451	21 439	228 477	237 462	211 514
66	Insurance and pension funding	16 837	18 792	17 455	129 557	130 231	131 354
67	Other financial activities	13 057	14 796	9 388	6 130	8 297	9 559
70	Real estate activities	686 454	720 762	662 328	5 310 781	5 143 845	5 811 426
71	Renting of machinery and equipment	230 987	464 254	558 181	319 216	502 925	548 293
72	Computer and related activities	268 415	233 378	287 118	642 551	878 253	999 805
73	Research and development	34 081	856 027	1 417 507	163 762	890 586	1 191 020
74-75	Other business activities and public administration	718 102	380 751	510 168	3 376 265	2 647 275	2 708 756
80	Education	75 592	92 318	65 294	1 651 628	1 528 235	1 923 316
85	Health and social work	64 873	79 823	83 010	2 860 135	2 642 240	3 306 445
90	Sewage and refuse disposal	3 086 246	2 959 452	2 741 307	0	0	0
91	Membership organizations	7 666	7 996	7 667	507 634	504 461	639 435
92	Recreational, cultural and sporting activities	74 779	153 946	148 150	914 501	1 022 167	1 280 638
93	Other service activities	46 129	50 121	70 947	194 524	176 452	251 999
95	Private households with employed persons	49	35	0	49	35	0

Unit: Ton/year

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Multifactor productivity growth in Sweden 1993-2010

Introduction[1]

Almost 50 years ago Robert Solow[i] started up a new era in growth measurement by publishing his article on economic growth and technological development in the US economy. He used the technique of Growth Accounting to break down growth in US labour productivity into components. His results indicated that almost all growth in the US economy was due to technological developments and very little to capital deepening. This inspired Zwi Griliches and Dave W. Jorgensen[ii] to try to improve the capital measurements. Another important contribution was made by Denison[iii] who tried to incorporate a measurement of the improvement in labour quality. This period of rapid development of the neoclassical growth theory and use of the Growth Accounting technique lost momentum due to researchers' increasing interest in short term questions, a lack of adequate data and the fact that growth was treated as exogenous in the neoclassical word, so these theories could not explain growth in itself.

Solow did however later argue, for instance, that increased capital-intensive investment embodies new machinery and new ideas as well as increased learning for even further economic progress. But Kaldor[iv] is the first theorist after the Second World War, who thought growth to be endogenous. Before the War it was of course Schumpeter who indeed saw growth as an exogenous process with creative destruction as one major concept. Kaldor regarded learning as a function of the rate of investments. Arrow went on and viewed learning as a function of cumulative investments. But this area stagnated nevertheless after the 1960s.

This changed drastically when Romer[v] published his breakthrough article 1986, where he finally incorporated endogenous growth in the model. This started up a new field of growth literature, which was called "new" or "endogenous" growth theory. But still the neoclassical growth theories have their supporters. Even if these theories cannot explain the driving forces behind different growth rates, they can still answer important questions, like if there is a tendency towards convergence (see among others Barro and Sala-i-Martin.[vi]) The technique of decomposing economic growth by Growth Accounting has been widely used during the last decade with many important contributions, not least by Dave W. Jorgensen[vii] , who is still very active in this field and was the editor of major book in this field 2009[viii]and is the leading figure in the WORD KLEMS consortium[2].

An important trigger has been the improved growth performance of the US economy. It ceased to lose ground to the European economies around 1995, as had been the case since the Second World War, and outperformed them thereafter. Now many articles have been published that have looked into the US economy in depth. The objective of these articles has been to get a better understanding of US transformation from the stagnating economy it was for many decades, into a growth economy. Some researchers have also compared US development to some European countries[ix]. Important work has also been done in Canada during the last 10 years; at Statistic Canada led by Professor John Baldwin[x], both on the

- [1] This part of the paper is mostly based on the paper "*Economic growth in Sweden, new measurements*" by Hans-Olof Hagén and Tomas Skytesvall in the Yearbook on Productivity 2005.

[2] http://www.worldklems.net/index.htm

Canadian development and its comparisons with the US. Bart van Ark[xi] at Groningen Growth and Development Centre the University of Groningen is another important researcher in this field. Another trigger of the increased use of the Growth Accounting technique was the interesting result Young[xii] came up with when he decomposed the economic growth of the "Tiger Economies" in East Asia. He found their very imposing growth in labour productivity was almost entirely due to a drastic increase in capital intensity.

This development in the research field together with the increasing importance of the European growth problem has also led the EU Commission together with Eurostat to act. They commissioned a development and analysis of a comprehensive long time series for most European countries. This was carried out by a broad consortium lead by Bart von Ark. Statistics Sweden was also linked up to this ongoing work. The torched are now carried by Michael Timmer who was part of Bart's team. Unfortunately this has not led to an integration of this in the regular statistical work of the European Union as was the intention a couple of years back.

The OECD has always had economic growth on its agenda, and has recently created a productivity section on their website on growth accounting, with both methodological papers and a database. This work as well as the analytical work in this field is led by Paul Schreyer at the Statistics Directorate and Dirk Pilat at the Directorate for Science, Technology and Industry. In the Nordic countries Statistics Denmark has led the way and published multifactor productivity growth figures on a very detailed sector level, already in 2004[xiii].

Over a number of years, Statistics Sweden has been conducting different types of test calculations within the area of multifactor productivity (MFP). On their own initiative, they have also delivered data to the EU KLEMS database.[3] Statistics Sweden has also produced some analytic reports based on growth accounting data. They are mostly based on Swedish data, with the exception of two reports that have been based data for Nordic countries. One was a project made for the Nordic Council and based on national data from each country. This project was headed by Statistics Sweden and one based on EUKLEMS data and was published in EUKLEMS' second book at the end of 2011[xiv]. This background has created a need to systemise previous inputs that have arisen over time. In connection with this, there is also a need to look at previous procedures, not only due to changed requirements and development of methods, but also because of changed access to data.

The data that was previously submitted by Statistics Sweden to the EU KLEMS project has not been produced in a systemised/software based form, but has been based on a mix of separate retrievals from the databases of the national accounts and supplemented modifications in Excel. In the project, we have begun to adapt ourselves to the intended transition and have also been able to clarify future needs.

This work was finished in December 2009. Now we have moved on to another phase. We have used the National Account data that has been converted into the new classification system and also developed a method of using data for the preliminary years in order to give more up to date results. We have also developed the capital service measurements by splitting it into ICT capital services and non ICT capital services. All this work will now be finished. However, these estimates will of course be changed when the national accounts are changed. And further work will be carried out on the capital stock in order to publish official ICT capital stocks in 2014. The first publication of our MFP estimates is planned to be before the end of 2012.

[3] See http://www.euklems.net

Theory and model outline

As mentioned above, we will take a KLEMS point of view in our productivity analysis. That is to say, we will incorporate the effects of input of capital (K), labour (L) and intermediate input on production. The intermediate input is broken down into input of energy (E), materials (M) and services (S).

The production function expresses the relationship between the factor inputs and the output in the economy. Let gross output be a function of capital, labour and intermediate input. A is an index of the level of technology in the economy.

$$Y = AK^{\alpha} L^{\beta} M^{\gamma}$$

A is commonly referred to as total factor productivity, MFP, or multi factor productivity. Changes in *A* shift the production possibility curve making it possible to produce more without changing the factor inputs.

Growth accounting is a technique commonly used in productivity analysis. This method allows the growth in production and labour productivity to be decomposed into growth of the factor inputs and growth in total factor productivity, MFP. Studying the production function, estimates on growth in production and growth in factor inputs is normally not a problem to obtain. Using growth accounting, total factor productivity is that part of growth in output that cannot be explained by growth in the input factors. While having estimates on growth in output and input factors MFP is estimated residually.

While using the production function stated above we assume standard neo-classical growth assumptions, constant returns to scale, perfect competition and profit-maximizing firms. All of this meaning that factor inputs will be rewarded by the size of their marginal productivity. Also we assume the growth in MFP be Hicks-neutral. Assuming constant returns to scale yields the coefficients to sum to one; $\alpha + \beta + \gamma = 1$.

Being focused on growth we need to reformulate the equation above. By taking the logarithm and the first difference of the production function we express all variables in terms of rates of growth and get:

$$\Delta \ln Y = \alpha \Delta \ln K + \beta \Delta \ln L + \gamma \Delta \ln M + \Delta \ln A$$

Δ refers to the first difference, i.e. $\Delta x \equiv x_t - x_{t-1}$.

Studying the model one realises that growth in gross output is possible only by raising the input of one of the input factors or by raising the level of technology in the economy, that is, the total factor productivity, MFP. By expressing the production function in growth rates (log differences) the growth in Y is split up in the share weighted growth in capital, labour, intermediate consumption and MFP.

Using this model enables us to study the share weighted growth in GDP. In so doing we need estimates on the weights of the factor inputs. By taking the starting point in the firms profit maximisation function, the quantities of capital services, labour and intermediate inputs are chosen so as to minimize total costs and maximize profits. Let Π denote the profit, Y is production, wL is the total cost of labour, rK is the total cost of capital and pM is the total cost of intermediate inputs.

$$\Pi = Y - \omega L - rK - pM$$

While maximizing Π subject to $Y = AK^{\alpha} L^{\beta} M^{\gamma}$ it can be shown that

$$\alpha = \frac{rK}{Y},$$

$$\beta = \frac{\omega L}{Y},$$

$$\lambda = \frac{pM}{Y}.$$

We see that the weights of the factor inputs, α, β and γ, are represented by each factor's share in total production.

Assuming perfect competition, there are no profits other than the remuneration to labour, capital and intermediate input. Hence the value of output can be expressed as:

$$Y = \omega L - rK - pM$$

Then we see that the weights are represented by each factor inputs share in total cost.

In the empirical analysis below we are using different types of capital. Splitting capital into these subcategories yields:

$$\alpha \Delta \ln K = \sum_j \alpha_j \Delta \ln K_j$$

where α_j represents each capital's share in total capital costs:

$$\alpha_j = \alpha \frac{r_j K_j}{\sum_j r_j K_j}$$

Since we are interested in the effects of different types of labour the set of labour were divided into a number of categories. Assume in this case that A is the set of different labour types, and L_a the quantity of labour of type $a \in A$.

$$\beta \Delta \ln L = \sum_{a \in A} \beta_{ait} \Delta \ln l_{ait}$$

Here l_{ait} is the share of category a in total labour, and the β_{ait}-coefficients represent each types share in total labour cost:

$$\beta_{ait} = \beta_{it} \frac{\omega_{ait} L_{ait}}{\sum_a \omega_{ait} L_{ait}}$$

Labour productivity

Economic growth is our focus thus the effects of changes in factor inputs on changes in labour productivity are of interest. Therefore we introduce total worked hours H_t. When dividing both sides of the production function above with total worked hours we get:

$$\frac{Y_t}{H_t} = A_t \frac{K_t^{\alpha} L_t^{\beta} M_t^{\gamma}}{H_t^{\alpha} H^{\beta} H_t^{\gamma}}; \qquad \alpha + \beta + \gamma = 1$$

Expressing the equation above in growth terms by taking the logarithmic first-difference we get:

$$\Delta Y_t - \Delta H_t = \alpha(\Delta \ln K_t - \Delta \ln H_t) + \beta(\Delta \ln L_t - \Delta \ln H_t) + \\ + \gamma(\Delta \ln M_t - \Delta \ln H_t) - \Delta \ln A$$

In this case we identify four sources of the growth in labour productivity. First we have the change in capital per the change in hours worked, known as capital deepening. The second component is the improvement in labour quality which is defined as the difference between the growth rates of labour services and hours worked. The third part is the growth in intermediate consumption per hour worked. The fourth source is the growth in MFP.

Data

In the empirical analysis we will study the growth in MFP both on gross production and on value added. We use data from the national accounts on capital stocks, worked hours and intermediate input. The data on labour is derived from RAMS, register-based labour market statistics at Statistics Sweden and is presented in more detail below. We have data on all variables for the period 1993-2010 from the yearly national accounts while the preliminary year of 2011 is based on the quarterly account. The data for the section below will in more detail describe the data on the factor inputs.

Capital services

As mentioned earlier we will in this empirical analysis use the flow of capital services streaming from capital rather than the value of the capital stock itself. By taking into account the heterogeneity of capital and those different types of capital have different marginal productivity, we get a more effective measure of the capital input in production.

The value of the flow of services from the stock is a better measure of the input in production than is the value of the stock itself. Over time there should be a substitution of capital towards capital with higher marginal productivity. For example, as prices on ICT capital are falling, industries tend to invest more in this cheaper and more productive capital.

For this study, estimates of capital stocks were derived from national accounts at Statistics Sweden to construct estimates of capital services. Official data on capital stocks is published by Statistics Sweden on *Machinery and equipment*, *Dwellings*, *Other buildings and construction* and *Other capital formations* which mostly consist of software. Using these stocks of capital, stocks of Machinery exclusive ICT, Transport equipment, Buildings and construction and ICT were estimated. The ICT stock was originally estimated for Lindström *(2002).* Following the recommendations of OECD an ICT stock was then estimated for the business-, goods-, manufacturing-, service- and ICT sector respectively for the period 1993 to 2000. For this study this time series was prolonged to the year 2003 using data on investments for the same period and the perpetual-inventory method, PIM. While using these new stocks of capital, capital service measures for ICT capital and non-ICT capital were constructed.

Consider the capital stock K_t. The capital stock is estimated by using the traditional PIM-method.

$$K_t = K_{t-1}(1 - \delta_{t-1}) + I_t$$

Here δ is the value of depreciation in period t-1 and I is the value of investment in period t.

The value of the stock is estimated at the beginning of the year. Assuming that new investments become available for production in the middle of the year we express capital services as

$$C_t = a(0.5K_t + 0.5K_{t+1}) \quad \text{(footnote D. Jorgenson)}$$

The capital service flow is assumed to be proportional to the average of the current and lagged capital stock where α denotes the proportionality constant[xv]. The flow of capital services is then estimated by using asset specific user costs to weight the growth in each type of capital and to account for the substitution between them.

User cost

The flow of capital services is weighted with the user cost of each type of capital. The user costs are, under certain assumptions, equal to the marginal productivity of capital. User cost can be seen as the cost of borrowing capital and investing in a capital good, renting it out, and collecting a rent.

The estimation of the user cost can be made more or less complex regarding tax regulations. In this study we are relaxing all effects of taxes.

The components of user cost are the rate of alternative investments, depreciation and the change in the price on investment goods. There are different options of choosing the rate of return. In this study we use the endogenous internal rate of return derived from the national accounts. By relating gross operating surplus to the capital stock, the rate of return was derived. This was done for each of the sector aggregates in the study. The rate of depreciation is estimated per sector and type of capital. Changes in prices on investment goods were derived from implicit price indices on investments in the national accounts.

In a very simple form the user costs were estimated as:

$$\mu_t = r_t + \delta_t - \Delta p_{t,t-1}$$

where μ is the user cost, *r* is the rate of return, δ is the rate of appreciation and $\Delta\, p$ is the rate of price change in new investment goods.

The estimated user costs are then used to calculate the weights by which the flows of services are aggregated. The weights are defined, for a capital good C_k as:

$$\upsilon_{k,j,t} = \frac{\mu_{k,j,t} C_{k,j,t}}{\sum_k \mu_{k,j,t} C_{k,j,t}}$$

Labour composition

The effect of the labour input on production is not only a question of quantity but also of quality, or more correctly on its composition. Thus a calculation of an indicator of the labour composition has been performed. The method which has been used is very much a market oriented one. The working population has been split in many subgroups according to four different characteristics. For each of the subgroups we calculated the average incomes from both the employed and the self-employed.

If the labour market functions well, the average income for each subgroup is the market's valuation of the different categories as labour inputs. This is in accordance with a long tradition represented by Jorgensen[xvi] and Bureau of Labour Statistics[xvii] both of which have somewhat different approaches for the US labour market. This has been further developed on US and Canadian data by Gu and Maynard[xviii]. The income means are then treated as the market valuation of different categories of labour in respective workplaces. In most workplaces there are of course only a small number of these categories represented. But with help of the average prices it is possible to calculate a synthetic labour cost or labour composition indicator for the whole workplace. It is necessary to go via the workplace level since this is the unit that has an industry definition, not the individuals. They get an industry connection by their workplace. The workplaces can then be aggregated to industries on different aggregation levels.

Instead of creating an average for the whole time period the changes that take place have been taken into account in the valuation of different types of labour over the years. To take account of the changes over the years in relative prices is rather uncommon in the literature, but has been used by the researchers mentioned earlier at Statistics Canada[xix]. To be able to follow the changes in the labour market over the years in a meaningful way, it is necessary to deflate these mean incomes for different categories with the general wage increase; otherwise the labour composition indicator, which is based on the mean incomes, includes both inflation and real wage increases.

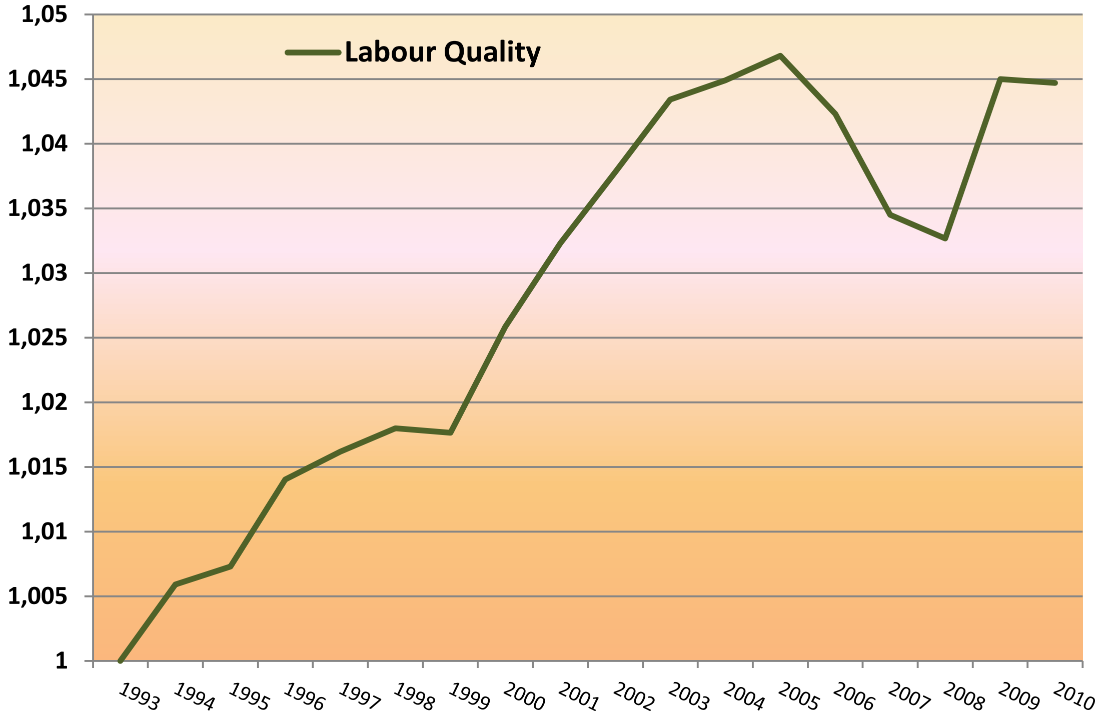
For this purpose the structure from one year, that is, the relative size of each category, is combined with the earnings for each category the following year. This is then aggregated to a fictive average earning of that year which is divided with the factual mean earnings of the last year. The increase in average earnings is then treated as a common price index that is used to deflate the incomes of each subgroup. The resulting changes of the deflated prices of a subgroup over the years is then only reflecting the market's relative appreciation, or its depreciation, of the value of this group as labour input compared with all other subgroups.

The characteristics that have been used are the traditional ones: age, education and ethnicity with one exception, i.e. gender is not included. The choice of the different categories for each variable is based on how they are valued on the market. The education variable is split into two dimensions: orientation and levels. There are seven different levels but only two fields: 1) the technical and natural science orientation and 2) all other orientations together. The levels starts with primary less than 9 years (level 1) and primary with 9 years of schooling (level 2), and ends with post graduates and research education (both level 6). Concerning age, the workforce is split in as many as five categories, but of these the first and the sixth are not very frequent on the Swedish labour market although the last one is has increased substantially. These categories are namely those who are 16-20 years of age, and those who are between 60 and 70. The ethnicity variable is based on the countries where people are born. Those with an origin outside of Sweden are divided in two groups. The definition of origin outside Sweden includes both whose has been born outside Sweden themselves and those with both their parents having been born outside Sweden. This category have been split into one group whose who have an origin in one of the Nordic Countries, the rest of EU-15 and Switzerland, US, Canada, Australia or New Zeeland and one who have their origin outside these countries.

The reason why the gender variable is excluded is because most of the differences of yearly earnings between men and women in the Swedish labour market are more of an indicator of the differences of working hours than of anything else. We do not have any data on worked hours for all individuals, but we know that there are many more women than men who are working shorter hours. Since the quantitative labour input is measured in hours, the sector difference is already incorporated in that variable, and if the gender is included it is measured twice. The rest of the differences between the two sexes are considered to be a reflection of discrimination and not a difference in labour quality. All these variables and their different categories give in theory as many as 210 cells in total, but some of them are of course empty. And only a handful of these groups are represented in a small or medium sized workplace.

Regional differences in wage levels also exist on the Swedish labour market, but these differences are not mainly due to differences in competence but rather to the size and character of the local labour market. The same is true for industries. In general there could be a tendency for an expanding sector to pay more for the same skill since it needs to attract more people. Sector differences can also be a reflection of regional differences. This is not only due to chance, but also to conscious choices. Industries that are maturing are driven out from growth areas due to high wages and high rents. These factors are the reason for not including regions and sectors among our variables.

Figure 1. Labour quality in the Business sector



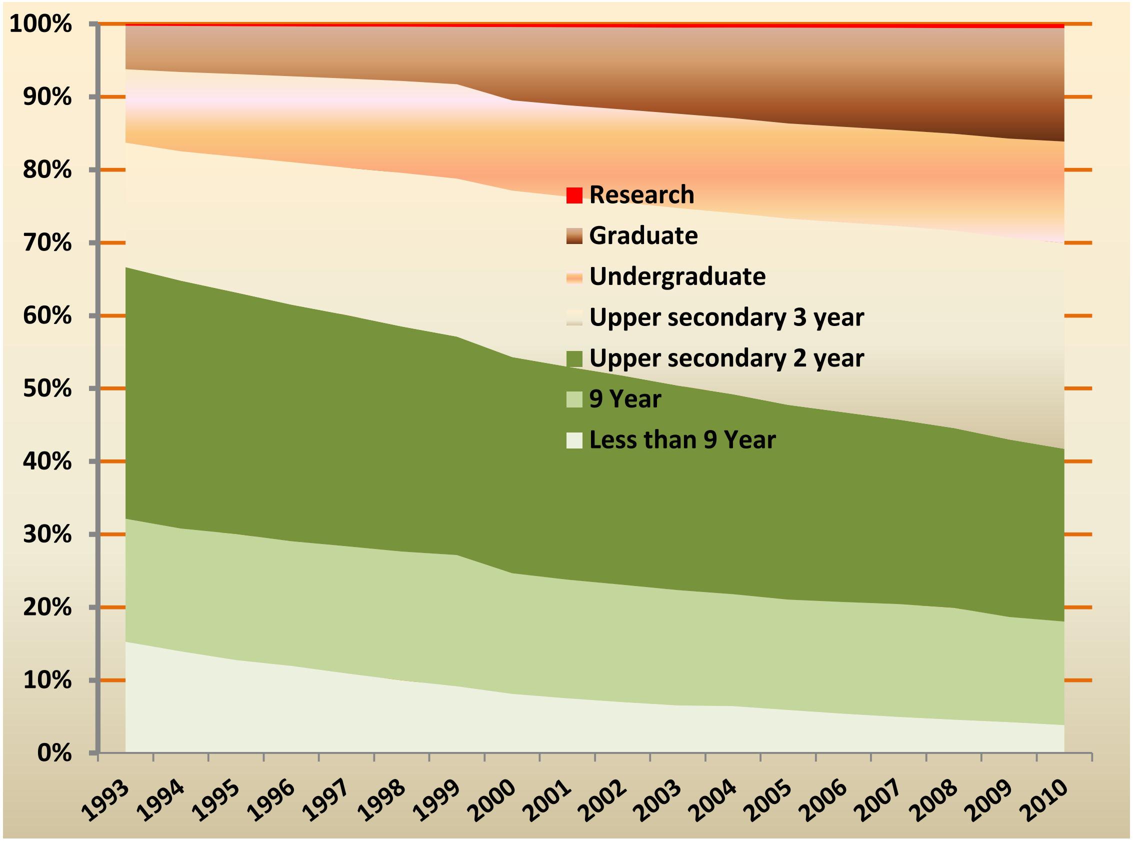
Source: Statistics Sweden

The calculation has been limited to the private business sector since it is only this sector that is analysed in this project. It is also known that the public sector is paying less for the same competence. Only broad education categories for the education orientations are used, since if they are narrower they tend to become more sector-specific.

The development of the quality measurement has been decomposed into 1) the change in the relative importance of each category and 2) the change of its quality or price. The effects of the weights are of course positive if a high quality group increases its importance as well as if a low quality group decreases it. The total effect for each group is the sum of the price and the relative size effects. The average increase during the period 1993-2010 is a quarter of a percent per year. However, the increase was faster up to 2005, after which a decrease followed during the years of substantial increase in overall employment. That was in turn reversed under the crisis year 2009 when worked hours in the business sector fell by 4 percent. This is in accordance what could be expected since large changes in employment will have an effect on the overall labour quality, because groups with a low than average quality are those that move in and out of employment to a greater extent with these chocks.

The most important contribution to the overall increase in labour quality is of course the changes in the education distribution. The postgraduates had in 2010 twice the average income as those with less than 9 years of schooling. As can be seen from figure 2 there have been large changes in the composition during these years. In 1993 one third of the labour force did not even have secondary school and another third had just two years of secondary school. These groups had been reduced to just over 40 percent of the workforce in 2010. At the same time the university educated have doubled their share to a third in the same year.

Figure 2. The changes in education structure in the Business sector



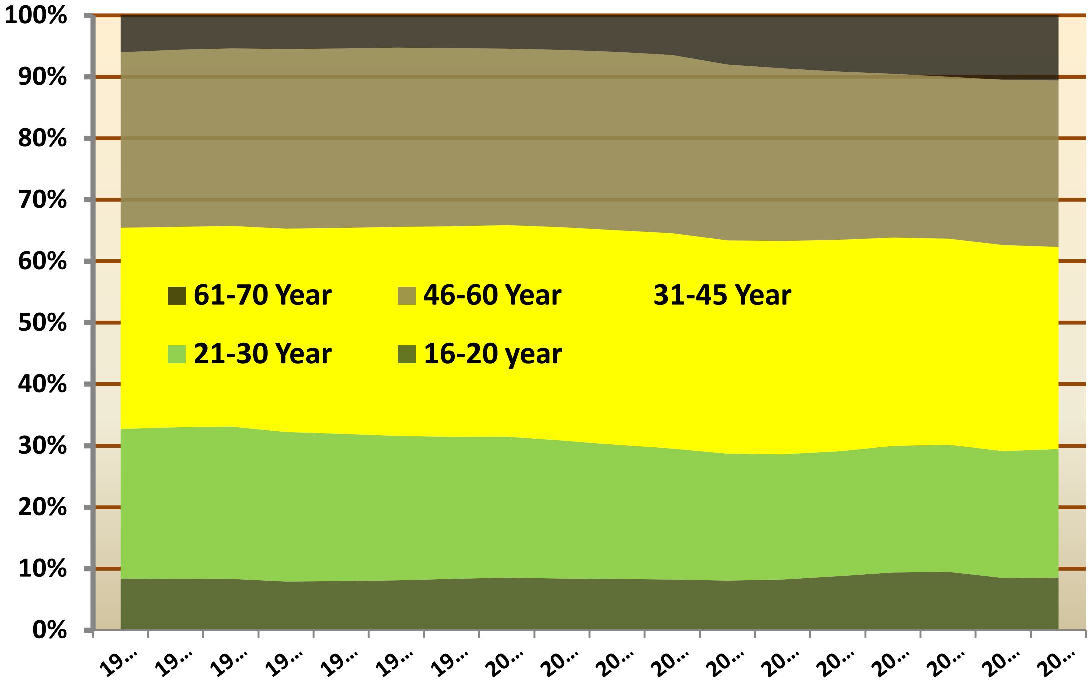
Source: Statistics Sweden

Even if those with a technical orientation in their education have 20 percent over average income, more than half of that is due to a longer education. Since these shares have hardly changed, this difference in relative incomes has had no impact on the changes in average quality.

The two age groups which are above the average incomes are as expected those aged 31-45 and those aged 45-60. Both these groups have increased almost at the same pace as the overall increase during these years. The younger group is exactly one third of the labour force both in the starting year and in the end year, and the older one has just dropped a little more than a percentage point over this time period. The only age group that has significant increased in relative size is the oldest, which has more than doubled its number and almost doubled its relative size in persons.

The average income level of this group is much lower, actually by one third, compared with the two younger groups. This is mostly due to fewer worked hours per person. However, it has increased its relative size on the behalf of the 21-30 year age group and compared to this age group, their incomes are higher. So in total, the structural change in the age structure has contributed to the overall increase in labour quality.

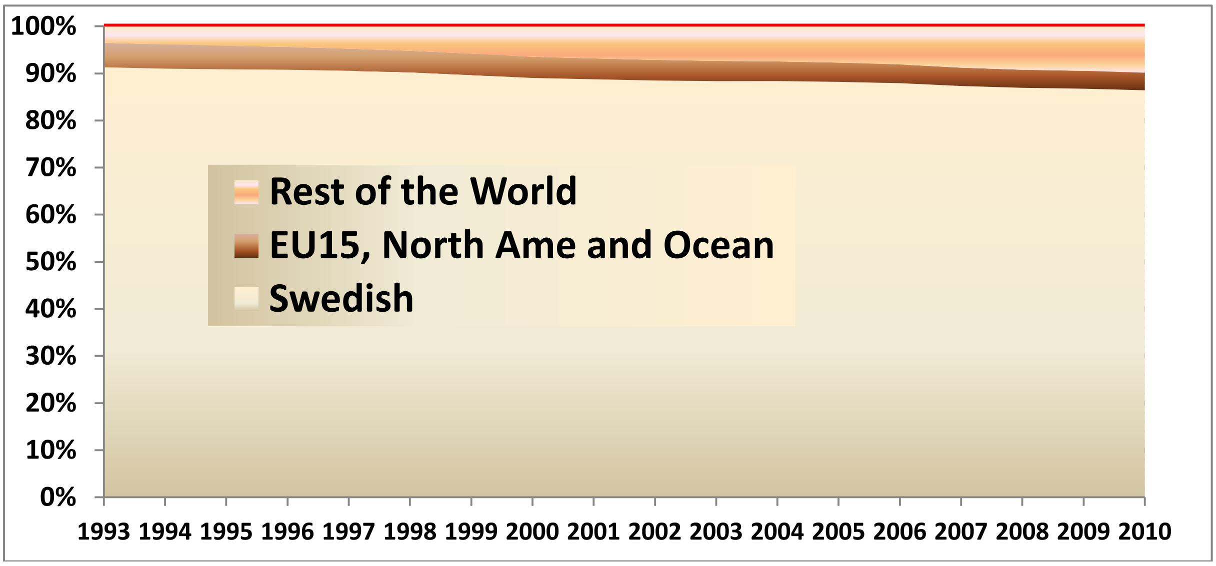
Figure 3. The change in age-structure in the business sector labour force



Source: Statistics Sweden

The last variable is ethnicity. This effect is not large since those with a Swedish background have been very dominant over the whole period even if they have decreased their share from 91 to 87 percent. In relative terms the group that consists of those who come from the western word have experienced a much larger drop. Their share has decreased by one third from over 5 percent to well under 4 percent. It is apparent that those coming from the rest of the world have become a more important part of the labour force during these years. They have more than tripled in absolute numbers and almost done so in relative terms. This group now makes up 10 percent.

Table 3. The change in ethnic structure in the business sector labour force



Source: Statistics Sweden

This group is not valued as much as those with a Swedish background and this cannot be explained by the difference in education levels. And this gap has not had any tendency to diminish during this time period. Those coming from Western Europe or Anglo-Saxon nations also have lower incomes compared with natives, and this difference has increased.

Intermediate input

The intermediate input is divided into three categories: energy, materials and services. Input of energy consists of products in NACE: B08-09, C22 and D35. Material input consists of products in A-F exclusive B08-09, C22 and D35. Services are the total input of products in groups G-T of the Business sector.

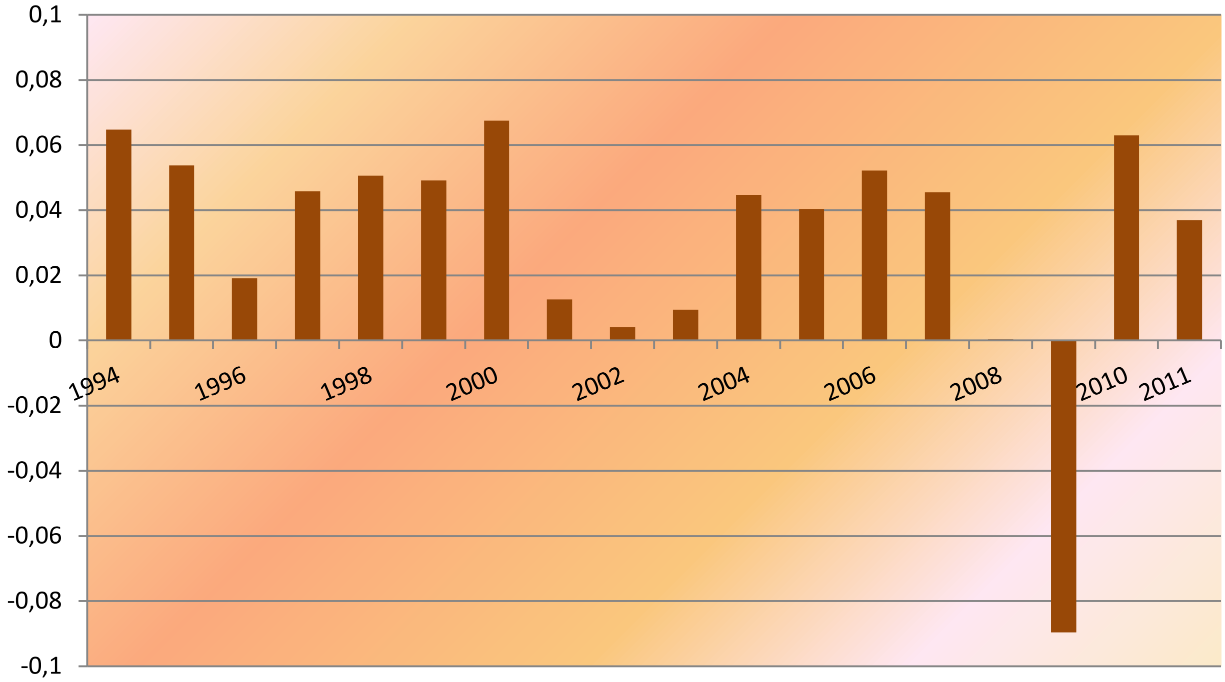
The growth in input per category is calculated as the percentage change in volume consumed. The relative effect of each category on the growth in total input is estimated as the weighted growth of the three parts. The weight is calculated as the relative value of the three categories to the value of the total input in current prices. Consider $Z_{i,j,t}$ as the value of input of each category. Then the weight for each type of intermediate input is estimated as

$$\upsilon_{i,j,t} = \frac{Z_{i,j,t}}{\sum_i Z_{i,j,t}}, \qquad i = \text{energy, material, services}$$

The growth decomposed

The growth of the Swedish business sector has been rather good most of the years, as can be seen in figure 5. However, there have been two periods of low growth: one not that severe 2001-2003 after the burst of the ICT bubble and one very servere that hit Sweden in the last quarter 2008 which led to a zero growth in 2008 as a yearly average and an extremely large decrease in 2009. In gross output terms it was not back on the earlier production level until two years later.

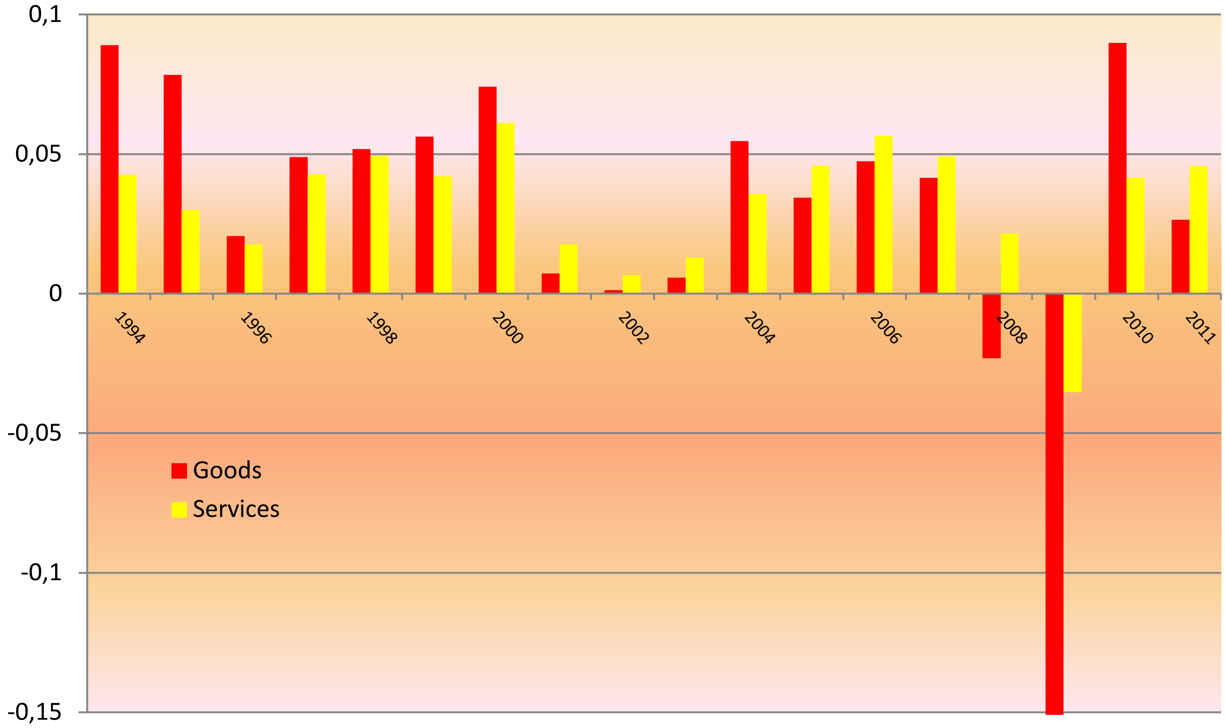
Figure 5. The growth in Gross Production in the Swedish Business sector 1993-2011



Source: Statistics Sweden

If this development is decomposed into the goods and service producing parts some interesting features are revealed. The service producing industries have appearently taken over the lead during the second half of the time period and especially the last crisis was primarily in production terms a crisis for the goods-producing industries. The production of services was not that more serverely affected this time than in the crisis 2001-2003.

Figure 6. The growth in Gross Production in the goods and service producing industries 1993-2011



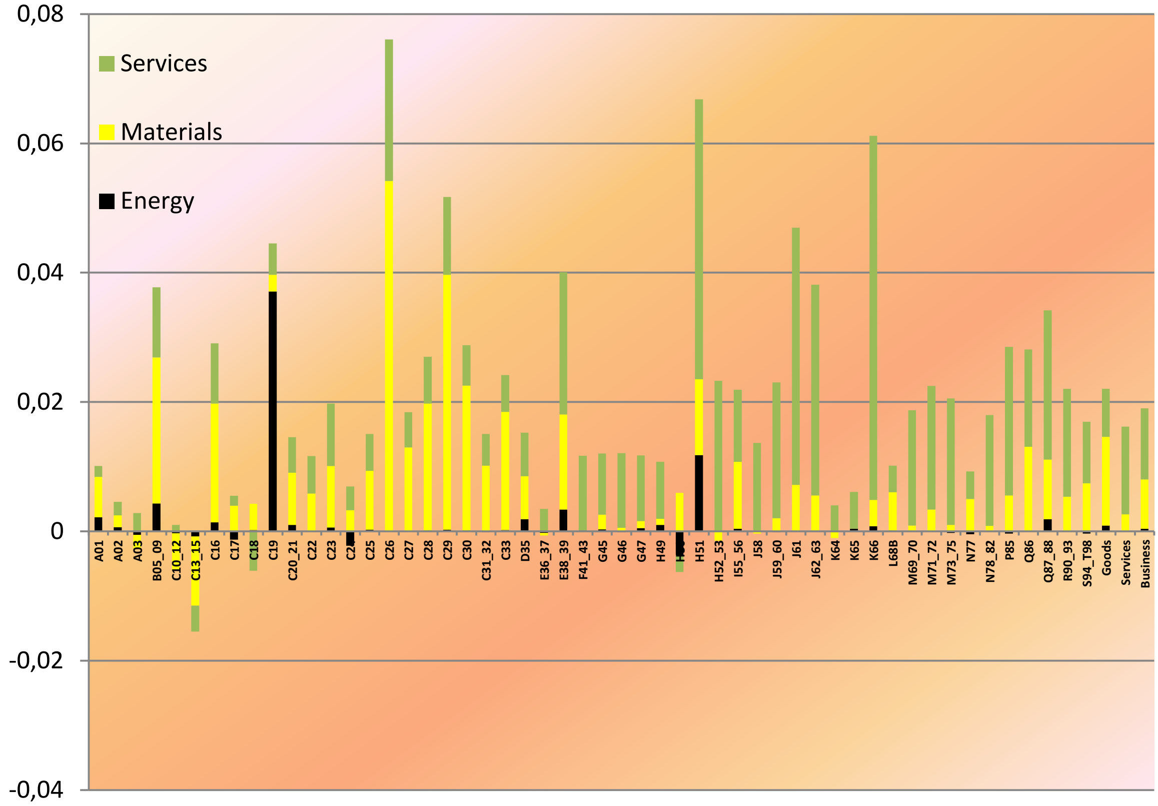
Source: Statistics Sweden

However the development in Gross Production is not the whole story, since the intermediate goods are of large and increasing importance. In the developing of global and local value chains and increasing specialisation, the input of goods and services is growing. The changes in intermediate input during the last three years are almost a perfect mirror of the changes in gross production. This indicates that the firms have been able to react very fast indeed to the very large demand chocks; this is true for the negative as well as the positive ones.

The intermediate input, EMS, is split in the already mentioned three categories: energy, materials and services. In figure 7 this decomposition is illustrated for the national accounts' industry breakdowns. In this figure the actual growth rate is not shown but the impact on the gross production growth rate of the growth in respectively category. That means the growth rates are weighted with their average cost share for the preceding and actual year. So for example for the change between 1993 and 1994 it is the average cost shares for 1993 and 1994 that are used.

There are just two industries that the impact of the energy input is substantial, and that is the oil transformation industry, petroleum refineries C19, where it is dominant and in the air transport industry where it makes an important contribution.

Figure 7. The average in Gross Production in the goods and service producing industries 1993-2011. Avarge for the yearly growth rates



Source: Statistics Sweden

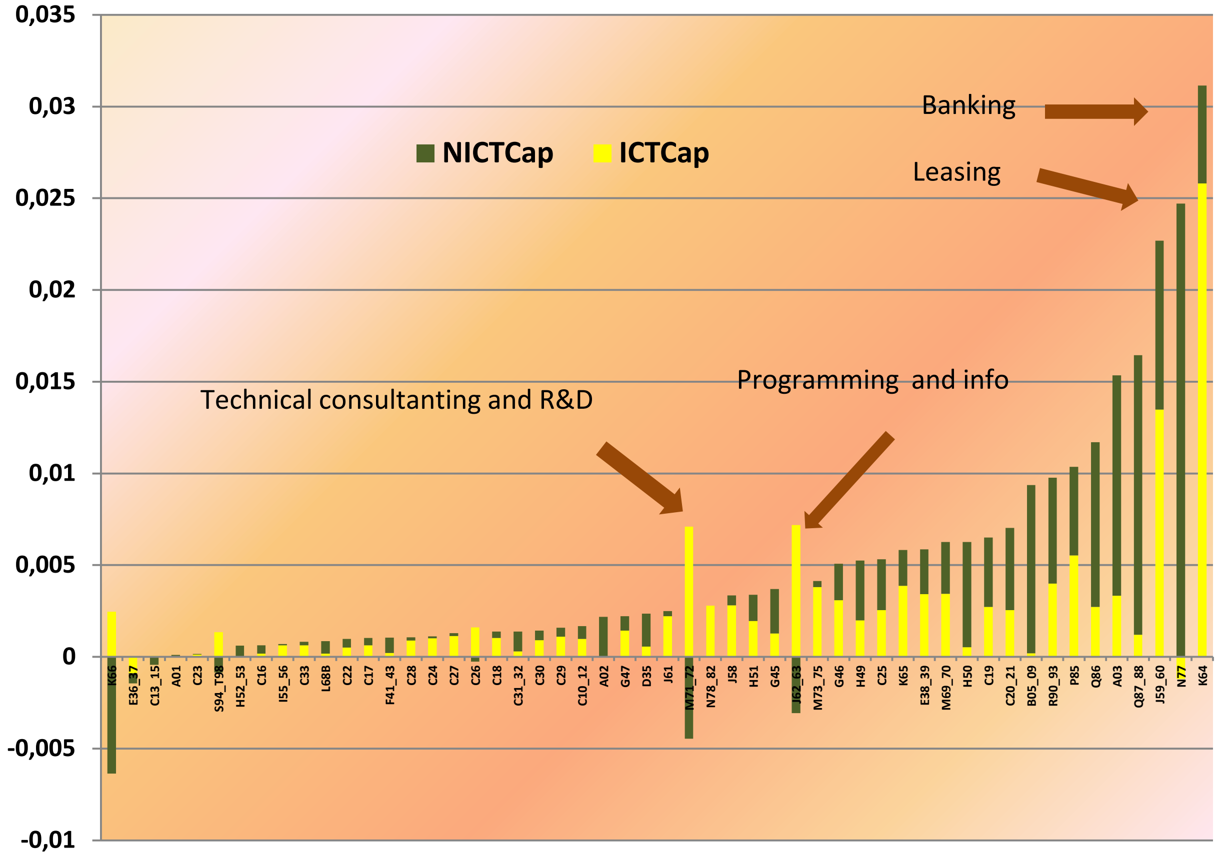
In the goods producing industries to the left in figure 7, from agricultural A01 up to Construction industries F41-43, the impact is much larger than for the service industries on the right hand side. And quite naturally the service impact dominates the service industries and none of the goods producing industries with just two exceptions: the last one of the goods producers, the construction industry, and the largest impact is in the waste management industry E38-39. Two other industries stand out when it comes to the overall impact and that is the electronics C26 and banking K66 which in both cases are due to high growth rates as well as from increasing specialisation.

Capital input

The impact of capital service is not very large; for all but a handful industry it is less than 0.1 percent.

Still, it is interesting to note that on average the impact from the ICT capital is almost twice as large as from the non ICT capital, 0.0011 compared to 0.0006. The impact is more substantial for a handful of industries, especially in banking K64 and of course in leasing K71. The difference in composition between them is in accordance with that could be expected. The banking is primarily an ICT capital service using industry and leasing a non ICT capital service using industry. Among other industries with a rather large impact are the two industries where production has been migrating from public production to private production: education O86 and care O87-88. These industries will have large impacts from most production factors due to their growth rate, although this was not the case for the intermediate input. This is because they are very much self sufficient producers. It is also of interest to note the transformation from non ICT capital to ICT capital in programming and info industries J62-63 and the technical consulting and R&D M71-72.

Figure 8. The impact from ICT Capital and Non ICT Capital. The average of yearly growth rate



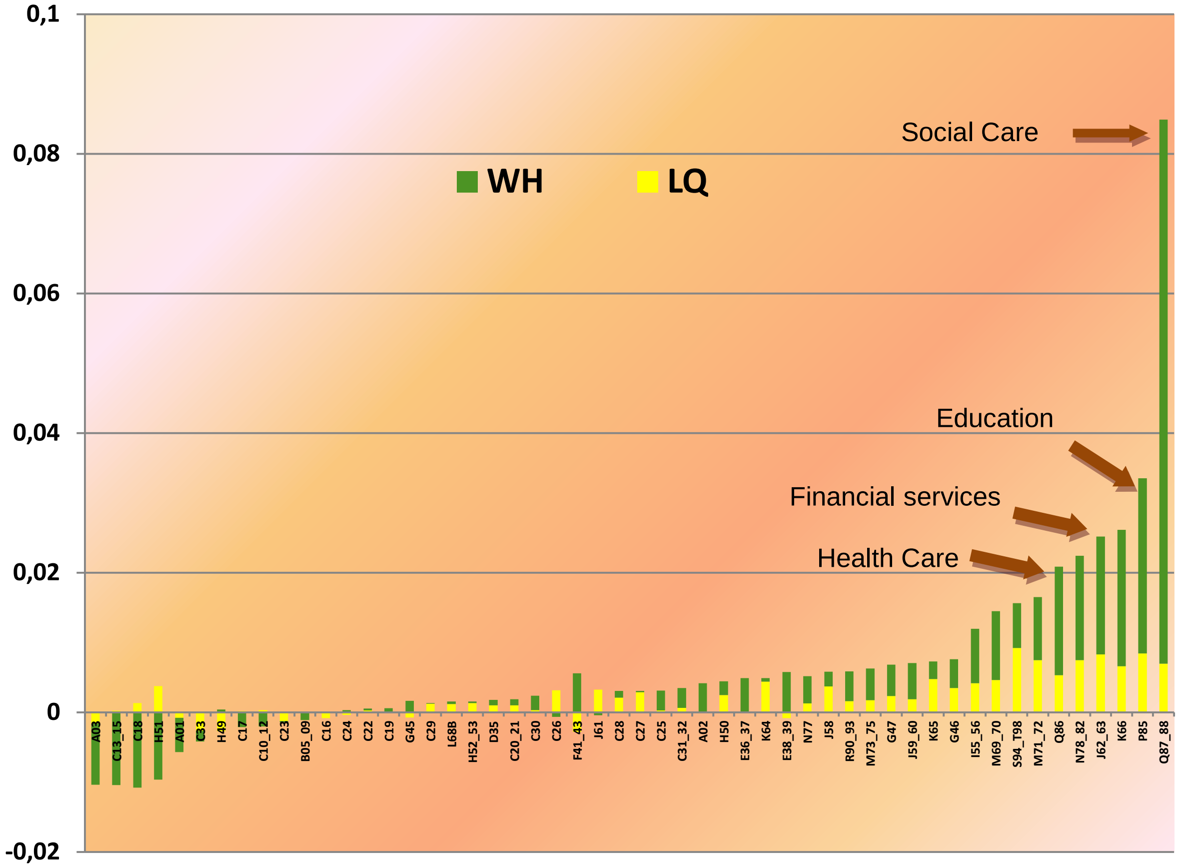
Source: Statistics Sweden

Labour impact

The impact from labour services on the gross production growth rate is of course larger than from capital services. Actually it is on average more than twice as large or 0.44 percent compared to 0.18 percent. In contrast to many other European countries, the Swedish population is increasing as well as its labour force. This is mostly due to migration; especially refugees but lately there has also been more work-oriented immigration. For most years and all of the last ten years there has also been a natural growth due to a birth surplus. Even if there have been major problems in integrating refugees in the Swedish labour market, the total impact on employment has been an increase in numbers as well as an increase in quality.

The impact of employment on gross production growth rate has on average been 0.17 percentage points respectively 0.27 percentage points. This is almost only a service industry question since the labour service input have had no impact on the goods producing industries on average. The industries with large impacts are dominated by the increase in worked hours while the labour quality is much more evenly spread.

Figure 9. The labour impact split into worked hours and labour quality



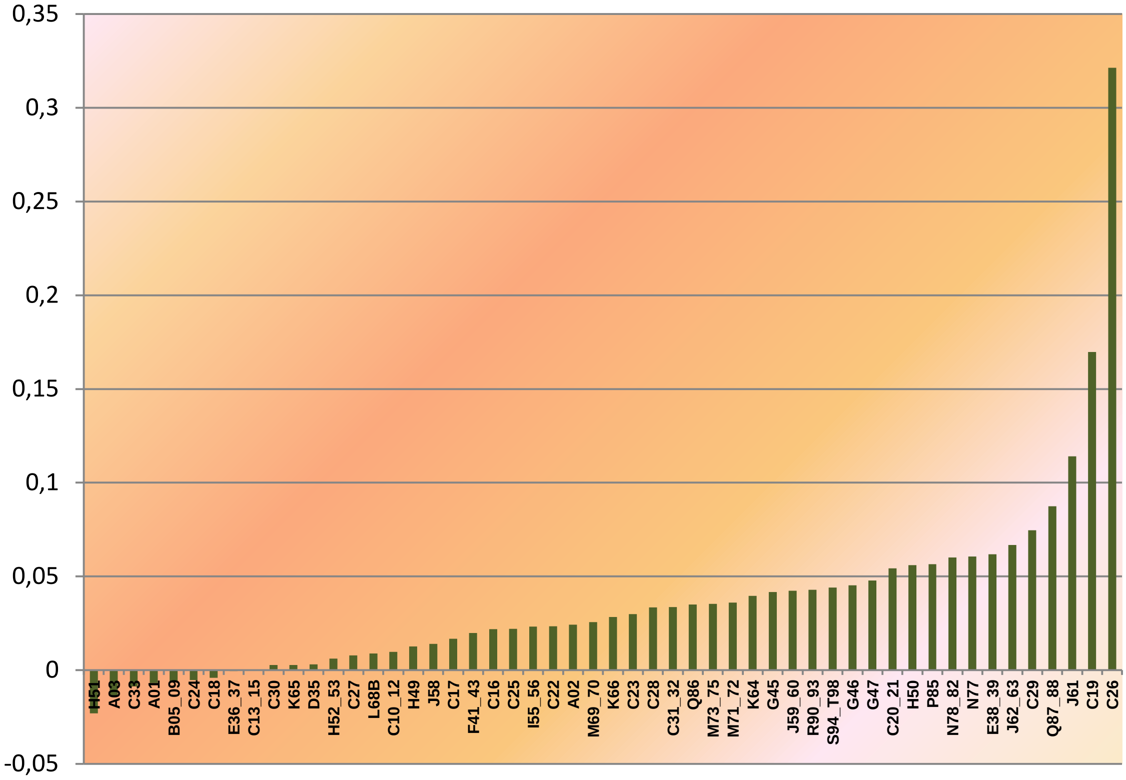
Source: Statistics Sweden

The migration of production from the public to the private sector is even more evident for labour than for capital service. The care industry O87-88 is by far the industry the biggest effect, but also for education P85 and health care O86 it is quite substantial. The financial service industry K66 has a relatively large growth impact from both worked hours and from labour quality. In the other end of the scale two small industries that have become almost extinct during these years are fishing A03 and textile and clothing C13-15.

Value added

If the EMS, input of intermediate inputs, in the form of energy, materials and service is subtracted from gross production, the value added remains. That means that value added is the sum of the increase in value that the firm has created itself. The highest growth rates are found in the industry categories: the ICT driven industries and the migration industries. Among the ICT driven industries, the one with by far the largest increase in this period is the electronics producers C26 with an average growth rate of over 30 percent per year. The telecom operator industry M61 with a yearly increase over 10 percent and the programming and information industries with almost 7 percent have also been fast movers. The other group are two industries that have migrated from public to private production are Care O87-88 and Education P85 which both have increased their value added between 5 and 10 percent per year. Perhaps more surprising is that two traditional manufacturing industries, petroleum refineries and car manufacturers, are found among the high growth industries, while it is no surprise to find the waste management industry among them.

Figure 10. Value added industry differences in growth rates



Source: Statistics Sweden

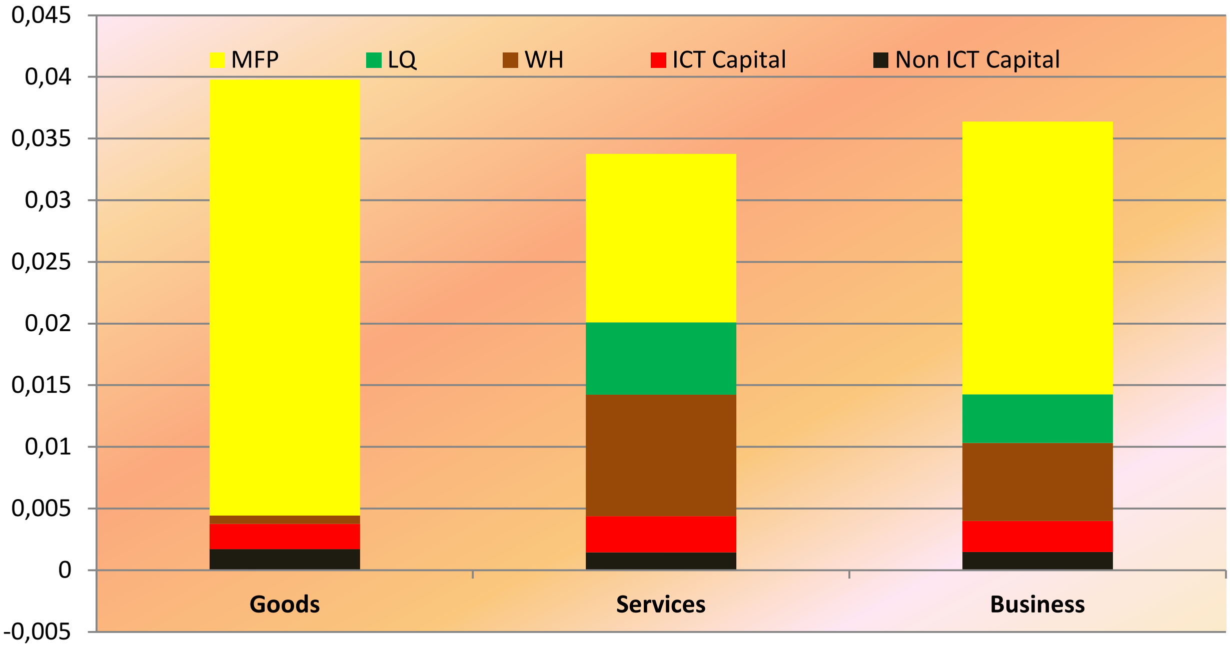
Multifactor productivity

The growth in value added can in parallel to the growth in multifactor productivity be decomposed into the different contribution from production factors. In this case it is just capital services and labour services and its two sub factors that are relevant. In figure 11 the growth in value added in the whole period 1993 to 2011 is split into these four categories and the unexplained growth in form of multifactor productivity.

As can be seen in figure 11 the growth in the goods producing industries are explained very differently from that in the service industries. In the goods producing industries the increase in production factors can explain very little. It is just about the multifactor productivity and to some extent capital services. The impact of capital services are of the same magnitude in the service industries. However in these industries the labour service input has a larger impact than the multifactor productivity.

The worked hours have almost doubled the effect of the labour quality, although the latter one is in itself more important than the total impact of the increase in capital services. In total the increase in value added has been half a percent larger in the goods producing industry than the service producing industries and this is only explained by the very large increase in multifactor productivity for the goods producers. The difference in multifactor productivity is a full two percent points per year. The growth pattern has been very stable with an increase of 3-4 percent per year in all but the slump year in each business cycle. However there is one extreme exception and that is of course the latest crisis.

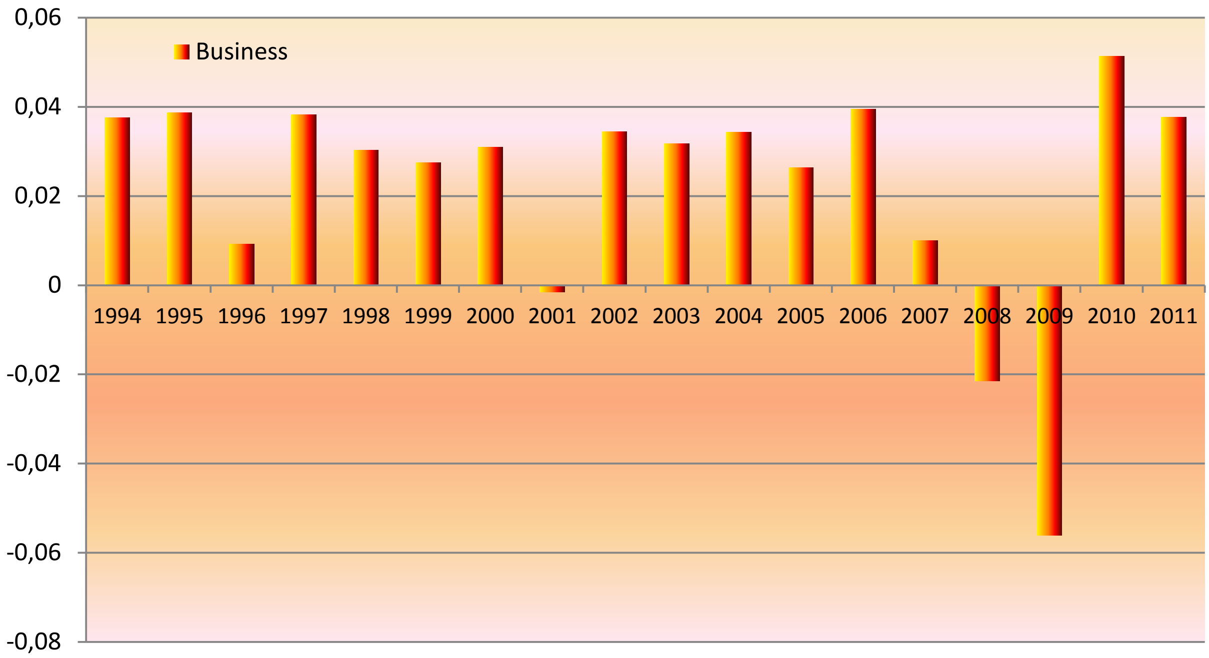
Figure 11. Value added decomposed in production factor input and multifactor productivity. Yearly average growth rates



Source: Statistics Sweden

With the normal pattern, 2008 and 2009 should both have had an increase of 3-4 percent, but instead multifactor productivity decreased by over two percentage points in 2008 and more than 5 percent in 2009. In total a loss of 15 percentage points which is more than five years normal growth.

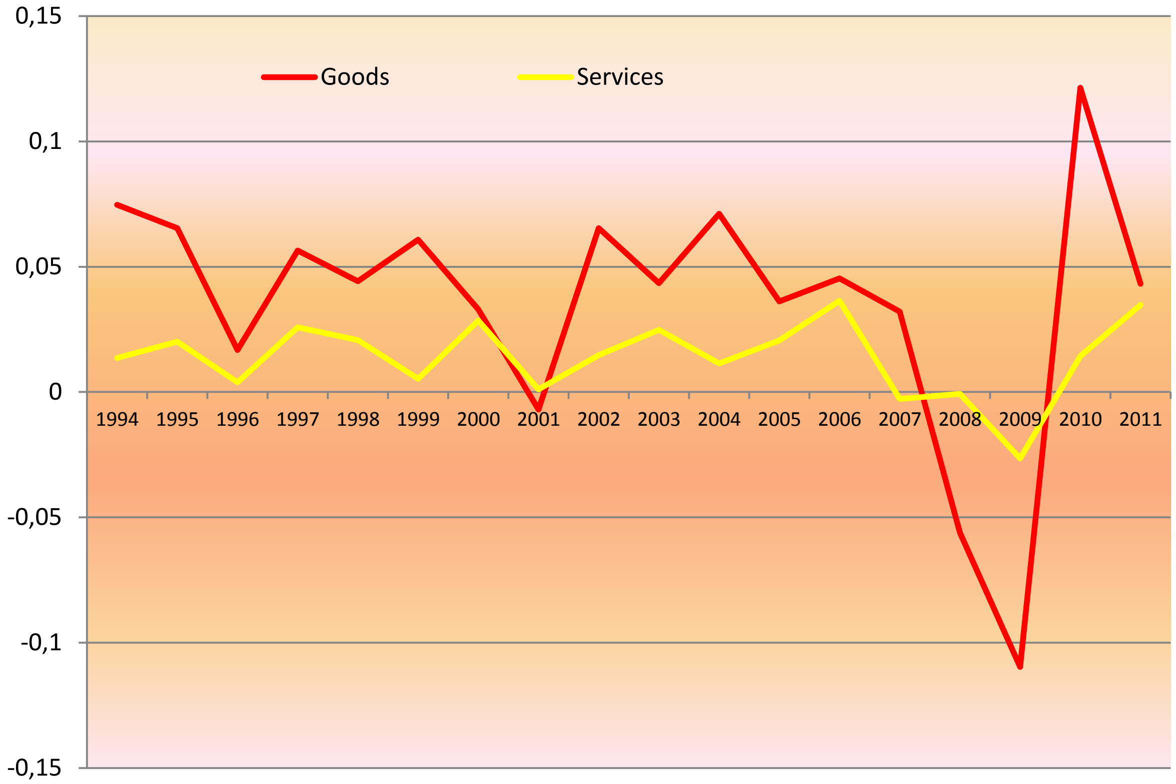
Figure 12. Growth pattern for Multifactor productivity for the time period 1993-2011



Source: Statistics Sweden

Even if the growth in 2010 was the largest in the whole period and also 2011 was one of the best years, this still meant that just two percentage points have been reversed. So it is still the growth under an almost full cycle that is lost.

Figure 13. The difference in the multifactor productivity growth pattern between the goods producing and service producing parts of the business sector

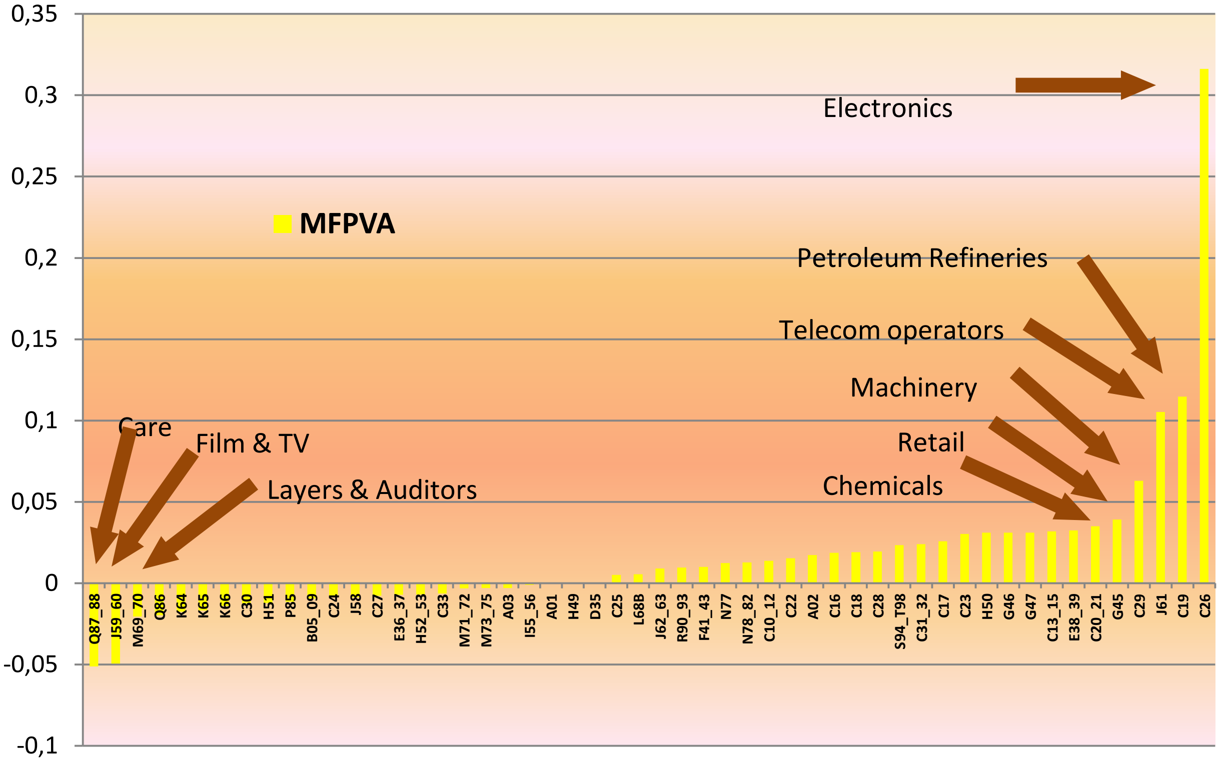


Source: Statistics Sweden

The difference in the growth pattern between the goods producers and service producers has not been very large before the crises. In most years the development has been parallel but on largely different levels. The years in between have been relatively weaker for the goods producers and so the amplitude is much larger for these industries. This is true also in the recent crisis. Both parts of the business sector were hit more severely in productivity terms than any time before in this period, and the difference in amplitude was much larger than before. However, the relative impact on the average growth rate was quite similar. The average growth rate 1993-2011 compared to 1993-2007 was 23 percent lower for the goods producing industries while it was 20 percent lower for the service producers. So in multifactor productivity terms, the loss in relative terms was of the same magnitude.

As could be expected from the figures shown earlier, it is the production of electronics that has by far the highest growth rate in value added multifactor productivity. The telecom operators and broadband facilitators have also increased their multifactor productivity substantially. So the ICT have been most important drivers over this time period. Perhaps a little surprising, the petroleum refineries have managed to squeeze in between them. Actually their efficiency has decreased in using intermediates so the large increase in productivity in their own process is not that impressive.

Figure 14. The industry difference in average multifactor productivity growth for the time period 1993-2011



Source: Statistics Sweden

The fact that the next three industries in line contain two technologic advanced industries machinery C29 and chemicals C20-21 is expected, so it is more important that the third industry is retail G 45. However, this as well as the ICT-effect is still in line with the US experience. On the other hand we find Care O87-88, Film and TV J59-60 and Layers and Auditors M69-70. This is definitely not a copy of American development. The first one is already an industry that has expanded very rapidly due to a policy change that has opened up for private production. The new entry does seem to initially lead to improvement in the industry productivity. The other two industries are more of success stories in the US than in Sweden, even if the last one has also expanded rapidly in Sweden.

Trade and prices

Technical change and competition are the main driving forces

Multifactor productivity is often called technical change; this implies that innovation is the main force behind the MFP growth. Important factors that are involved in the creation of an innovate environment are research, ICT use and human capital.

Let us look at the situation for a single firm. If it is operating in a perfect market all the benefits of a MFP increase would go to the customers. However, if the products are not homogenous and differ between firms, as they do in at least most high tech industries, this is not the case. And if a firm is really innovative and does not just spend a lot of money on R&D, it will increase the value of its products and services or improve its production and distribution, if its innovation has more of a product orientation or process orientation. If the firm is a true monopolist or has more limited monopoly power, in scope or time, based on patents or on the advantage of being first in the market, the firm can expect to benefit a lot from its innovation. But if its position on the market is weaker due to strong competition by other innovative firms, the rewards will be just a fraction of the total benefits of this innovation to society. A market where there are many examples of both these alternatives is the market for ICT goods and services.

In the 1960s IBM had a very large market power and huge profits, as Microsoft in the 1990s and Google and Apple in recent years. But most of the submarkets of the ICT market are characterised by fierce competition, where a firm's innovative ability does not guarantee large profit margins. Those who have benefited most from the rapid technological developments are the customers who have continuously received better products and services for the same or lower prices.

In an industry that is less dynamic and where fewer innovations are taking place, the customer can normally not expect falling prices even if the competition is intense. But if such a market undergoes a dramatic change, for example opens up to international competition, the prices can fall even on a rather stagnant and not so innovative market as the Swedish food market. When Sweden joined the EU the Swedish food producers, both the farmers and the food processing industry, suddenly had to compete with other European firms. And after that new players have entered in the national distribution market in the form of foreign grocery chains that have established themselves in Sweden. Both these major changes in the competitive environment have led to lower prices for the Swedish consumers. During the 1980s the CPI for food increased by 0.4 percent more per year than the total CPI, but after 1990 it did increase by 1.2 percent less up to year 2000 for being completely parallel movement during the last 12 years. So there are two major forces that influence price development: technical changes and competition in the market.

Who benefits most from MFP growth?

It is not only a continuous fight between producers and their customers of how much each should benefit from technological development. It is also in fact a competition among nations. If for example a country produces a lot of IT hardware it could in a world with imperfect markets be expected to benefit from the rapid productivity growth that gives a boost to their GNI. This is of course true in volume terms with fixed prices, but is not as self evident when it is measured in current prices. And the transactions between countries are done in current prices. If a country's trade balances, it does so in current prices. The country has to buy its imports with the euros it receives from its export. If international competition is fierce, the national firms have to charge lower prices than they could this year in order to sell their products to other countries next year also. This means that they cannot distribute as large sums to their employees and their owners as they otherwise could have done. In turn their employees and owners cannot buy as many foreign consumer goods as if their employer could have been able to keep the price level from this year.

In the trade battle between nations it is of utmost importance for a country to sell its products for as much money as possible and buy as cheaply as possible. If a country's export is dominated by products and services that are produced by industries with high MFP growth sold on very competitive markets, it will have to sell them at decreasing prices and thus give away a large part of the rapid MFP increase to customers in other countries. But on the other hand it is of course an advantage to specialise in high tech industries with a high MFP growth since this increases the growth rate of the country. The trick is to produce products with high MFP growth rates with rather weak competition or use a lot of them in your own country. But it is definitely an advantage to import a lot of products and services with high MFP growth sold on very competitive markets.

The input of goods and services also matter

The prices of goods and services are not only dependent on the changes in the internal process of the firm that sells them, that is, the development of its value added. The income from sales, or gross production, depends thus on the value added, or the contribution that a firm does itself to all the inputs that it buys from other firms, as well as inputs such as: raw materials, intermediate goods, energy and services. For companies that produce goods, their value added is in general worth considerably less than half of the value of the finished good. Value added is more important for many service firms, but for all firms the inputs bought from other firms are of great importance.

The change of the prices of the goods or services that a certain industry sells therefore depends not only on the MFP growth of its own industry but also on the MFP growth of all the industries that it uses as inputs. For example, if the price of crude oil increases, some industries like the petroleum refineries that use crude oil as an input are faced with increasing costs. Since they do not add much to the value of their inputs and thus cannot absorb any of this cost increase, they pass them on to their customers. Among these customers, some industries such as the real estate business are important. Some other industries like telecom operators J61 have a good MFP growth and do not need to pass on so much to their customers. On the other hand, the real estate firms have difficulties to improve their productivity so fast.

The input of goods and services also matter

The prices of goods and services are not only dependent on the changes in the internal process of the firm that sells them, that is, the development of its value added. The income from sales, or gross production, depends thus on the value added, or the contribution that a firm does itself as well as what it buys from other firms, inputs such as: raw materials, intermediate goods, energy and services. For companies that produce goods, their value added is in general worth considerably less than half of the value of the finished good. Value added is more important for many service firms, but for all firms the inputs bought from other firms are of great importance.

In order to incorporate all these linkages it is necessary to use the inverse of the input-output matrix. This matrix gives the required information if each element is reduced in the diagonal vector by 1 and scaled down to the input share of gross production. The reason why it is necessary to do this is that the question it answers is a different one. The strict Leontief inverse answers the question: if one unit of a product shall be produced, how much must the production of different industries increase? This answer includes of course the production of one unit of this product, and then on the intermediate input of all products including the intermediate consumption of the same product. However, in this case the interest lies not on the output of a product but on the production. This means we have separated the value added of the production on one hand, and the intermediate input of this product and of all other relevant products on the other hand. The proportion of these two elements is of course given by the proportion of value added respectively on the intermediate input in the gross production. The relative weights of the different products in the final intermediate consumption are given by the proportion in the Leontief Inverse elements with the diagonal element reduced by 1.

These elements are then scaled down to the share of the intermediate consumption in the gross production for the respective industry. Had not the diagonal elements been reduced with 1 the company’s own product had seemed to be the most important product in the intermediate consumption for all products. This is of course not the case. These final versions of the inputs are in value added terms. Therefore the vector with the growth rates of the value added multifactor productivity (MFPVA) is multiplied by this adjusted version of the inverse of the I-O-matrix. This transaction will give the MFP of the inputs of each industry. Then the MFP for the value added of each industry will be weighed together to get a new embedded multifactor productivity measurement with respective weights for the value added and the intermediate inputs for each industry.

Embedded MFP = (1-(VA/GP)) x [MFPVA x $(I\text{-}O)_{Adjust}^{-1}$] + (VA/GP) x MFPVA

Embedded MFP = 53x1-vector with the growth rates for the new measurement, which is defined in the equation above for Multi Factor Productivity for Value added for each industry

MFPVA = 1x53-vector with the growth rates for Multi Factor Productivity for Value Added for each sector

$(I\text{-}O)_{Adjust}^{-1}$ = The inverse of the input-output matrix with an adjusted diagonal vector, and thus a 53x53 matrix

(VA/GP) = The value added part of the gross production

Ideally an I-O matrix for every year from 1993-2010 should have been used, but since there are only a matrixes in the new industry classification for 2008, this has been used for the whole period. In figure 15 a and 15 b the relationship between the traditionally calculated MFP for different industries and the embedded MFP for the same industries is shown.

Two things are apparent, the relationship between the two measurements is quite strong but still the differences between industries are much less for the embedded MFP compared to the original MFPVA. The last observation is due to the fact that the intermediate consumption is a weighted average of several industries which of course are less extreme. Especially some industries that are used intensely as inputs have generally low and in some cases even negative MFP developments. Actually, the industry that has the by far the largest average weight, the business consultancy industries, have all negative MFP-developments.

Figure 15 a. The relationship between the MFPVA and the embedded MFP

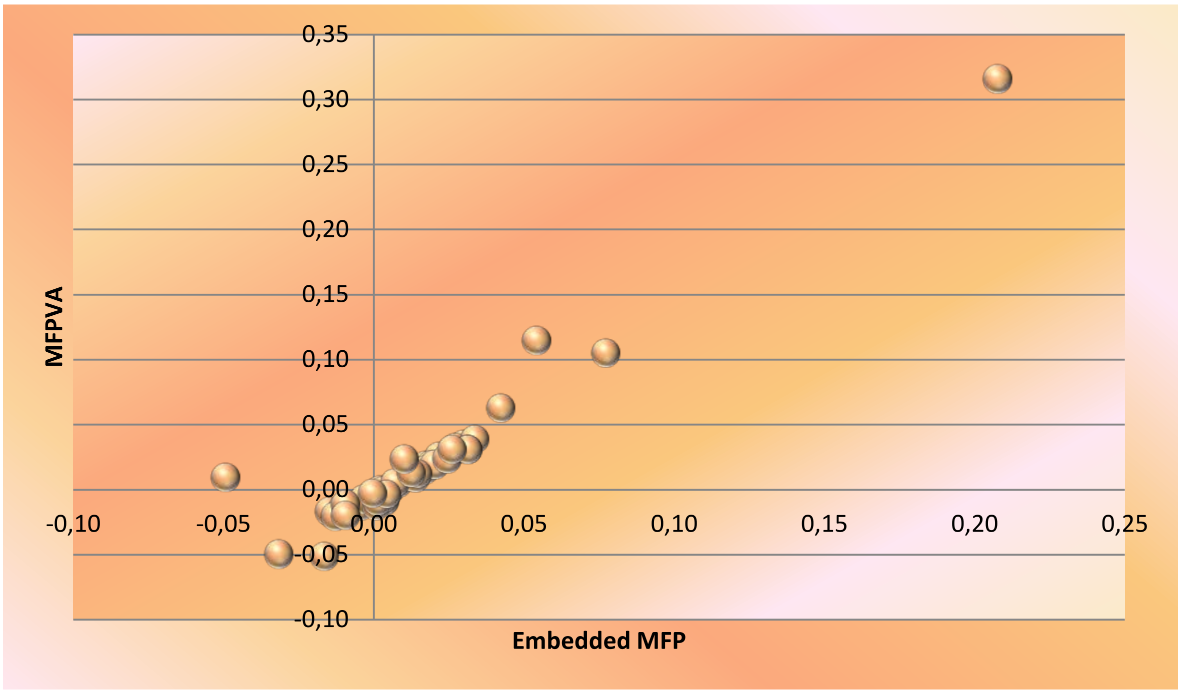
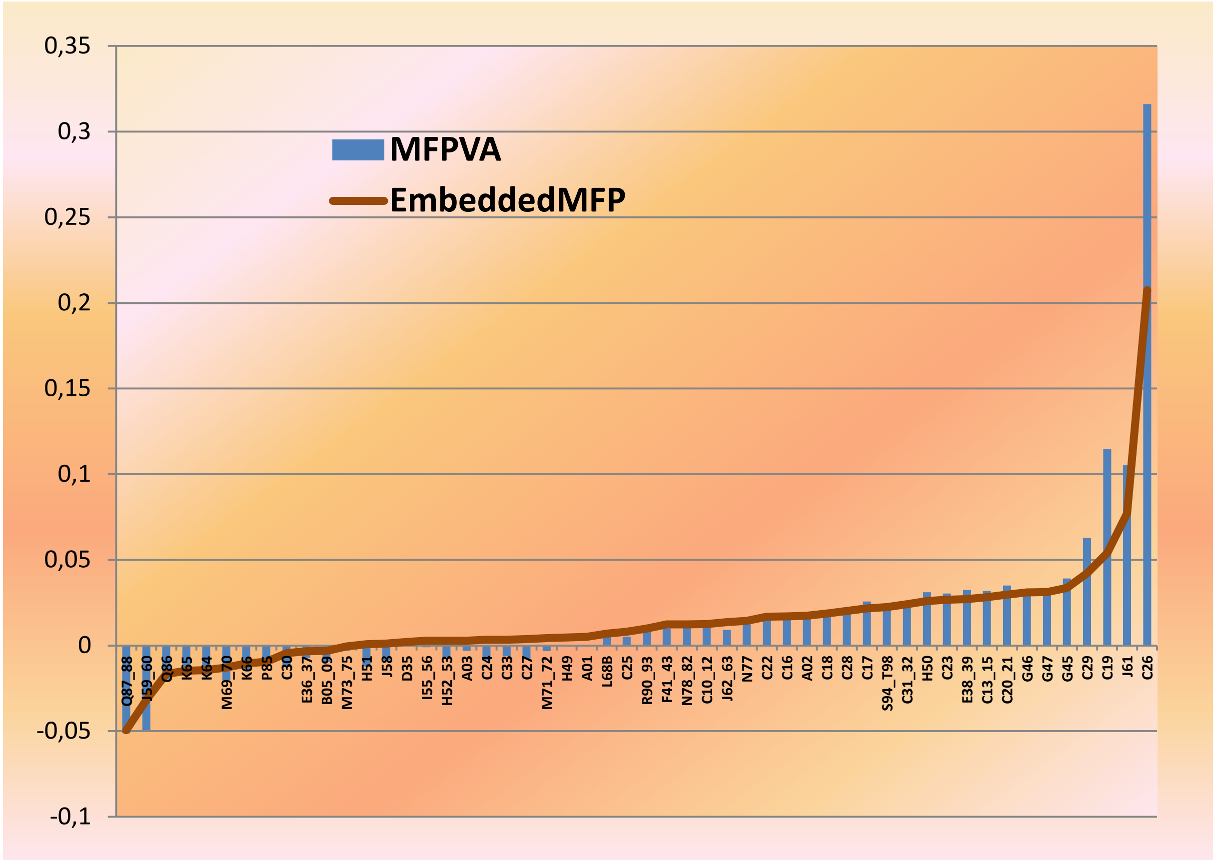


Figure 15 b. Industries ranked according to the embedded MFP and the original MFPVA

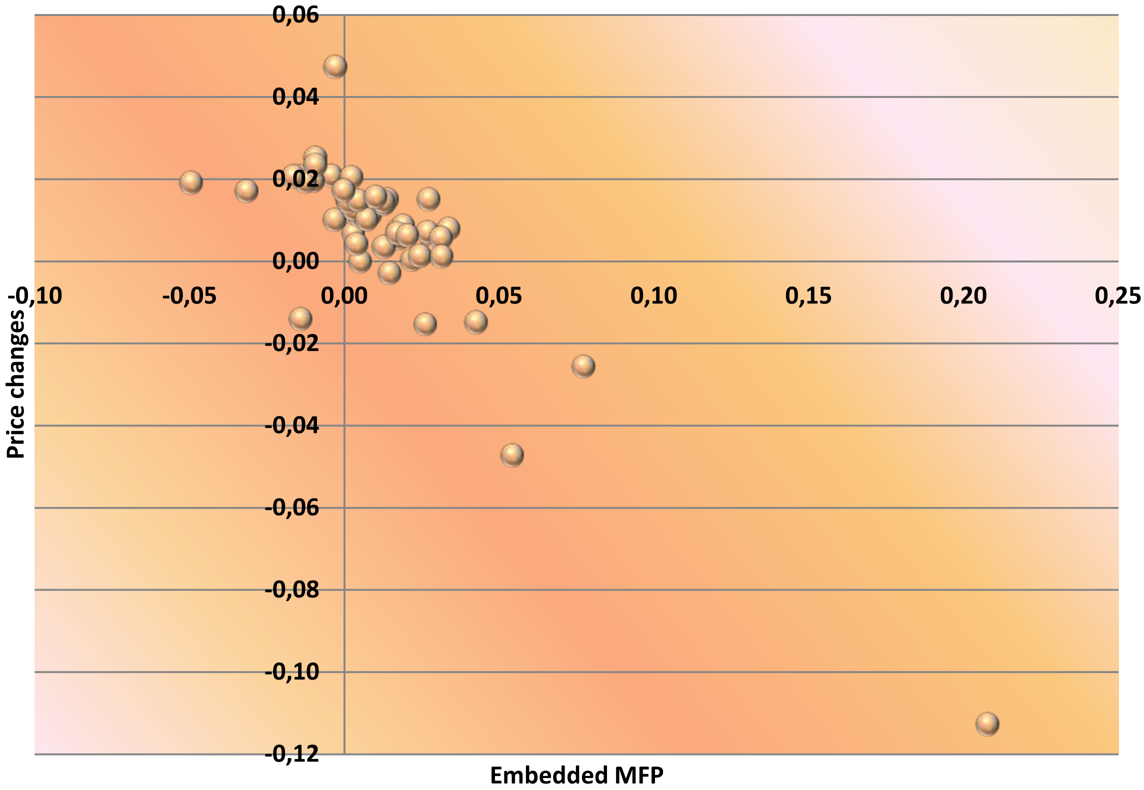


Source: Statistics Sweden

Quite naturally the differences have in general been reduced. The input of intermediates is of course a weighted average of a number of industries, even if their weights vary between industries, and thus reduces the differences. Especially three industries have large negative differences in growth rates between the firm's own multifactor value added productivity and the average multifactor productivity that is incorporated in their output these are: electronics, telecom and petroleum refineries. The electronics industry is by far affected with the largest impact since no other industry could match its own productivity growth rate.

But these MFP growth rates are based on our national data, and especially the inputs of goods are imported to a large extent. This creates a problem, since there are differences between countries in specialisation within a certain industry. And the specialisation has become very intensive, especially for a small country like Sweden. However, in our globalised world the products in same product-family are probably not that different in technological development or the competitive pressure in their respective market. This is probably true for at least the goods producer in the more advanced countries, and these industries still dominate the international exchange not only in goods trade, but also in service trade. At least three quarters of our import of goods comes from countries which are on the same level of economic sophistication as Sweden, and probably a lot of the imports from other countries are also quite advanced. This assumption should in most cases give us a reasonably good approximation for the goods producing industries and the service industries are still mainly national. So in this exercise the MFP growth rates for the same industries in Sweden are used as proxies also for the imported part of the intermediate goods and services. Still it is necessary to keep this assumption in mind in the analyses.

Figure 16. The relationship between the embedded MFP and Prices 1993-2011

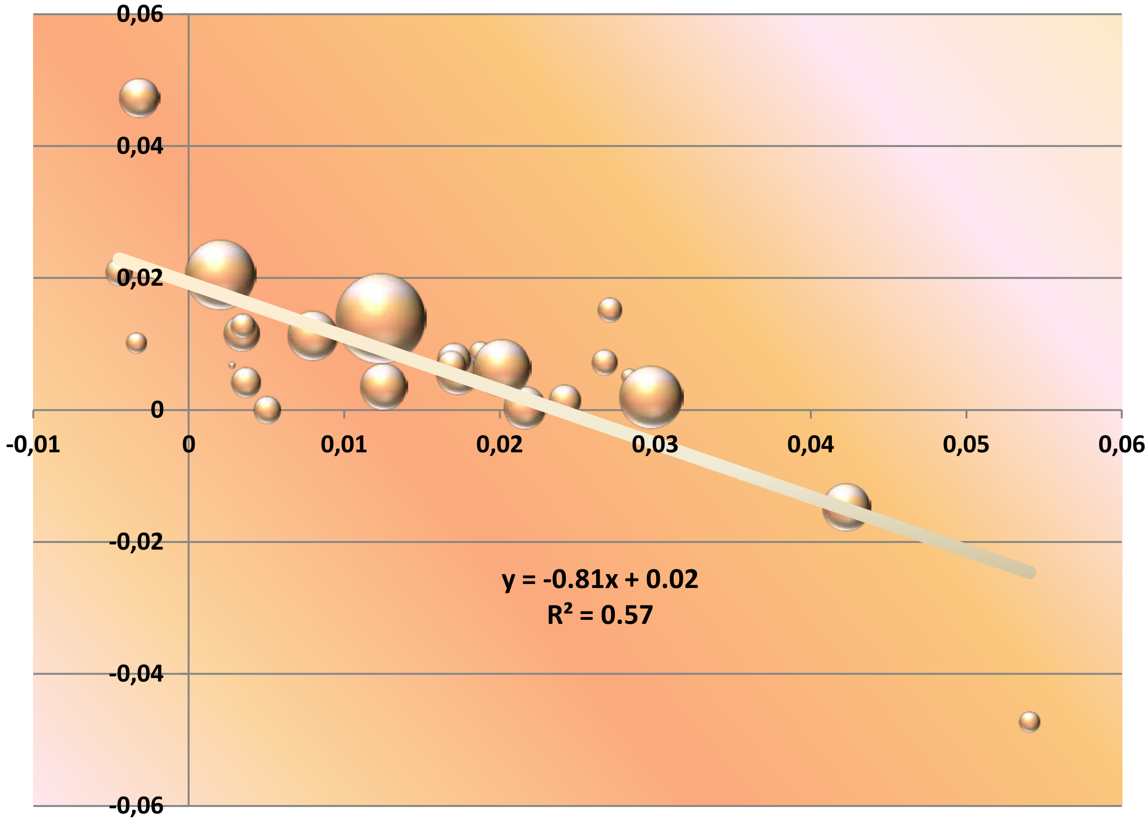


Source: Statistics Sweden

However, there is a reason why a country imports a certain type of goods from a particular country. And this reason is of course that the latter country is in relative terms a more competitive producer of this type of goods. If some countries have a comparative advantage in producing certain types of goods, they probably also have done well in the MFP field, so all the MFP growth rates are definitely not the same. This does not mean that that the types of machinery Sweden exports are more advanced than the types it buys from other countries. So hopefully this does not influence our results that much, but as already mentioned it has to be considered in the analysis.

As can be seen in figure 16 the relationship between the prices and MFP is clearly quite strong, but apparently a couple of extreme observations have affected this relationship very markedly. If two extreme observations are excluded the R^2 drops to two thirds of its original value. However, taking the result as it is and uses a GLM-model with weights and VCE robust estimation; this tells us that an increase of the MFP growth rate by 1 percent per year gives a price increase of 0.6 less percent per year. That means that almost three fifths of the benefits of a technological change are on average passed on to the buyers. As already mentioned, with perfect markets all the improvements of the MFP should be passed on to the customers so 1 percent higher MFP would result in a 1 percent lower price development. This is apparently the case of the reasons already described. And if these extreme industries with very fierce competitions are excluded, the average firm in the average industry keeps a little less than half of the technological change in their industry as well as in their supplying industries. The goods producing industries are more exposed to international competition so they can keep less than one fifth as can be seen from figure 17.

Figure 17. The relationship for the goods producing industries between the new total production MFP and Prices 1993-2011. The sphere surface is proportional to the value added of the industry



Source: Statistics Sweden

Compared to the similar Canadian[xx] calculation there is a marked difference especially taking into account the importance of the extreme observations in the Swedish case. The Canadian data is based on a very long time period, namely from 1961 to 1995, and the traditional gross production concept. The correlation coefficient in this dataset is 0.8 which is the same for the full Swedish data with the same MFP definition. Since the Swedish result is dependent on some extreme values, this gives an indication that the competition on the Canadian market is generally somewhat stronger than on the Swedish market. One explanation could be influence from the US market.

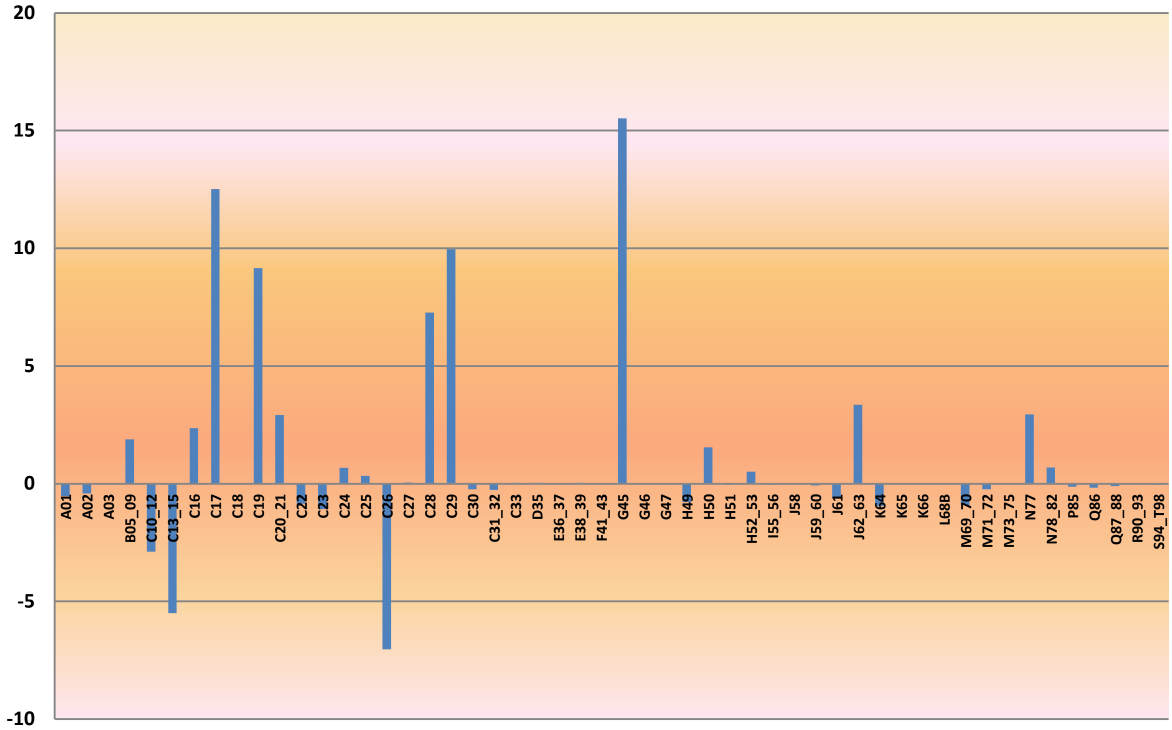
Swedish export and import of MFP

It is not only companies and industries that have to give away some of their productivity increases to their customers; nations must also do so. Some indications on how the Swedish trade balance looks in this perspective have thus been constructed. The Swedish trade data in current prices for 2011 is used. The different industries' weights in the total export for each year have been multiplied by the average growth rates of the new embedded MFP measurements for the period 1993-2011.

Almost all the MFP export has been created by just a handful of industries, since less than the 10 most important ones accounted for around 90 percent of the export of MFP. It is the Swedish electronic products industry C26 that alone stands for almost half of it, followed machines C29, petroleum refineries C19, cars C28 chemicals C20-21 and car trade G 45. Exactly the same industries but the car trade make out the imports of MFP, with electronics being even more dominant.

The interesting question is then if Sweden is a net exporter of MFP or a net importer. The average of embedded MFP is identical for the Swedish export and import. However since Swedish net export is quite large in relative terms also so is its net export of MFP. In figure 18 it can be seen that it is four industries in particular, and three other in lesser degree that makes this up.

Figure 18. The product of the embedded multifactor productivity and net export 2011



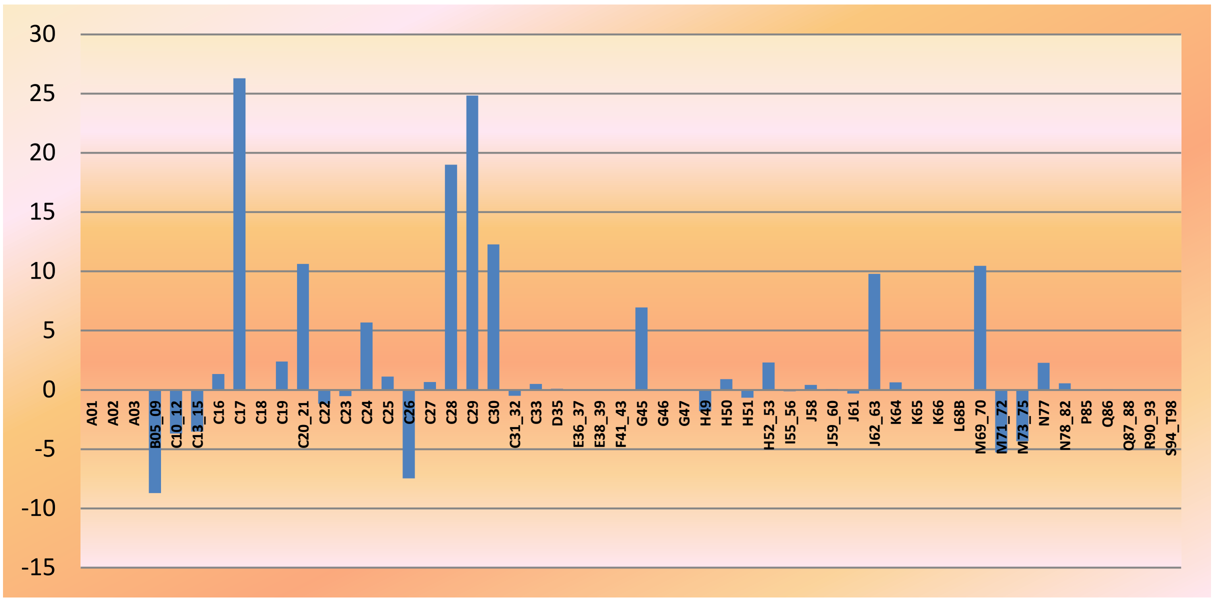
Source: Statistics Sweden

Perhaps a little surprising is that there is also a traditional industry that makes it into this category and that is paper C17. The more technological advanced industries in this category are the car industry C28 and machinery C29. And perhaps more surprising, petroleum refineries C19, and last but not least the car trade G 45 which does not change this impression that even if a lot of the Swedish export is in high tech industries, it is not these industries that create our net export of MFP. However, besides electronic goods, our net-import of MFP is based on land transport C 49 and, as traditional goods producers, textiles C13-15 and food C10-12. The assumption that the imports of all goods and services are produced in the same way as in Sweden is of course more problematic for these two industries. This makes it less obvious that we do import that much MFP in these products.

Our very tentative conclusion is then that Sweden would not export MFP to any significantly larger extent than its imports, but for its large trade surplus. Since our terms of trade have somewhat deteriorated during the last decade, our specialisation is apparently not optimally seen from this perspective. But this is not a major explanation of the paradox of a good growth performance and an undervaluated currency. Perhaps the large change in the exchange rate with the Euro-countries will change this situation in the coming years?

The picture of net export of research and development resembles that of the net export of embedded multifactor productivity. Among the four largest contributors, only the petroleum refineries C19 have dropped out and the car trade G 45 is quite reduced now in the second line of some new industries emerging. There are two high tech industries: chemicals and pharmaceuticals C20-21 and other transport equipment than cars C30, and a very traditional one: metal producers C24.

Figure 19. Net export of R&D. Net export as percent of total import times the embedded R&D

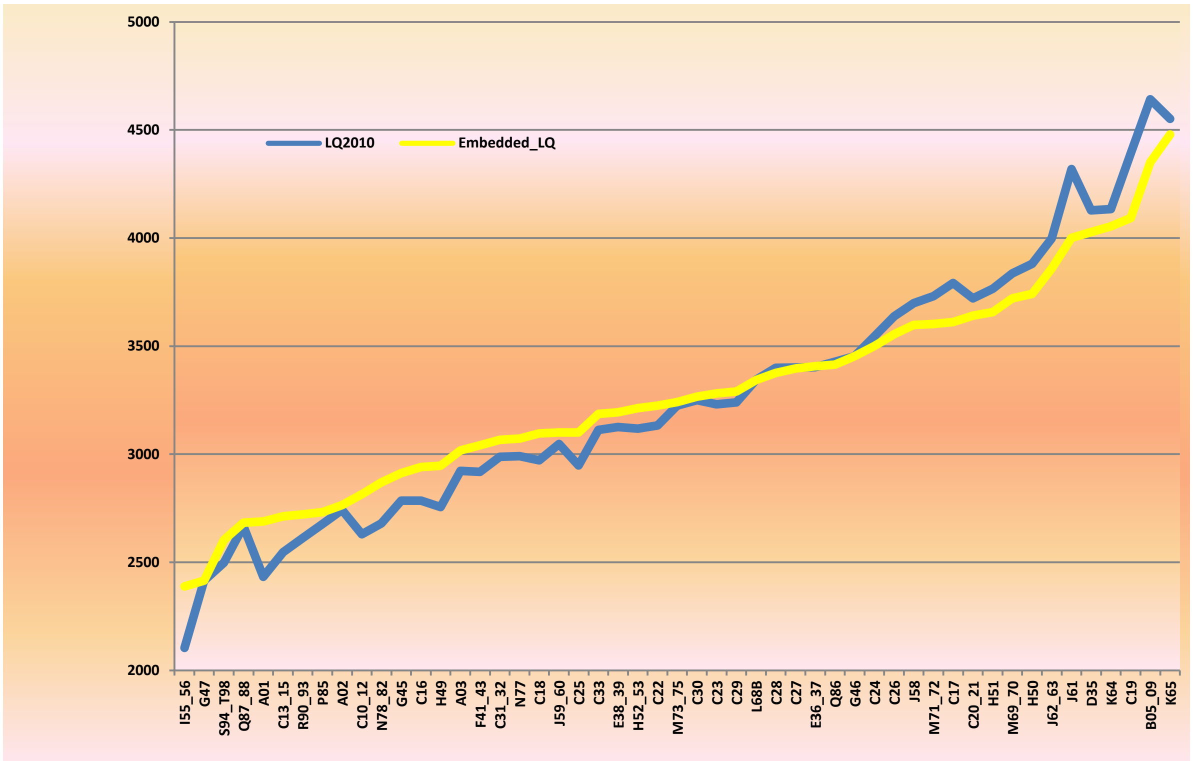


Source: Statistics Sweden

There are also two service industries beside trade with cars G 45, that give some contributions: programming and data service J62-63 and lawyers and auditors M69-70.

Figure 20. Comparison with labour quality and embedded labour quality

So



urce: Statistics Sweden

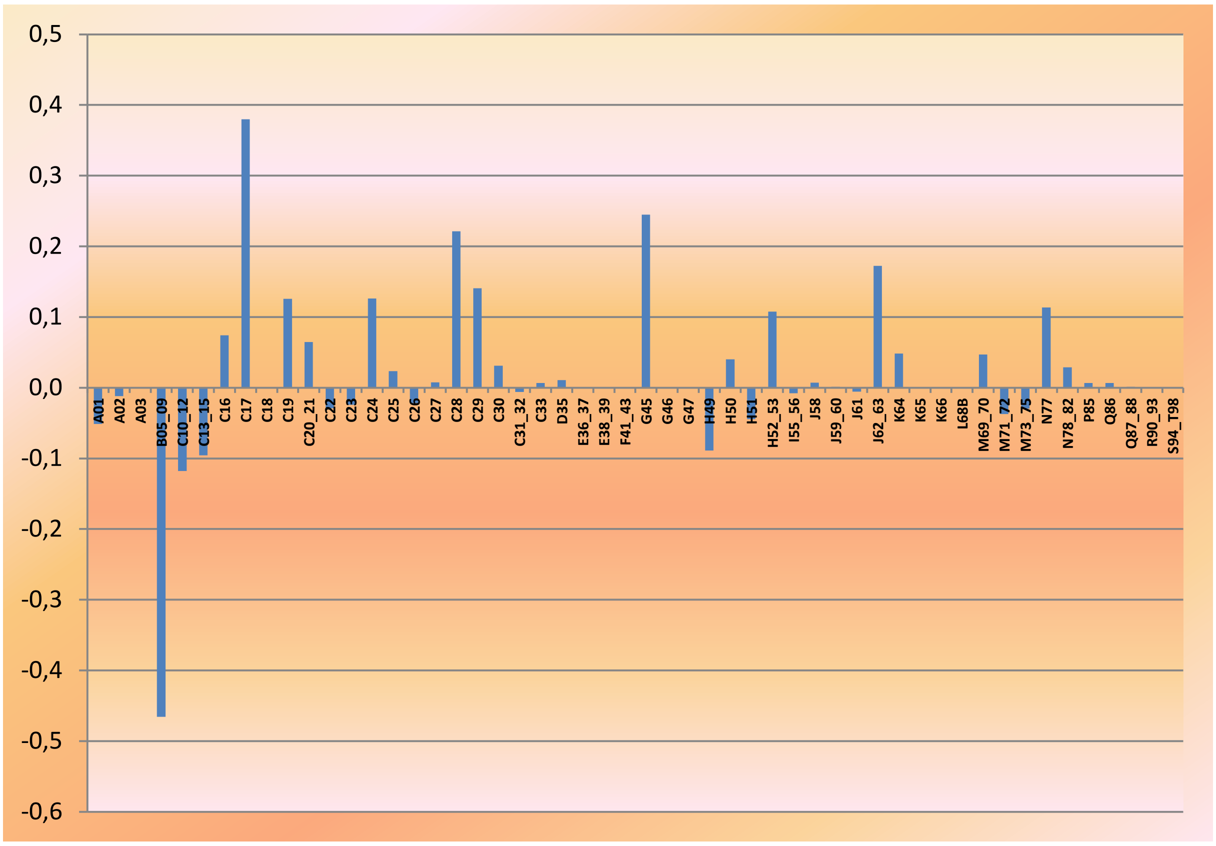
The general effect of substituting the labour quality measurement with the embedded labour quality did reduce the industry differences, but not that much. Still, three industries got their labour quality substantially (with more than 5 percent) reduced: mining B05-07, petroleum refineries C 19 and also a qualified services industry: telecom operators J61.

On the other end of the scale we find that hotels and restaurants I 55-56 and farming A 01-02 have benefitted most (more than 10 percent) from their suppliers but also N78-82 other supporting services as well as land transport H49, car sellers G45, food producers C 10-12, textiles C 13-15 and wood producers C 16 have got a substantial boost (more than 5 percent) to their labour quality.

As already mentioned, the average labour quality weighted by the export shares is almost identical to that weighted by the import shares. However, the large net export means that Sweden does export also more embedded labour quality than it imports. It is not that surprisingly that the main contributors are still the very same industries as for the multifactor productivity. This is because the differences in net export are much larger when in productivity growth rates, R&D intensity and labour quality levels.

The final comparison, the net export of labour quality differs a little more. Also, if the export-basket is compared with our import-basket in human capital terms, we cannot find any particular pattern. This conclusion is derived from a similar analysis when the labour quality indicator is used in the same way as the value added multifactor productivity.

Figure 21. The net export of labour quality



Source: Statistics Sweden

From figure 20 it is possible to deduct the net export of labour quality. Still, the three industries with the largest contribution to the net export of embedded multifactor productivity and research and development are still the same: paper C17, the car industry C28 and the car trade G 45. Machinery C29 and programming and data service J62-63 are added to this.

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ICTNET

EUROPEAN NETWORK FOR THE RESEARCH ON THE ECONOMIC IMPACT OF ICT

ICTNET is a project financed by the European Commission DG CONNECT (Directorate General for Communications Networks, Content and Technology, formerly DG Information Society and Media) and aimed at enhancing the coordination of the research in the economics of information and communication technologies (ICT) in Europe.

The objective of the ICTNET is to bring together leading researchers on the economics of ICT in order to discuss recent scientific contributions and increase the policy relevance of the research in this field.

ICT have been a major driver of productivity and growth over the last two decades. They have been the most dynamic component of investment, have increased the productivity of labour and all production factors and have accounted for the bulk of business R&D. Through all these channels, ICT have created the opportunity for firms to innovate in products, processes, organisation and marketing methods.

As the financial and economic crisis continued to unfold around the globe, the strategic role of ICT has taken on even greater relevance and urgency. The application of ICT and the innovations enabled by ICT will be one of the keys to emerging from the downturn and putting countries back on a path to sustainable – and smarter – growth.

Indeed, many of the stimulus packages contain measures to accelerate the deployment and development of fixed and wireless communication infrastructure. Internet broadband networks, in particular, are regarded as crucial platform to promote innovative products and services throughout the economy.

As the crisis forces our societies to look for a different growth path and policies engage even more in the support to ICT, an assessment of their impact become crucial to ensure that today's measures serve as an investment in long-term growth.

Coordination of research is key to this assessment. The overall impact of ICT and ICT policies depends not only on their success in specific areas but on the coherent articulation of ICT diffusion and policies in different segments of the economy. Coordination of the research permits to exploit synergies among different areas of investigation, better address policy questions and provide a comprehensive assessment of their impact.

Four areas appear important for the assessment of ICT and ICT policies:

1. What is the contribution of ICT to growth and productivity? How can policy create the conditions that maximize their contribution?

2. What is the contribution of ICT to investment in R&D and intangibles? What policies are most effective to support these investments?

3. What is the role of ICT as an enabler of innovation? How can policies create an environment that is conducive to ICT-enabled innovation?

4. What factors affect the diffusion of ICT among firms and households? What is the regulatory framework required to promote diffusion?

In all four areas, economic research has been very active over the last few years. Databases created at the European level have opened up new possibilities to analyse the diffusion of ICT across countries and industries, its different forms and its relation to R&D investments, innovation and productivity growth.

Recent empirical work on R&D and innovation aims at understanding the relation between accumulation of ICT and other physical capital and investment in human capital and knowledge creation in detail. In particular, research efforts concentrate on defining and measuring intangible capital at the macroeconomic level.

At the firm-level, research focuses on methods to disentangle efficiency gains and increased innovation activity resulting from ICT investment and complementary strategies from instances of reverse causality. Moreover, there is a rising interest in understanding the chain of effects from ICT diffusion among individual firms, to competition within industries and to aggregate economic growth.

Most research contributions have a particular focus on one of these areas. In fact, these areas are closely linked to each other and the coordination among them is crucial in terms of transforming the research results into policy measures.

In this respect, ICTNET is articulated around four work packages that reflect these priority areas:

- ICT, growth and productivity;
- ICT, R&D and intangibles;
- ICT-enabled innovation; and
- ICT diffusion to the economy.

In order to achieve its objectives, ICTNET has been relying on a network of over 30 research institutions with an established research record on the economics of ICT. The coordination group was composed of the Imperial College London (United Kingdom), University of Parma (Italy), ZEW Centre For European Economic Research (Germany) and the Organisation for Economic Cooperation and Development (OECD).

In the course of 2011 and 2012, eight ICTNET workshops took place in Parma, London and Mannheim on the topics of the four work packages. Four issues and four assessment papers served as background documents to the workshops.

Participation to the workshops was open to all researchers and policy analysts with a documented activity in the field of ICT. Workshop of a particular research area was jointly held with the workshop of another area. This allowed researchers from an ICT field to learn about and to feed the research activities in other ICT areas. In this way, synergies among different research groups have been exploited efficiently.

The Final ICTNET Conference took place in 25-26 June 2012 at the OECD Headquarters (Paris, France) and brought together researchers from the network together with a large number of ICT researchers and policy makers external to the network (see Annex 3 for the Final Conference agenda). The conference allowed diffusing the results of the project to the broader research community, the policy makers and the media. Important conclusions have emerged with respect to key topics of the current ICT policy agenda such as the importance of new industry policies for ICT diffusion, economic challenges related to the development of "big data", the role of policy incentives to enhance ICT-enabled innovation and the impact of ICT on employment and growth at the aftermath of the crisis.

All the material related to the workshops and the final conference is available on the project's website: www.ict-net.eu

The ICTNET Final report on *Economic Impact of ICT: Economic Evidence and Policy Drivers* (forthcoming) aims to provide a comprehensive assessment of the economic impact of ICT and ICT-related policies and to define a research agenda for the years to come. The following chapter is part of this report and focuses on ICT, R&D and intangibles.

ICT, R&D AND INTANGIBLES

In recent years, intangible assets have gained a prominent position in the agendas of researchers and policy makers alike. One factor behind the heightened interest is the increasingly nuanced understanding of the drivers of innovation. While research on innovation has traditionally focused on "hard" assets (universities, laboratories and scientists) more recent literature, including the *OECD's Innovation Strategy* (www.oecd.org/innovation/strategy) has drawn attention to the importance of intangibles such as design, software and marketing.

Current macroeconomic conditions in many advanced economies have also hastened the drive to find new sources of growth. This search has naturally focused on the intangible assets that are defining features of the knowledge economy. Simultaneously, the economic crisis has stoked fears that investments in productivity-enhancing intangible assets might have been curtailed.

As part of the increasing interest for intangible assets, ICT have received a special attention for at least three reasons. First, computerised information (software and databases) accounts for a significant proportion of total intangibles. Second, successful adoption and use of ICT by businesses require complementary investments in intangibles, like training, management and organisation.

Finally, ICT themselves are raising the economic value of information. The data gathered on the purchase preferences of e-costumers has become a business asset for on-line retailers. Iconic companies, such as Microsoft and Google, are renowned for owning relatively little tangible capital and for placing high importance on the skills and creativity of their employees.

While intangibles are regarded as a key driver for innovation and growth, intangible assets are still poorly measured. A better understanding is essential to diagnose policy priorities for driving growth: ignoring or wrongly measuring intangibles is likely to lead to a distorted picture of changes in economic growth and productivity and their causes.

This chapter presents the empirical evidence on the value of intangible assets in advanced economies (Section 1) and their contribution to growth and productivity (Section 2) with a focus on ICT-related intangibles. Measurement problems that arise in the estimation of intangibles, particularly for computerised information, and some feasible directions to address them are presented in Section 3. Finally, Section 4 discusses the potential role of public policies and framework conditions to foster the accumulation of intangible assets, notably software, inter-firm networks and digital data, and to increase their contribution to innovation and growth.

1. The value of intangible assets: the statistical evidence

Sometimes referred to as 'knowledge assets' or 'intellectual capital', intangible assets have been defined as "claims on future benefits that do not have a physical or financial embodiment" (Lev, 2001). Much of the focus on intangibles has been on R&D, key personnel and software. But the range of intangible assets is considerably broader. One classification, offered by Corrado, Hulten and Sichel (CHS, 2005), groups intangible investments into three main types: computerised information (such as software and databases); innovative property (such as scientific and non-scientific R&D, copyrights, designs, trademarks); and economic competencies (including brand equity, firm-specific human capital, networks joining people and institutions, organisational know-how that increases enterprise efficiency, and aspects of advertising and marketing).

The extensive literature on intangibles focuses mainly on some assets such as R&D expenditures, leaving out other components such as organisational capital or brand equity. Following Sichel (2008) the most recent approaches to measuring intangibles in the economic literature can be classified into three groups:

- Financial market valuation;
- Alternatives performance measures and;
- Direct expenditure data.

The financial market valuation approach assumes that the value of intangible capital corresponds to the difference between the market value of a firm and the value of its tangible assets (Hulten, Hao and Jaeger, 2008). The "market-to-book" gap seems too large to be attributed solely to the mismeasurement of conventional equity while the absence of most intangible assets from financial statements appears like a more convincing explanation of this gap.

This approach has been followed by Brynjolfsson, Hitt and Yang, among others, in order to analyse the link between intangible investments and investment in computers in the United States (Brynjolfsson and Yang, 1999; Brynjolfsson, Hitt and Yang, 2002). Their estimates suggest that each dollar of installed computer capital in a firm is associated with between five and ten dollars increase in the market value. According to the authors, this difference reveals the existence of a large stock of intangible assets that are complementary to computer investment.

Webster (2000) adopts a similar approach with Australian data, assuming that any residual market value of the firm (stock market value plus liabilities) not explained by the balance sheet value of tangible assets must be due to intangible assets. The ratio of intangible to all enterprise capital rises by 1.25% a year over a period of 50 years, from 1948 to1998.

Following a similar approach, the World Bank (2006) has made estimates of intangible capital at the country level. The value of intangible capital is then obtained as the difference between total wealth (measured as the net present value of future sustainable consumption) and natural capital plus produced capital.

The financial market valuation approach may be subject to considerable measurement error as the stock market value is sensible to market inefficiency (Cummins, 2005). It may reflect a mismeasurement due to the investors' limited information on the value of firm's intangibles. It may also be affected by the large variability of the market value of a company due to the short-run expectations of the investors.

Another widely used method to estimate the value of intangible capital uses alternative measures of firms' performance, such as expected profits, earnings or sales. This approach is well exemplified by Cummins (2005). Contrary to the tendency in the literature to treat intangibles as any other fixed factor of production (firms buy intangibles as they would buy machinery), Cummins defines intangible capital as the distinctive way companies combine the usual factor of productions (inputs). Therefore, the value of the intangible capital can be measured as the difference between the "market value" of inputs and the "firm value" of the same inputs, i.e.: their value once they have been internalised in the production of the firm. This difference corresponds to the adjustment costs that the firm is willing to support in order to use these inputs in its production process.

To estimate the return on intangible capital, Cummins proxies the intrinsic value of the firm as the discounted value of expected profits, based on analysts' forecasts (which is argued as reflecting the analysts' valuation of intangibles). The results show no appreciable intangibles associated with R&D or advertising but sizable intangibles (organisational capital) created by IT.

The argument by Brynjolfsson, Hitt and Yang (2002) may be useful in interpreting the above results. Authors argue that such analyst-based measure of the value of a company may be subject to measurement error as it reflects the biases of analysts and the mistakes in the way forecasts are discounted. Therefore, the effects of intangible assets on the firms' market valuation would materialise over a longer period of time.

McGrattan and Prescott (2005) infer the value of intangible capital from corporate profits, the returns to tangible assets and the assumption of equal after-tax returns to tangible and intangible assets. The value of intangible capital then ranges between 31 and 76% of US GDP (using respectively a restricted and a broader definition of intangibles).

From a similar perspective, Lev and Radhakrishnan (2005) develop a firm-specific measure of organisational capital, modelling the effect on sales of organisational capital (proxied by reported sales, general and administrative expenses' as these include expenditures that generate organisational capital).

The direct expenditure approach is adopted the first time by Nakamura (1999 and 2001), gross investment in intangible assets is measured by summing a range of expenditures including R&D, software, advertising and marketing expenditure, and the wages and salaries of managers and creative professionals.

Building on Nakamura's work, Corrado, Hulten and Sichel (2005) developed expenditure based measures of a larger range of intangibles for the US, classified capital into three broad categories: computerised information, innovative property, and economic competencies. Since this seminal paper, increasing emphasis has been put on the need to capitalise expenditures on intangible assets beyond R&D and software (such as training, design and branding) in national accounts, rather than considering them as intermediate expenditures, and to better measure intangibles more generally. Consensus now exists about the importance of intangible capital and the CHS growth accounting framework has been extended to a number of countries.

The table below lists the countries for which estimates of intangible assets exist to date and highlights the main projects and studies in which they are proposed. These studies generally look at how the growth in total output at the national level can be accounted for by the growth in factors of production, with unexplained growth attributed to Total Factor Productivity (TFP) growth. A common result is that accounting for previously omitted intangible capital significantly changes previous measurements of productivity growth, with both a change in output growth (since now output includes investment in intangibles) and a shift away from TFP towards capital deepening as the source of productivity growth.

Country	**Data sources/ Studies**
Australia	Barnes and McClure (2009); Barnes (2010)
Austria	InnoDrive, Hao, Manole, and Van Ark (2008)
Belgium	InnoDrive
Bulgaria	InnoDrive, CoInvest
Canada	Belhocine (2009), Baldwin, Gu and Macdonald (2011)
Cyprus	InnoDrive
Czech Republic	InnoDrive, Hao, Manole, and Van Ark (2008)
Denmark	InnoDrive, Hao, Manole, and Van Ark (2008)
Estonia	InnoDrive
Finland	InnoDrive, Jalava, Aulin-Ahmavaara, and Alanen (2007)
France	InnoDrive, CoInvest, Hao, Manole, and Van Ark (2008)
Germany	InnoDrive, CoInvest, Hao, Manole, and Van Ark (2008)
Greece	InnoDrive, Hao, Manole, and Van Ark (2008)
Hungary	InnoDrive
Ireland	InnoDrive
Italy	InnoDrive, Hao, Manole, and Van Ark (2008)
Japan	Fukao, Miyagawa, Mukai, Shinoda and Tonogi (2009)
Korea	Chun, Pyo and Rhee (2011)
Latvia	InnoDrive
Lithuania	InnoDrive
Luxembourg	InnoDrive
Malta	InnoDrive
Netherlands	InnoDrive, Van Rooijen-Horsten, Van den Bergen, and Tanriseven (2008)
Norway	InnoDrive
Poland	InnoDrive
Portugal	InnoDrive, CoInvest
Romania	InnoDrive
Slovak Republic	InnoDrive, Hao, Manole, and Van Ark (2008)
Slovenia	InnoDrive
Spain	InnoDrive, Hao, Manole, and Van Ark (2008)
Sweden	InnoDrive, CoInvest, Edquist (2011)
United Kingdom	InnoDrive, CoInvest, Gil and Haskel (2008); Giorgio Marrano, Haskel, and Wallis (2009)
United States	Corrado, Hulten, and Sichel (2009)

Source: OECD based on Squicciarini and Criscuolo (2011).

COINVEST and INNODRIVE are the two main initiatives undertaken at the European level to measure the importance of intangible assets and their impact on economic performance and growth.

"COINVEST — Competitiveness, Innovation and Intangible Investments in Europe", is a project financed by the European Commission (FP7 Work Programme) aiming to understand the contributions of intangible investments to innovation, competitiveness, growth and productivity in Europe. According to the main outcomes of this project, the United Kingdom and Sweden are the relatively highest intangible-intensive countries in 2005, at around 14% of market sector value added (excluding real estate, including intangibles). This ratio is just above 10% in Germany, France and Portugal. Sweden and Germany are relatively high investors in R&D, whilst the United Kingdom invests rather heavily in economic competencies.

The sectoral studies of COINVEST highlight that intangible investment in the United Kingdom was 30% in manufacturing and 70% in services over the recent period; whereas the opposite picture was observed in Germany. In Sweden and France intangible investment was of equal importance in the manufacturing and services sectors. In manufacturing, intangible investment exceeded tangibles in all countries. The United Kingdom is one of the countries that invest the most in intangible assets in finance and business services as well.

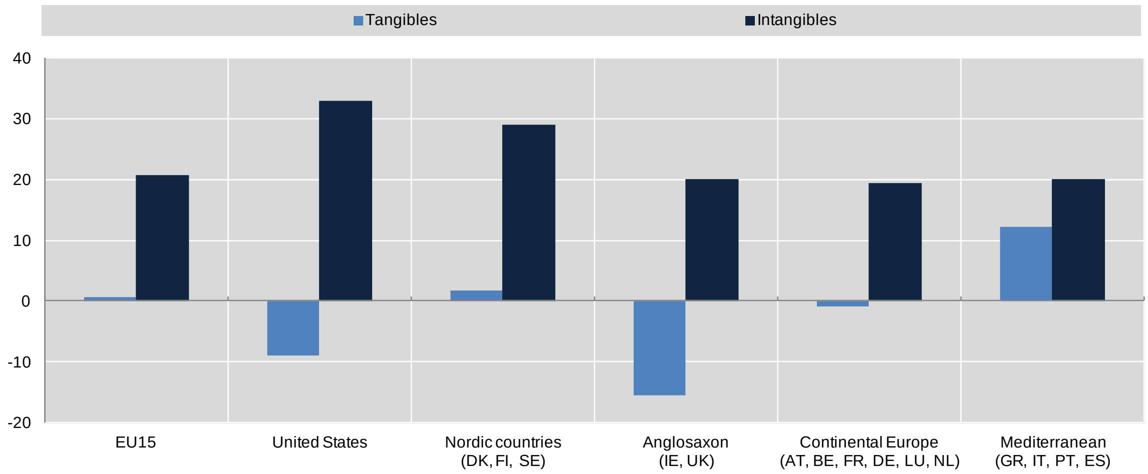
"INNODRIVE —Intangible Capital and Innovations: Drivers of Growth and Location in the EU", is another project financed by the European Commission (FP7 Work Programme) with the aim of providing new data on intangibles and new estimates of the capacity of intangible capital to generate growth both at firm-level and at national level. The main findings are in the same direction as COINVEST: intangible expenditure accounts today for a significant share of GDP in Europe especially in the Northern European and Anglo-Saxon countries. Over the 1995-2005 period, intangible investment increased in all EU25 area, especially in the Slovak Republic followed by the Czech Republic. In parallel, investment in tangible capital decreased or slowed down in all countries. R&D and organisational capital appear to be the main components of intangible investment in most countries.

Both of these two EU-funded research projects follow the CHS framework to estimate the amount of investment in intangible assets for EU countries but the estimates differ in terms of underlying data series and the proxies used for different expenditures that account as intangible investment. For example, to construct the series for investment in advertising, INNODRIVE uses data from Eurostat's Structural Business Survey (turnover for "K74-Other business activities") and from Zenith Optimedia, while COINVEST uses country specific data sources such as estimates from advertising associations for the United Kingdom, or from the Central Association of the German Advertising Industry (ZAW) and the Mannheim Innovation Panel (MIP) for Germany.

In the same way, INNODRIVE uses the Eurostat Continuing Vocational Training Survey (CVTS) as main data source for investment on training, while COINVEST uses country-specific sources like the National Employer Skills Survey for the United Kingdom and the Mannheim Innovation Panel (MIP) data on training expenditures for Germany.

Recently, INNODRIVE/COINVEST/The Confence Board data have been harmonised by Corrado *et al.* (2012). Major revisions include the estimations as regards organisational capital and new financial products. Their results show that European countries lag behind the United States with respect to the investment in intangible assets. Figure 1 plots the percentage changes in tangible and intangible investment in Europe *vis-à-vis* the United States over the 1995-2007 period. The increase in the intangible investment of the Nordic countries and the decrease in the tangible investment in the Anglo-Saxon countries are particularly comparable to the trends observed in the United States.

Figure 1. Tangible vs. Intangible investment GDP shares, Market sector, 1995-2007
Percentage changes



Source: Corrado *et al.* (2012).

In addition to these consortia projects, the CHS methodology has been applied in a number of country studies:

Giorgio Marrano and Haskel (2006) show that in the United Kingdom the private sector spent on intangibles a sum equivalent to 11% of GDP in 2004.

Investment in intangible capital in Japan over the 1995-2002 period was of 7.5% of GDP (Fukao *et al.*, 2007).

According to Jalava, Aulin-Ahmavaara and Alanen (2007), the Finnish investment in intangibles represented 9.1% of GDP in 2005.

Van Rooijen-Horsten, Van den Bergen and Tanriseven (2008) show that the Netherlands spent 10% of its GDP in intangibles over the 2001-2004 period.

Hao, Manole and Van Ark (2008) estimate the spending on intangibles as percentage of GDP in Germany, France, Italy and Spain in 2004 and find that this share was around 5.2% in Italy and Spain, 7.1% in Germany and 8.8% in France.

The total spending on intangibles in Sweden was equivalent to 10.6% of the GDP in 2004 (Edquist, 2009).

In Australia, intangible investment of the market sector is almost half the size of tangible investment and the average annual growth in intangible investment was about 1.3 times that of tangibles from 1974-75 to 2005-06 (Barnes and McClure, 2009).

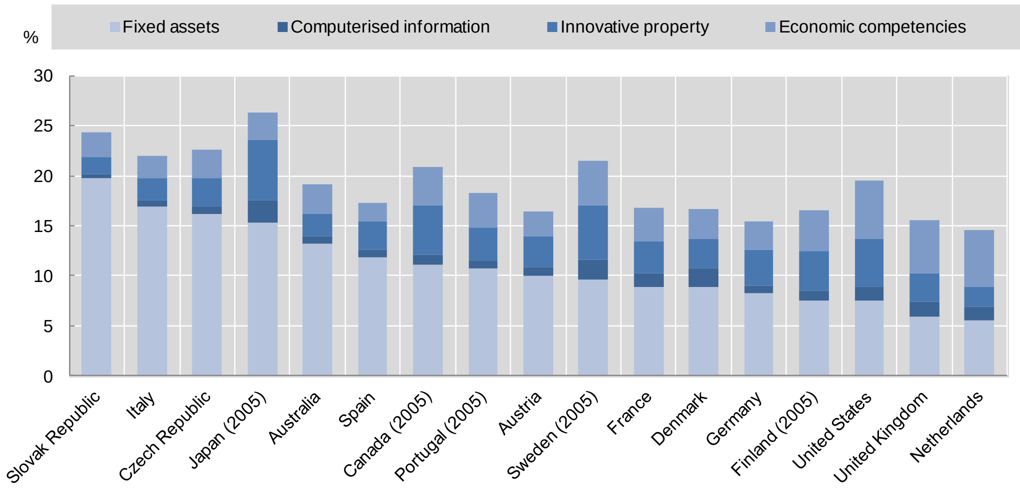
Investments in intangibles in the United States were as important as investments in tangibles over the period 1959-2007 (Nakamura, 2010).

Baldwin, Gu and Macdonald (2011) estimate a total of 151 billion dollars investment in intangibles in the Canadian business sector in 2008, representing 13.2% of the GDP.

Intangible investment in Korea increased from 5.8% to 8.4% of GDP between the periods 1991-2000 and 2001-2008 (Chun, Pyo and Rhee, 2011).

Several studies show that investment in intangible assets is rising and overtaking investment in physical capital in countries such as Finland, the Netherlands, Sweden, the United Kingdom and the United States (Figure 2). The breakdown of intangibles by type of assets shows that ICT intangibles (proxied as computerised information) account for a small share in all countries for which data are available. Investments in computerised information reach about 2% of GDP in Japan, Sweden and Denmark. For the other countries the share of ICT appears lower and typically below 1.5% of GDP.

Figure 2. Investment in fixed and intangible assets as a percentage of GDP, 2006[1]



Note: Estimates are based on national studies. They do not reflect standardised methods and definitions.

Source: *OECD Science, Technology and Industry Scoreboard 2011*, OECD Publishing. Data on intangible assets are based on COINVEST project and national estimates by researchers. Data for fixed investment are OECD calculations based on OECD, Annual National Accounts and EU KLEMS Databases, March 2010[2].

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1. Estimates refer to the total economy for Canada, Japan and Sweden; the market sector for Australia, France, Germany, Italy, Spain and the United Kingdom; the non-financial business sector for Finland; the commercial sector for the Netherlands and the non-farm business sector for the United States.
2. Data on intangible assets for the United States provided by C. Corrado; data for Japan provided by T. Miyagawa; data for Sweden provided by H. Edquist; data for the Netherlands provided by M. Tanriseven; data for Germany, Italy, Spain and the United Kingdom provided by J. Haskel, A. Pesole and members of the COINVEST project; data for Austria, Denmark and the Czech Republic provided by J.X. Hao and B. Van Ark; data on intangible and tangible investment for Australia provided by P.

2. Intangibles assets, productivity and growth: the economic evidence

It is widely recognised that intangibles are a major determinant of innovation, growth and employment in the ‘knowledge economy’. Endogenous growth models have emphasised knowledge and skill as important intangible assets and stressed the role of intangibles, such as knowledge spillovers, in generating persistent growth (e.g. Romer, 1986 and Lucas, 1988).

The importance of R&D and innovation is also explicitly recognised at the European level within the Lisbon process which aims to improve the growth and employment performance of the member countries. However, our understanding of the contribution of intangibles to economic performance remains incomplete.

Several empirical studies have tried to estimate the contribution of intangibles to productivity and growth at macro, sectoral and firm-level.

2.1. Macroeconomic studies

Corrado, Hulten and Sichel (2005) developed a methodology to estimate the contribution of intangible capital to economic growth using the growth accounting framework by the US Bureau of Economic Analysis. Intangible capital, classified into three broad categories (computerised information, innovative property, and economic competencies), is used as additional inputs into the US economy-wide production function.

The inclusion of the intangible assets makes a significant difference in the observed patterns of US economic growth. The rate of change of output per worker increases more rapidly when intangibles are counted as capital and capital deepening becomes the unambiguously dominant source of growth in labour productivity. The role of multifactor productivity is correspondingly diminished, and labour's income share is found to have decreased significantly.

CHS results show that the capitalisation of intangibles increased the rate of productivity growth by 20% in the period 1973-1995 and by 11% in the period 1995-2003 in the United States. The portion of productivity growth explained by intangibles is 26% and 27%, respectively. In 1995-2003, the contribution of intangibles to economic growth became as large as the one of tangibles while the multifactor productivity decreased from 51% to 35% of GDP growth.

Giorgio Marrano, Haskel and Wallis (2009) apply the methodology of Corrado, Hulten and Sichel (2005) to the United Kingdom. The inclusion of intangibles in the asset boundary increases productivity growth by 11% in 1979-1995 and by 13% in 1995-2003. About 15% of growth in output per hour is accounted for by intangible capital deepening in 1979-2005 and 20% in 1995-2003 while the contribution of multifactor productivity declined from 25% to 16%.

Barnes; for Canada by N. Belhocine. Data on tangible investment for France is based on INSEE. For other countries figures for tangible investment are OECD calculations based on the OECD, Annual National Accounts and the EU KLEMS Databases.

Jalava, Aulin-Ahmavaara and Alanen (2007) undertake a similar growth accounting exercise for Finland and find that intangible capital rose in importance after 2000. Intangible capital accounts indeed for 16% of labour productivity growth in 1995-2000 and for 30% in 2000-2005.

According to Fukao *et al.* (2007), an increase in the growth contribution of intangible capital over time seems to hold also for Japan. Intangible capital explained 11% of the Japanese growth rate in 1980-1990 and 40% in 1990-2002. In addition, the inclusion of intangible capital increased growth by 3% in 1980-1990 and by 7% in 1990-2002 while the importance of multifactor productivity declined.

Baldwin, Gu and Macdonald (2011) show that investment in intangibles increased much faster than investment in tangibles over time in Canada and the ratio of intangible investment to tangible investment increased from 23% to 66% between 1976 and 2008. In addition, intangibles made a significant contribution to labour productivity growth and the contribution of intangibles to labour productivity growth was only slightly lower than that of tangibles in the Canadian business sector over the period 1995-2003 (29% versus 33% for tangibles).

Hao, Manole and Van Ark (2008) analyse Germany, France, Italy and Spain over the period 1995-2003. According to the main findings, intangible capital deepening accounted for 31% of labour productivity growth in Germany, 37% in France, 59% in Italy and 64% in Spain. Labour productivity growth increased by 10% in Germany, 14% in France, 37% in Italy and 40% in Spain.

More recently, the growth accounting exercise carried out by Corrado, Hulten and Sichel (2009) for the United States and some selected EU27 countries show that intangible capital accounted for 28% of labour productivity growth in the United States but only for 22% in Germany, France, Italy, Spain, Austria and Denmark over the 1995-2006 period.

Chun, Pyo and Rhee (2011) also use the CHS framework to assess intangible investment in Korea and its contribution to the labour productivity growth. The results show that the contribution of intangible capital deepening to labour productivity growth has steadily increased since early 1980s. However, the contribution of intangible assets to the labour productivity growth in the early 2000s was only about 13%.

INNODRIVE-based growth accounting estimations on 11 EU countries are also consistent with the CHS framework as shown in Jona-Lasinio, Iommi and Manzocchi (2011). The inclusion of intangible capital in the growth accounting over the 1995-2000 period allows explaining a greater share of the "unexplained" Solow's residual while physical capital appears to be strongly complementary with intangible capital.

In sum, growth accounting studies find a positive effect of intangible capital on various measures of economic growth in different countries and for different time periods. However, the assumptions underlying the growth accounting approach are strong (e.g. perfect competition, constant return to scale, perfect knowledge of the returns from intangibles) and, generally, not tested. Spiezia (2011) provides a comprehensive discussion of these drawbacks.

In addition to the growth accounting literature, many empirical studies investigate the impact of investment in intangible assets on productivity at the macro level. It is recognised for a long time that spending on R&D is positively related to growth in output and productivity (e.g. Lichtenberg, 1993; Bassanini and Scarpetta, 2002; Guellec and Van Pottelsberghe de la Potterie, 2004). Studies suggest that R&D performed by the business sector is the strongest driver of this positive association (but that private-sector R&D is often linked in complex ways to public sector R&D).

As for R&D, a country's human capital endowment is also closely related to its economic growth. At a macro-level study on OECD countries, Coulombe, Tremblay and Marchand (2004) show that a country able to attain literacy scores 1% higher than the international average will achieve levels of labour productivity and GDP per capita that are 2.5% and 1.5% higher, respectively, than those of other countries. And increasing average educational attainment by one year has been estimated to raise aggregate productivity by at least 5%, with stronger long-term effects through innovation (de la Fuente and Ciccone, 2003).

More recently, Roth and Thum (2010) provide evidence on positive effects of intangibles on economic growth from panel data on EU15 countries over the 1995-2005 period. A positive and significant relationship is found between business investments in intangible capital and labour productivity growth. Intangible capital deepening is associated with faster labour productivity growth. In addition, intangibles seem to explain a significant portion of the unexplained variance in labour productivity growth across countries and over time. The relationship between intangibles and labour productivity growth appears stronger in the period 1995-2000 and in Germany, Austria, Belgium, Netherlands, Luxembourg and France, but it does not hold when controlling for country-specific effects.

Lopez and Mairesse (2011) estimate jointly the impact of ICT and R&D as intangibles on productivity using data on 20 OECD countries over the 1985-2004 period. The results show an average value added elasticity *vis-à-vis* R&D capital stock ranging between 0.071 and 0.156, and an average elasticity *vis-à-vis* ICT capital stock ranging between 0.099 and 0.181.

In a policy perfective, rather than taking investment in intangibles as a given, Hao and Haskel (2011) investigate the correlation between the intangible investment share of GDP and various measures of product and labour market regulations in 16 countries over the 2001-2004 period. The main finding is that intangible investment (as a proportion of GDP) is negatively and significantly correlated with all variables of product market regulation and employment market regulation. Thus, countries with a high level of regulation seem to suffer from low intangible investment levels. This has been said, further analyses are needed before establishing any causal relation.

2.2. Sectoral studies

Assessing the impact of intangible investment on productivity and growth at the sectoral level is not straightforward because of substantial limitations of the currently existing datasets. Starting from the Solow paradox on the inability to suitably measure the impact of ICT on productivity ("You can see the computer age everywhere but in the productivity statistics", Solow

1987, p. 36), many studies have focused on ICT as a sector and explored the link between investment in ICT and economic performance.

Oliner, Sichel and Stiroh (2007) augment traditional growth accounting models by allowing for variations in factor utilisation, adjustment costs, cyclical influences on productivity gains, and intangible assets. Intangible capital is assumed to be a complement to ICT capital (considered as a sector) when investigating the link between industry level productivity growth and ICT intensity. The results show that the productivity growth over the 1995-2000 period in the United States becomes stronger once investment in intangibles is accounted for, as is the post 2000 fall in productivity growth.

Based on linked EU LFS and EU KLEMS data, O'Mahony and Peng (2011) investigate the impact of training on productivity linking to the literature that emphasises the need to invest in intangible assets when reorganising production following adoption of ICT. Main findings suggest significantly positive effects of training on productivity, both direct and interacted with ICT, with different impacts in services than in production industries.

Dahl, Kongsted, and Sorensen (2011) empirically test an intuition similar to Oliner, Sichel and Stiroh's (2007) by using sectoral-level cross-country panel data from the EU KLEMS over the 1970-2004 period. The results show that the post-1995 macroeconomic slowdown in productivity growth in Europe can be explained by a large productivity decline in non-ICT intensive sectors, which has been only partially mitigated by the growth in ICT-intensive sectors.

Using a merged dataset from EU KLEMS, COINVEST and INNODRIVE projects, Corrado, Haskel and Jona-Lasinio (2012) also provide evidence on the impact of intangible investment in explaining productivity growth differentials between low and high ICT-intensive industries. The productivity growth differential appears to be 0.4% higher in countries with faster intangible capital accumulation over the 1995-2005 period.

The exceptional TFP growth observed after the mid-1990s in some ICT-using industries in the United States and to a lesser extent in other OECD countries is often explained by the productivity gains in the production of ICT (e.g. Jorgenson, Ho and Stiroh, 2008). However, other studies showed that the TFP growth accelerated in non-ICT-producing sectors in 2000s whereas it slowed down in ICT-producing sectors (e.g. Corrado, Lengermann, Bartelsman and Beaulieu, 2006; Bosworth and Triplett, 2007). Acharya and Basu (2011) test intangible capital and productive externalities of ICT-use as two explanatory factors of this puzzle going against the neoclassical framework of analysis. Empirical evidence from 24 industries of 16 OECD countries over the 1973-2004 period show positive and significant impact of intangible capital accumulation but no evidence of positive spillovers to ICT investment.

Oulton's (2010) two sector growth model investigate as well the importance of ICT as a source of growth. The model considers an ICT-producing sector selling its output to a consumer good producing sector, and allows countries that do not produce ICT to benefit from falls in relative prices through an improvement in the terms of trade. The main boost in growth is seen as coming from ICT use and not from ICT production and the fall in relative prices of ICT is considered as boosting the GDP growth together with consumption because it induces a faster accumulation of ICT capital.

Based on the EU KLEMS data for 19 countries over the 1970-2007 period, estimates show an average output effect of ICT on productivity growth of 0.24% points and an average use effect of 0.54% points per year.

On a broader perspective, Che (2009) addresses different patterns of intangible capital accumulation in a model that sees the presence of two sectors, which differ in the intensity of intangible capital used in the production function. Within each sector, labour has to be allocated between the production of a final good and the production of intangible capital. Simulation results support the predictions of the model and suggest that investment in intangible capital leads to higher output growth, all the more so in the intangible intensive sector. The effect of intangible capital investment on employment is only significant in the intangible intensive sector.

Haskel and Wallis (2010) use data on market sector productivity, R&D and non-R&D intangible assets, and public sector R&D spending to provide evidence on market sector spillovers from intangible investment and from public R&D. The results, however, do not show any evidence of spillover effects from intangible investment at the market sector level, including from R&D but a strong evidence of market sector spillovers from public R&D spend on research councils. Their findings tentatively suggest that for a maximum market sector productivity impact, government innovation policy should focus on direct spending on research councils.

Another stream of work at the industry level resorts to the Input-Output (I-O) tables in order to address inter-sectoral linkages, as they map out the backward and forward linkages of each sector in an economy *via* inter-industry transactions of goods and services. The effect of an industry on total economic activity can be subdivided into three main components as follows:

- A direct effect on final demand from selling output to consumers;
- Backward linkages (demand multiplier effect): As each sector uses inputs from multiple sectors, an increase in the production of a sector leads to higher demand for the output of other sectors, through its need for more inputs;
- Forward linkages (supply multiplier effect): The goods and services of a sector increase the possibility of downstream sectors to offer new products and services.

I-O tables are considered as extremely useful data sources to trace the effects of sectoral behaviours such as R&D intensity, CO_2 emissions, presence of foreign direct investment, or policy reforms, on other sectors linked through input-output relationships.

In this respect, Wolff (2011) tests the importance of spillovers from R&D expenditures across sectors using I-O data. In a comparative perspective with previous studies (Wolff and Nadiri, 1993; Wolff, 1997), the author finds evidence in support of the existence of inter-industry spillovers, and of its strengthening over time. Furthermore, knowledge transmitted by the R&D embodied in a certain input seem to depend on how important that very input is for the (buying) industry considered, rather than how much of that input is sold to the industry.

Input-output tables also allow investigating possible spillovers from organisational practices of multinational firms. Based on foreign direct investment data, multinational firms can be seen as carrier of organisational know-how which is then transmitted to other firms through interactions with suppliers and customers. In this respect, Javorcik (2004) estimates the relationship between firm-level productivity and measures of multinational presence in backward, forward and horizontally linked sectors in Lithuania over the 1996-2000 period. An increase in the foreign presence in downstream sectors seem to be associated with a rise in output of supplying domestic firms, which is interpreted as a spillover from the organisational capital of the foreign customer. Using a similar methodology, Javorcik and Spatareanu (2011) find that spillovers from FDI through backward linkages in Romania are more pronounced when foreign firms have to rely more on local suppliers, for geographic or tariff-related reasons.

The effect of an industry-specific policy measure on the performance of other sectors can be assessed by resorting to I-O tables as well. Bourlès *et al.* (2010) estimate in this respect the impact of anticompetitive regulation in upstream sectors on the productivity of downstream sectors. Panel data results on 15 OECD countries and 20 industries over the period 1985-2007 show that product market regulations in upstream markets have significantly reduced the productivity of downstream sectors. Similarly, using firm level data from the Czech Republic, Arnold, Javorcik and Mattoo (2011) find that liberalisation in the services sectors is positively correlated with the performance of domestic firms in downstream manufacturing sectors.

Finally, Spiezia (2008) offers a different approach to using I-O data for the estimation of the contribution of a sector to overall economic performance by estimating the multiplier effect of the ICT sector, on output growth in a number of countries. To this end, the actual level and the growth of output between 1995-2000 and 2000-2006 are compared with the (counterfactual) level and with the growth of output if no output had been produced in the ICT sector. The results show that on average, ICT sectors accounted for 2.4% points a year of total output growth in 1995-2000 and 2.1% points a year in 2001-2006, in the 14 OECD countries for which data is available.

A broader discussion of the issues raised by sectoral level analysis of intangible assets and the related OECD measurement agenda can be found in Squicciarini and Criscuolo (2011).

2.3. Firm-level studies

Many studies recognise the investment in intangible assets as a driver of productivity and growth at the firm level.

Bontempi and Mairesse (2008) examine the size and productivity of total intangible capital relative to total tangible capital for a large panel of Italian manufacturing firms. Total intangibles are decomposed in two ways: intangibles expenses in firms' current accounts (as usually considered in empirical studies) *versus* intangible capitalised in firms' balance sheets (usually not considered); and "intellectual capital" (i.e. R&D expenditures, and patenting and related costs) *versus* "customer capital" (i.e. advertising expenditure, and trademarks and related costs). The results suggest that firms' accounting information on intangible investments is genuinely informative, and that intangible capital and its different components are at least as productive as tangible capital. These findings are robust to different specifications of the production functions, although they result into different elasticities of substitution between tangible and intangible capital.

Oliveras and Castillo (2008) measure the effect of intangible assets on productivity using data on 10 000 Spanish firms selected randomly by size and sector, over a ten-year period, from 1995 to 2004. The results differ across sectors and firm size but generally confirm the hypothesis that TFP weight has increased during the period, especially in those firms that have experienced a significant raise in intangible capital. This suggests the existence of complementary effects between capital investment and intangible resources on productivity growth.

Another stream of work at the micro-level aims at providing evidence on the impact of complementarities between different type of intangible assets (such as ICT capital, organisational structure and human capital) on firms' productivity.

In this respect, Milgrom and Roberts (1990 and 1995) argue the existence of complementarities at the firm level, both in the use of various types of inputs and between different types of practices and activities, which is often referred as organisational capital.

Oliner, Sichel and Stiroh's (2007) assumption about the complementarity of the different types of intangibles relies on an extensive body of evidence documenting the existence and quantifying the magnitude of these complementarities. The methodology involved relies on firm level data and often calculates both the correlation between investments in different types of assets and a firm level production function, whereby the presence of complementarities can be directly interpreted from the regression coefficients.

Evidence of complementarities is strongest when considering ICT capital in combination with other types of intangible assets, especially human capital and organisational capital. Athey and Stern (1998) find evidence that the returns to investment in ICT capital, at the firm level, are increased in the presence of training. Building on this, Bresnahan, Brynjolfsson, and Hitt (2002) explore for the presence of complementarities between ICT capital and organisational structure by means of investigating firms' investment decisions concerning ICT capital, organisational structure and human capital and estimating a production function that includes cross terms in IT, organisational and human capital. The results show evidence of complementarities between investment in ICT capital, investment in human capital and decentralised work practices, and new products and services. Furthermore, the importance of IT-enabled organisational change is underlined and the overall computing capacity of a firm is seen as a good predictor of investment in human capital.

Bloom, Sadun and Van Reenen (2007) and Bloom and Van Reenen (2007) also show that corporate management practices are correlated with firm-level productivity, particularly in connection with the creation of organisational capital complementary to information technology, and that significant differences exist in such management practices across countries.

Within the framework of the INNODRIVE project, Piekkola (2010) resorts to occupations data in order to assess intangible investment at the firm level in Finland over the 1998-2007 period. His findings show that organisational capital, R&D and ICT increase the market value of firms beyond a level that can be explained by standard economic analysis. Using a similar approach, Jurajda and Stančík (2011) investigate the share of "organisational workers" in the Czech Republic and their relative productivity, which is estimated as being 50% higher than other workers.

Finally, based on a firm and regional level data from the United Kingdom, Riley and Robinson (2011) analyse the extent to which returns to intangible capital exceed their direct value to individual firms and generate regional spillovers. Their findings suggest a positive association between productivity and organisation capital in particular, consistent with the presence of spillovers.

3. Measurement issues and possible solutions

3.1. Conceptual problems in measuring intangibles

Conceptual measurement challenges are significant when assessing intangible assets both in relatively mature subject areas, such as human capital, and in newer fields of attention such as design or software.

Developing statistics on investments in software poses indeed numerous challenges. As it is well-documented, there are variations in the accounting treatment of software investment, and in how to value software developed in-house, as well as problems in comparing price levels internationally (e.g. Ahmad, 2003). Some software is provided free of charge, compounding measurement and valuation difficulties. To analyse the economic impact of software on growth, annual investments in software need to be aggregated over time to estimate the capital stock. This requires adjusting prices paid for the asset over time for any inflation and for any change in the quality of the asset. Construction of the asset stock also requires estimates of the depreciation that have may have occurred over time.

Measurement challenges associated with design stem partly from the pervasive, integrative and hard-to-define nature of design. For instance, the Community Innovation Survey describes design in broad terms as being “for the development or implementation of new or improved goods, services and processes”. The existing design scoreboards also employ wide definitions of design, viewing it as synonymous with new product development and/or the work of industrial design professionals. As regards the availability of data on design, responsibilities often fall between government departments. In some countries design is viewed as supporting technical innovation, but in others it is considered a part of the creative industries (UK Design Council, 2009). Some attempts to strengthen measurement are underway. The United Kingdom has developed in this respect additional questions on design for the Community Innovation Survey. Nevertheless, reliably assessing and comparing the national economic or non-economic benefits of investments in design is problematic to date.

Human capital is large concept involving components of knowledge, skills and attitudes. Among intangibles, human capital has perhaps been the object of the most long-standing research attention. Nevertheless, measurement of human capital is far from straightforward. Approaches to for skill measurement mainly consider, educational attainment (research on the relationship between human capital and macroeconomic growth most often uses average years of schooling in the labour force as a measure of the stock of human capital), the prevalence of occupational classifications, skill tests (indeed, literacy scores as a direct measure of human capital perform better in growth regressions than indicators of schooling), self-assessment of skills, and job requirements assessments (a relatively recently developed technique that involves surveying employees on the time dedicated in the workplace to different finely-specified tasks). Each of these proxies has its own strengths and drawbacks.

More technically, the data that is used to proxy investments in intangible assets typically need to be converted into “quantity” series or “constant price” series, in order to be consistent over time and across countries. Researchers have used various assumptions to derive deflators for new investment in intangibles, but there are several measurement issues that need being addressed when doing so, in particular, for price deflators and depreciation rates.

3.2. Price indexes

The value of an intangible asset, as for tangible or natural assets, should be in principle determined by the present value of the future stream of services it provides. However, intangibles are very different from tangibles by their nature. Their present value is often highly uncertain and the distribution of these values is highly skewed across assets. They are not subject to wear and tear but their quality (and value) decrease over time. They not subject to maintenance and repairs *per se* but they can be amended or augmented for different reasons. Some intangibles possess characteristics of public goods; they are non-rival and non-excludable. They are scalable for relatively low costs. All these elements make their valuation and pricing difficult to assess.

Using the right price indexes to deflate expenditures on intangibles is more than a simple statistical issue (Oulton, 2010). The fall in the price of an asset, such as ICT, can itself be a source of growth, through its impact on the productivity of downstream sectors. Corrado, Goodridge, and Haskel (2010) discuss the two more widespread deflating methodologies, both of which are incorporated in the growth accounting framework. The first is used by national accounting offices and calculates the price of R&D from the prices of the inputs in the R&D-producing sector. The authors argue that this leads to a biased measure of the price of R&D in the presence of productivity gains in the production of knowledge. An alternative approach is then proposed to calculate the price of R&D from the R&D-using sector. Under the assumption that the R&D-using sector is a price-taker, the price of R&D can be derived from the final output price, factor costs and the sector’s TFP.

Following this last approach, Corrado, Goodridge and Haskel (2010) construct an industry database for the United Kingdom that comprises both gross output-based TFP estimates and R&D performance statistics for 29 UK market sector industries from 1985 to 2005, relying on EU KLEMS data and data from the Office of National Statistics R&D surveys. The results suggest that the real price of R&D has fallen dramatically in the United Kingdom from 1985 to 2005, which in turn indicates that real investment in R&D is much higher than previously measured.

3.3. Service lives and depreciation rates

An intangible asset can in theory supply an infinite stream of quantities of services but it can be retired if there is no longer any demand for its services. Intangibles are then subject to obsolescence and depreciation: Recent R&D design replaces the old ones, an expired copyright or patent no longer provide value to their owner. In case of software, the decline in demand is due to the technical progress whereas in case of artistic originals, it is due changing tastes or fashion.

Intangibles have then limited service life in practice and it becomes crucial to accurately determine, service life of an intangible asset and the rate at which its productive capacity and value are expected to decline as it ages.

In this respect, Huang and Diewert (2011) aim to quantify the depreciation rate of R&D, using an interpretation of depreciation that differs from that used in the case of traditional physical capital. The depreciation of R&D capital comes from the discovery of new knowledge and technology that makes the existing R&D capital stock obsolete. In their model, R&D investment is used to increase the stock of knowledge and affects the technology frontier of the production function. They find depreciation rates of R&D to be linked to the nominal interest rate, the mark-up of prices on marginal costs and the evolution of the price index of R&D.

Huang and Diewert (2011) calculate the R&D price index using an input price approach and find that the estimated R&D depreciation rate is 39% for manufacturing as a whole, 1% for chemical products, 3% for non-electrical machinery, 14% for electrical products and 27% for transport equipment. These results suggest that assuming a common rate of depreciation for all R&D spending probably hides important sectoral dynamics. However, depreciation rates and the price index of R&D cannot be estimated simultaneously, and therefore the model cannot be identified without making assumptions about at least one of the two variables.

3.4. Variations in asset prices and depreciation rates, and double counting issues

The use of a common deflator for several industries can be justified by the fact that these industries may get their input factors from the same markets and should thus face the same prices. But this fact does not hold universally for all types of intangible assets. For example, it is quite likely that different industries have the same advertising costs but not the same R&D costs. Similarly, the use of the same set of depreciation rates across industries is also controversial. As shown by Huang and Diewert (2011) R&D depreciation rates are not the same for all industries.

Double counting is another issue which deserves a particular attention. Generally, output data would need to be adjusted in order to adjust for output used as intermediate input by other industries, which should instead be treated as an investment. In addition, not all intangible assets are of the same quality and some sort of hedonic quality adjustment may be needed to get the volume series of intangible investment in terms of efficiency units.

Finally, in order to obtain internationally comparable data, especially if the analysis entails comparing intangible capital levels or intensities, series might need to be adjusted for the price level differences that exist among countries. However, this might be less of an issue if inputs are bought in global markets.

3.5. Possible solutions

Since the 1993 revision of the System of National Accounts, software is the only intangible asset which is capitalised and treated as an investment to date. Such recognition of the asset characteristic of software was an important step in accounting for the magnitude of intangibles. It brought the treatment of software purchased separately into line with software purchased as a bundle with hardware, which has always been capitalised.

One of the major innovations of SNA 2008 is the recognition of expenditures on R&D as capital formation but this is not an easy task. As for other intangibles, the main difficulties in R&D capitalisation relate to the valuation, double accounting (e.g. with software), measurement of prices and volumes, deflators to obtain price indices, age-efficiency and age-price profiles of R&D assets and their depreciation.

Recognising these difficulties, satellite accounts will provide a way to work towards robust and internationally comparable measurements (while currently using a satellite approach, the United States will feature R&D in its headline measure of GDP in 2013). It is also hoped that new survey-based analyses in countries such as the United Kingdom and the United States will provide evidence with which to improve measurement of intangibles investments (e.g. Clayton and Mitra-Kahn, 2009). In this respect, OECD (2010a) provides recommendations and guidelines for compiling capital measures of R&D, together with other IP products.

More recently, a horizontal project on the New Sources of Growth has been initiated at the OECD with the aim of providing structured evidence on the economic value of intangible assets as a new source of growth and improving our understanding of current and emerging challenges for policy. The project has an important measurement component where efforts are underway to review the strengths and drawbacks of methodologies for the definition and measurement of the flows and stocks of key intangible assets and their link to innovation. The work agenda comprises the development of measurement guidelines for selected intangible assets at the firm level, production of new evidence on the contribution of intangible assets to firm-level, sectoral and aggregate performance together with the analysis of value creation from intangible assets. The outcomes of this project are potential important steps towards a better understanding of the importance of intangible assets in today's knowledge-based economies.

4. Is the there a role for policies?

The increasing importance of intangible assets raises several challenges for policy in areas such as taxation, competition, intellectual property rights (IPRs), the regulatory treatment and use of private and public data or corporate reporting. Nolan (2011) brings the attention to several of these policy issues which will be covered by the OECD's New Sources of Growth project.

4.1. Framework conditions

Framework conditions (e.g. tax and competition policy, rules on corporate reporting) are crucial for shaping the economic context in which investment in intangibles take place.

Tax policy

Tax policy settings affect investments in intangibles and innovation through numerous channels.

With respect to the R&D, policy settings impact the way that R&D is undertaken together with its incidence and scale. R&D usually combines inputs such as labour, materials, machinery, ICT, buildings and costs associated with overheads, licensing and services. Each of these inputs might receive a different tax treatment. To date, 26 OECD countries use fiscal incentives to promote business R&D and some are discussing their introduction.

Policy measures can also influence how intangible assets are used through decisions on whether to license or sell the intangibles resulting from R&D, or to use them as inputs to the creation of innovative products, processes or services.

IPR regimes are heavily impacted by policy in terms of returns or terms of access. Tax settings affect outbound transfers of intellectual property, which in turn enlarge profit opportunities for domestic R&D performers and some countries offer tax incentives on intangible income in the form of a partial exemption or reduction in the corporate tax rate on foreign royalty income. In Hungary, Switzerland, Korea and Belgium, 80% of gross patent income is not taxed. In terms of access to intellectual property, for instance, the setting of the non-resident withholding tax rate on royalty payments may impose a burden on the importation of technology. Different tax treatments for purchased, licensed or in-house developed patents are another example of the important role played by the policy for investment in intangibles.

The incidence and scale training and education expenditures are also affected by policy. Tax settings shape incentives for education and training, both for firms and individuals. A key issue relates to the progressivity of the system of personal income tax, and how this may affect incentives for individuals to pursue advanced studies.

The location decisions of innovation-oriented investments and of intellectual property are also affected by both domestic and foreign tax settings and their interactions. In this respect, Ireland has exempted patent income from corporate taxation for many years, becoming a favourable location for intellectual property.

Furthermore, a high average tax rate on wage income could be a discouraging factor for attracting skilled mobile labour force. Those intending to work on a short-term basis might also be discouraged if links are weak between social security contributions and social benefits received.

The importance of venture capital in fostering innovation is now broadly recognised among policy-makers. For example, it is generally agreed that the rate of tax on capital gains can have an impact on risk-taking and investment in start-ups. Many countries have sought to increase the supply of venture capital by providing tax credits to private investors who invest directly in start-up firms or indirectly through venture capital funds. Measures have also been taken to ensure a favourable tax treatment to the return on venture capital investments.

From a business perspective, intangible assets entail risks that are typically higher than those of physical or even financial assets. Thus, tax settings that relate to risk-taking are particularly important. For instance, asymmetric tax treatment of business profits and losses may discourage certain types of risky innovative investments. Asymmetric tax treatment of capital gains and losses on shares issued by high-risk innovative companies may indeed discourage investment in such companies' equity.

The design and administration of tax regimes affecting intangibles (including the tax treatment of costs and returns on investment in intangibles) raise complex issues in a globalised economy. Knowledge has many of the characteristics of a public good and there is a risk that those who invest in and create new knowledge will not gain sufficient (private) returns to make this worthwhile. A favourable tax regime for R&D can help raise the private return on such investment and so make this outcome less likely.

Moreover, multi-national enterprises (MNEs) increasingly operate as integrated global businesses, whereas tax regimes are set by national jurisdictions. This can mean additional compliance costs for MNEs, but also new opportunities for tax planning to reduce global tax liabilities. Conventional methods to assess the effective rate of tax on many intangibles are considered to be incomplete, as they largely ignore the international dimension of tax policy and the tax planning behaviour of MNEs. For instance, in many OECD countries, firms performing tax-assisted R&D are able to largely avoid domestic corporate income tax on returns to R&D (e.g. patents). For example, through special cost sharing agreements between domestic parent companies and their foreign subsidiaries and/or through the application of non-arm's length transfer prices, profits on the exploitation of R&D may be shielded from home-country tax. Such structures may be also used to strip out of the host country taxable profits earned on other business activities. The issue of MNE tax planning is particularly acute with respect to intangibles, as intangible assets are generally easily transferred from one location to another at low cost.

Corporate reporting

A significant and increasing component of company value is nowadays generated by intangibles rather than tangibles but accounting standards and related financial accounts are generally deemed to be unsuited to the reporting of intangible assets. As a result, we may miss a clear vision of a company's real value and long term growth outlook[3]. This may have a negative impact on individual firms, as management decisions could be distorted, as well as on the broader economy. In particular, there is a risk that the allocation of capital is distorted. A lack of reliable and relevant information on intangibles may also result in companies having to bear a higher cost of capital than necessary and, in the case of listed companies, being subject to high stock price volatility.

In addition, enhanced disclosure of intangible assets could have a positive impact on corporate governance, by improving internal controls and risk management, oversight of senior management and strategy by the board, as well as transparency and accountability to shareholders

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3. International accounting standards (IAS) do include provisions on intangibles, i.e. IAS 38. However, these standards do not fully account for the richness of intangibles. For instance, neither intangible assets arising from research, nor internally generated brands, are recognised as intangible assets in financial accounts. Although accounting standards may be further developed to take into account a wider range of intangibles, they suffer from inherent limits in establishing monetary values that are consistent across firms, verifiable and not prone to manipulation (Bismuth, 2006).

and other stakeholders. Efforts to ensure that intangible assets are properly reported are even more important in the aftermath of the financial and economic crisis, as potential investors may have become more risk-averse and may require fuller information on corporate growth prospects.

The OECD has previously carried out a significant body of work on corporate reporting of intellectual assets. Several policy reports were produced examining how corporate reporting can be used to create value (Bismuth, 2006), also focusing on small caps (Bismuth, 2007). As underlined in the OECD's synthesis report on intellectual assets and value creation (OECD, 2008a), better reporting of intangible assets in companies' balance sheets could yield substantial benefits in terms of market efficiency. Narrative reporting may provide enhanced disclosure and forward-looking information on value creating activities that involve intangibles assets. Such recommendations on corporate reporting issued by the OECD are broadly aligned with those of other international bodies.

To encourage more companies to improve their disclosure practices as well as their internal management practices requires that the potential benefits be more widely disseminated. There is an important role for policy-makers in raising awareness of best practices for intangible assets reporting. Governments can also encourage some degree of consistency across companies and across time.

Competition policy

The information economy has brought the rapid creation of new industries and business models. New businesses have challenged incumbents in novel ways, while some incumbents have used controversial strategies to fend off competitors, sparking occasional complaints of anticompetitive conduct in the digital economy. New business practices enabled by information technologies have also created particular challenges for competition authorities.

Intangibles, and especially R&D, are increasingly internationalised (e.g. Picci and Savorelli, 2012). New knowledge networks and markets rise across countries. Collaboration plays an increasing role in innovation. The Community Innovation Survey based evidence, as outlined in OECD (2010b) and OECD (2011), shows that firms increasingly collaborate for innovation. Inter-firm networks, both domestically and internationally, enable economies of scale and scope, while informational spillovers can be internalised among collaborating firms. Support for collaborative research can also reflect the realisation that many research projects can be too complex for any individual firm or institution. Accordingly, many countries exempt R&D partnerships from anti-trust legislation.

By contrast, competition policy has a principal role in the commercialisation, use and diffusion of new science and technology. In these processes, IPRs are critical and directly shape firms' competitive strategies and conditions of market entry. Issues that can arise for competition authorities relate, in particular, to mutually blocking patents - which require a need for patent pools or cross-licenses - and the protection of trade secrets.

As underlined by Tony Clayton at the ICTNET Final Conference (OECD, 25-26 June 2012), the existing intellectual property frameworks are often not sufficiently well designed to promote innovation and growth. In this respect, Hargreaves (2011) takes stock of the IPR system in the

United Kingdom and draws attention the importance of a dynamic intellectual property regime that is able to adapt to the changes in the business environment worldwide. The report puts forward an important recommendation in terms of modernising copyright licensing of the country by establishing a cross sectoral Digital Copyright Exchange. For all the creative industries of the United Kingdom, this step forward would represent "efficient, open and effective digital markets where rights can be speedily licensed and effectively protected".

Competition policy also touches upon networks. Networks generally become more valuable as they increase in size (in terms of nodes or users). Thus, they exhibit scale economies from the side of demand. This accentuates the importance for competition of the terms on which access to a dominant network can occur.

Many high-tech products are constituted from complex systems of components that need to interface both with each other and, in some cases, with external networks. Consequently, firms must work together to set standards and ensure interoperability. This process of working together raises the possibility of collusive practices, which is another important issue for competition policy-makers.

Shapiro (1999 and 2002) and Farrell and Shapiro (2004) underscore that the key goals of competition policy in the information economy should be to erode monopoly power where this persists, and to prevent the use of monopoly power to restrict competition in adjacent markets. While authors do not see a need for technology-specific enforcement policy, nor an extension of the reach of competition policy, they highlight that the nature of competitive strategies, the sources of scale economies and the barriers to entry in the information economy are distinct.

Finally, many information products involve large scale economies given that after the costs for the first copy have been incurred, subsequent marginal costs can be negligible. Producers are also under pressure to engage in price discrimination, producing multiple versions of a related product – such as software – for slightly different market segments. This can pose practical challenges when trying to identify abuses of market power.

4.2. Policy actions focused on specific ICT intangibles: the case of software and digital data

Software

Software increasingly plays the role of an enabling economic infrastructure. It is instrumental in the path towards knowledge-based economies that require abstract analytic skills. The Internet itself is largely an outcome of developments in software. The software industry is a leader in terms of the extent and ways in which users are engaged in product development (Lippoldt and Stryszowski, 2009). Software enables trade, particularly in electronically delivered products. And, more generally, software is essential to addressing a number of key policy concerns in the information society such as security, privacy protection and protection for consumers engaging in e-commerce.

Because software has an extensive role in contemporary economic and social life, the policy issues it relates to are broad as well.

Investment in software, as with investment in R&D, exposes the developer to problems of appropriability. Some of the benefits of investment might be enjoyed by users or other producers, and the risk exists of software piracy. Governments protect software innovators in a variety of ways, including copyright and patent protection for software-enabled inventions.

As software becomes central to the economic infrastructure of advanced economies, its integrity and reliability also become a policy issue. Almost a decade ago, the United States' National Institute for Standards and Technology estimated that the annual costs to the United States of faulty software were in the range of USD 20 to 60 billion, then some 0.6% of GDP. This cost is a reflection of the growing complexity of various software systems (and their interaction) as well as a decreasing average market life, making it more difficult, and providing less of an incentive for developers to adequately test software (US NIST, 2002). Some observers hold that protection of integrity will best be effected through product liability lawsuits (Mann, 2002).

On the other hand, industry associations and commercial consortia have launched various initiatives to improve the interoperability of software. Governments can also consider software interoperability as a criterion in their procurement processes, although maintaining technological neutrality is important. An interesting example in this respect is the case of Japan where interoperability guidelines came into force in 2007. These encourage ministries and agencies to procure products that entail internationally recognised open standards. Government mandates, procurement practices, guidelines, standards and awareness raising campaigns have been employed in many other countries to encourage accessibility of software for persons with a wide range of capabilities.

Policy issues also arise in connection with how to balance the supply and demand in the labour market for software-related skills that are crucial for the development of the industry.

In sum, the growing importance of software as a tool in the innovation process needs to be better understood. Software development in the services sector is a key source of innovation in itself, representing a significant share of R&D performed by service-sector firms. To a large degree, service sector innovations such as "one-click" buying, instant messaging or financial derivatives are software. This form of innovation does not neatly conform to innovation promotion policies (e.g. R&D tax incentives) or to the institutions that support the innovation process like patent offices.

Public support for research funding in computer science and engineering has been significant in countries such as Ireland and the United States. Indeed, many fundamental breakthroughs in software, such as graphic user interfaces, relational databases and the browser, were developed in government laboratories in the United States with government funding (US National Academy of Science, 2000). Further analyses are needed to evaluate how the link between this funding and software development is evolving as the field matures.

Digital data

The explosive growth of digital technologies such as mobile networks, remote sensors and cloud computing creating vast fields of information, also referred as "big data". Personal data is now being heavily processed, analysed, re-deployed, shared and transferred across the globe. The economic value in such data is potentially enormous, and a growing number of businesses and are discovering novel and strategic uses for large databases. But measuring the value and the impact of the data is a complex task because of the important volumes and numerous uses. Better understanding the value of these data is crucial for policy-makers of the Internet economy and for those with responsibilities for rules governing the collection and use of data.

As highlighted by Eric Brynjolfsson at the ICTNET Final Conference (OECD, 25-26 June 2012), the digital revolution that economies face today makes the volume, variety and the velocity of the data more important than ever. Our ability of measurement has been dramatically increased thanks to digital data. Brynjolfsson, Hitt and Kim (2011) investigate whether firms that emphasise decision making based on data and business analytics ("data driven decision making") show higher performance. Using detailed survey data on the business practices and information technology investments in 2008, authors find that firms that adopt data driven decision making have output and productivity that is 5-6% higher than what would be expected given their other investments and information technology usage.

Techniques such as text/data mining and analytics are required to exploit the potential of the digital data. Many businesses resort to these techniques in order to analyse customer and competitor data to improve competitiveness. Academics use mining and analytics of large datasets in order to deliver new knowledge in many research areas. The availability of digital data expands our ability of experiment, share and replicate new ideas. Thus, the implementation of efficient policies, including revised copyright regimes which would allow the best use of the available data, remains on top of the current policy agenda.

Many organisations collect data from multiple sources and deploy tools to aggregate and to process it. Data flows and sharing among various players has generated significant economic value for organisations and consumers both in the private and public sector.

Public sector information (PSI) is generated directly during public service provision (for example, business statistics, meteorological and geospatial data) and commercially useable. PSI is distinct from content held by the public sector, such as cultural and archive material that may involve third-party rights, that may not have been generated by government and which may not have commercial uses (OECD, 2006). There are major differences across countries and in some cases across subnational jurisdictions, as regards policies on access to and reuse of PSI.

In this respect, the OECD Working Party on the Information Economy has undertaken extensive work analysing and providing policy principles for the development and use of public sector information. This information ranges from weather and map information generated by governments through to public sector broadcasting archives, museums and art repositories held by governments. The OECD Recommendation on Public Sector Information (OECD, 2008b) provides policy guidelines designed to improve access and increase use of PSI through greater transparency, enhanced competition and more competitive pricing. The Recommendation is adopted by the OECD Council in April 2008 and scheduled to be reviewed every three years in order to foster enhanced access and more effective use of PSI.

Houghton, Rasmussen and Sheehan (2010) seek to identify metrics for calculating the returns to government investment in open access archiving of publicly funded scientific, technical and medical research. Based on a cost-benefit model over a thirty year period, the benefits of the archiving mandate appear to exceed the costs by a factor of approximately eight.

Returns of investments in PSI might be significantly affected by even small changes in the conditions of access and use. OECD (2007) describes a set of principles and guidelines for access to research data from public funding. However, more robust frameworks for policymaking are required across the full spectrum of types of PSI. For instance, more needs to be known about pricing and licensing models. Pricing information in an objective manner is complex, as the identification of the different cost components can involve arbitrariness. Questions also exist regarding the circumstances under which the public sector should produce value added products from its PSI, if any. Many governments also wish to engage in cost recovery, partly for budgetary reasons and partly on the principle that those who benefit should pay but the calculation of benefits is often problematic. As argued by Stiglitz, Orszag and Orszag (2000), if a government agency that provides a data-related service has a valid economic role, then it is not fulfilling its role if it seeks to generate revenue from that service.

To conclude, intangible assets have gained a prominent position in economic research over the past years. Indeed, several studies show that investments in intangible assets are overtaking investments in physical capital and are a major driver for productivity and growth in many countries.

Intangible assets, however, are still poorly measured. Ongoing work by academia and international institutions is addressing the unsolved conceptual and measurement issues related to the evaluation and capitalisation of intangibles.

The increasing importance of intangible assets raises significant challenges for policy in areas such as taxation, competition, IPR, corporate reporting and privacy. Governments are called to play a key role in setting the right framework conditions and addressing potential market failures that may hamper investments in intangibles assets, particularly in software and digital data.

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REVIEW OF RECENT STUDIES ON PSI RE-USE AND RELATED MARKET DEVELOPMENTS

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Note: This paper is a shortened and updated version of a report prepared for the European Commission in 2011 available at:
http://ec.europa.eu/information_society/policy/psi/facilitating_reuse/economic_analysis/index_en.htm

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KEY FINDINGS

- Public bodies hold a very wide array of information and content ranging from demographic, economic and meteorological data to art works, historical documents and books. Given the pervasive availability of such information and content in digital form and the widespread use of information and communication technologies (ICTs) by secondary users, public sector information (PSI) and public sector content are increasingly valuable resources for the production of innovative value-added goods and services and a major source of wider educational and cultural knowledge.

- Knowledge is a source of competitive advantage in the "information economy", and for this reason alone it is economically important that public information is widely diffused. There are many benefits from improving access and facilitating reuse of PSI, taking into account legal requirements and restrictions. These benefits include development of new products built directly on PSI; development of complementary products such as new software and services; reduction of transaction costs in accessing and using information; efficiency gains in the public sector itself; and the crossing of different public and private information to provide new goods and services. There are further benefits from using PSI in a myriad of direct and indirect applications across the economy and society.

- Governments also have basic commitments that citizens can access public information and national cultural heritage such as paintings, monuments and books, and to ensure social inclusion. New communication tools, including social networks, interactive Web sites and games are facilitating wider diffusion of public sector information by reaching groups of people previously unlikely to directly access PSI or PSI-related services.

- This literature review looks at PSI market size and impacts following the widely cited estimates in the MEPSIR study (2006). MEPSIR concluded that the direct PSI re-use market in 2006 for the EU25 plus Norway was worth EUR 27 billion.

- On the basis of more recent studies the narrowly defined EU27 direct PSI re-use market was of the order of EUR 28 billion in 2008. All studies show relatively rapid growth in PSI-related markets, and assuming annual growth of 7%, the direct PSI-related market would have been around EUR 32 billion in 2010. Considering re-use activities in domains not included in the studies analysed in this report (for example, where re-use is not a principal activity, or in government and research activities) the market value of direct PSI re-use (the direct economic "footprint") is undoubtedly larger.

- PSI-related information can be used in a very wide range of direct and indirect applications across the economy. The aggregate direct and indirect economic impacts from PSI applications and use across the whole EU27 economy are estimated to be of the order of EUR 140 billion annually.

- The above estimates of direct and indirect PSI re-use are based on business as usual, but other analysis suggests that if PSI policies were open, with easy access for free or at marginal cost of distribution, direct PSI use and re-use activities could increase by up to EUR 40 billion for the EU27.

- With easier access, improved infrastructure and lower barriers, aggregate direct and indirect economic benefits for the whole EU27 economy could have been of the order of EUR 200 billion (1.7% of GDP) in 2008.

- Thus it is clear that new applications and uses in a wide variety of goods and services and future innovations associated with easier access to PSI are more important than the direct PSI market, and emerging second-order uses can be expected to add further benefits.

- Studies on individual PSI reuse sectors suggest that removing barriers to access and improving the underlying infrastructure could achieve considerable gains. In the geospatial sector, economic benefits could be increased by some 10-40% by improving access, data standards, and building skills and knowledge. Considering that the geospatial sector is a major applications area and source of applications in other sectors, this is a potentially major boost for European economies. If better policies were adopted, productivity gains from geospatial applications in local government could double over the next 5 years. Large new markets could also develop in financial, energy and construction sectors if access to information improved.

- In terms of efficiency gains in existing operations, improving access to information necessary for obligatory environmental impact assessments could potentially reduce EU27 costs by 20% or EUR 2 billion per year. Open access to government and higher education R&D results could give recurring gains of around EUR 1.8 billion per year and open access to all R&D results could yield gains of EUR 4.8 billion per year. If European citizens each saved 2 hours per year by more rapid and comprehensive access to public information this would be worth at least EUR 1.4 billion per year and multiples of this amount for each 2 hours saved.

- In comparison, direct revenues to governments from PSI are relatively low and much lower than the estimated benefits from access to PSI. EU27 government revenues could be in the range EUR 1.4-3.4 billion, based on data for the Netherlands and the United Kingdom. These two countries that have been relatively effective in revenue collection and EU27 revenues are likely to be considerably lower. Sales revenues are usually less than 1% of agency budgets and a maximum of one-fifth of budgets in a few cases.

- There is emerging evidence that improving access and dramatically lowering prices have large positive impacts on the number of users and new uses. At the same time, changing access and pricing policies provide opportunities to review the role of the public task in generating and distributing PSI and to implement changes to make PSI more accessible.

- Research suggests that where pricing is lowered to the marginal cost of distribution, government agency revenues foregone from direct sales of PSI could be provided via replacement funding from central government, mixed with "updater" funding models where, for example, businesses pay a higher levy to update data in business registers. The extra funding involved is estimated to be very small compared with the budgets of public sector bodies providing PSI and is even smaller compared with additional benefits from greater PSI-related economic activity. Research also suggests that the number of users may increase dramatically, increasing marginal cost pricing revenues.

- There are gradations in approaches to improving access and facilitating reuse depending on where countries are positioned in their PSI re-use policies. Policy strategies include: opening up PSI that has been difficult to access and reuse; reviewing restrictions on access and use and amending unnecessary restrictions; reviewing the public task; facilitating access to third party rights holders' material where rights holders agree. It is also worthwhile improving infrastructure and rationalising terms of access for intra-government PSI reuse (e.g. between national and local governments) with direct benefits to governments and the private sector. Furthermore the international dimensions of PSI access need strengthening, to access international data, and improve international access to national data. Finally, general equilibrium analysis and consumer surplus analysis could be undertaken to give more comprehensive pictures of benefits from better access to and use of PSI.

1. INTRODUCTION

Knowledge is a source of competitive advantage in the "information economy". The public sector is a large producer, collector and repository of a wide variety of data/information and content that contributes to generating knowledge and building competitive advantage. Two main technological developments have radically changed and re-shaped the role of public sector information (PSI) and public sector content (PSC). These are: *i)* technologies that enable the digitisation of public resources as they are produced and existing public resources; and *ii)* deployment of high-speed broadband technologies that enable better access and find-ability of PSI and more rapid dissemination of it.[1]

Digitisation is a crucial factor for the commercial exploitation of PSI and the diffusion of content held in public cultural establishments. Once digitised, information and content becomes more storable, transportable and exchangeable, bringing opportunities and challenges for the public sector in areas including information management, maintenance, access, preservation and interoperability. Benefits include development of new products built directly on PSI and PSC; development of complementary products such as new software and services; reduction of transaction costs in accessing and using such information; gains in the public sector; and the crossing of different information sources to provide new products.

New technologies also provide new tools for the diffusion of cultural and educational content to achieve socio-economic goals such as social inclusion and the provision of learning. Furthermore, international access to and use of public sector information make national data increasingly valuable and international data of greater national and local utility.

1.1. Definitions

Public sector information (PSI) directly generated by public institutions and information and content held by cultural establishments, archives, and the like (PSC) is any kind of information that is produced and/or collected and held by a public body as part of its public task. In Europe, better access to public sector information has received broad attention following Directive 2003/98/EC on the Re-use of Public Sector Information. This Directive is being reviewed as a key part of the Digital Agenda for Europe (European Commission, 2010, 2012), notably in its scope, principles on charging for access and use, and competition.

There is no standard international terminology for public information/content and its subsets. Outside of the EU27, Korea refers to "public knowledge information resources", and in the United States the terms "public information" and "government information" are widely used. Furthermore, PSI may be used as an umbrella term for all information and content produced and held by public bodies, but there may also be exclusions.[2]

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1 The Introduction is drawn from OECD work (2006). This distinguished between: public sector information generated by governments that tends to be readily re-usable; and public sector content held by governments with a clear public good task to make it widely available. In this report they are divided into two categories although they are on a continuum with no clear dividing line.

2 The EC Directive on the re-use of public sector information (2003/98/EC, 17 November 2003) excluded information and content generated and held by cultural and educational institutions, and public sector broadcasters, whereas the OECD *Recommendation of the Council for enhanced access and more effective use of Public Sector Information* [C(2008)36] includes all information and content generated and/or held by public bodies, defined as: "information, including information products and services, generated, created, collected, processed, preserved, maintained, disseminated, or funded by or for the Government or public institution".

For analytical and operational reasons it is useful to differentiate between:

- *Public sector information* which has characteristics of being: dynamic and continually generated, directly produced by the public sector, associated with the functioning of the public sector (*e.g.,* meteorological data, geo-spatial data, business statistics), and often readily useable in commercial applications with relatively little transformation of raw data, as well as being the basis of extensive elaboration; and

- *Public sector information held by cultural establishments and the like (public sector content)* which has characteristics of being: static (*i.e.* it is an established record), held by the public sector rather than being generated by it (*e.g.,* cultural archives, artistic works where third-party rights may be important), not directly associated with day-to-day functioning of government, and not necessarily associated with commercial uses but having public good characteristics (*e.g.,* culture, education).

The first category has received most attention and can be readily used in information-intensive industries. These employ raw PSI to produce increasingly pervasive products such as location-based applications accessed from smart-phones. The second includes cultural, educational and scientific public knowledge. Wide public diffusion and long-term preservation (*e.g.* in museums, libraries, schools) are major government objectives. The public good task is clearer, but with rapid growth of interest in all kinds of cultural goods and services the potential for market and non-market development is very large.

1.2. Objectives and scope

At European level there is little robust data on: *i)* the size, growth and impacts of PSI-related activities, and *ii)* the socio-economic benefits and costs of improved access to public sector content. The objectives of this study are to identify and fill some of these gaps by:

- Reviewing recent evidence on the importance and growth of PSI to the extent that quantitative studies are available;
- Summarising selected recent studies at sector level or in particular areas;[3]
- Providing top-down estimates of the value of the PSI market in Europe and the economic value of PSI in Europe in general.

Scientific information and research data is generally not included in this survey, and is outside the scope of the EC Directive. However open access to science and research results can significantly improve research (OECD, 2005) and estimates of the benefits from improved access to scientific research results are included at the end of this study.

Public sector information held by cultural establishments is included to the extent that it is covered in the publications and reports reviewed. Nevertheless as public sector cultural content was not part of the original Directive 2003/98/EC on the Re-use of Public Sector Information, it is generally not included in publications and reports related to the Directive.

Public broadcasting was specifically excluded from the EC Directive and along with most other cultural information is not covered in this survey.

2. DEFINITIONS AND VALUE CHAINS

2.1. Different information and content types

The pool of public information/content is highly diverse (see Table 1). Data is collected to underpin regulation, provide information for research, preserve cultural heritage and facilitate taxation, registration and administration. Collecting institutions include national and

3 A comprehensive catalogue of recent studies is also available in de Vries, 2012.

local governments, non-departmental public bodies, executive agencies, research organisations and international organisations.

2.1.1. Information and content domains

Public sector information and content domains and examples are shown in Table 1. The different domains are a continuum of examples rather than a mutually exclusive and collectively exhaustive classification system. Information commonly used in commercial applications includes geographic, meteorological, business, financial, social, transport and legal information. Cultural, educational, scientific and political information are often made widely available by governments. Over time, distinctions have become less clear-cut and there is a continuum of uses running from public sector information to public sector content.

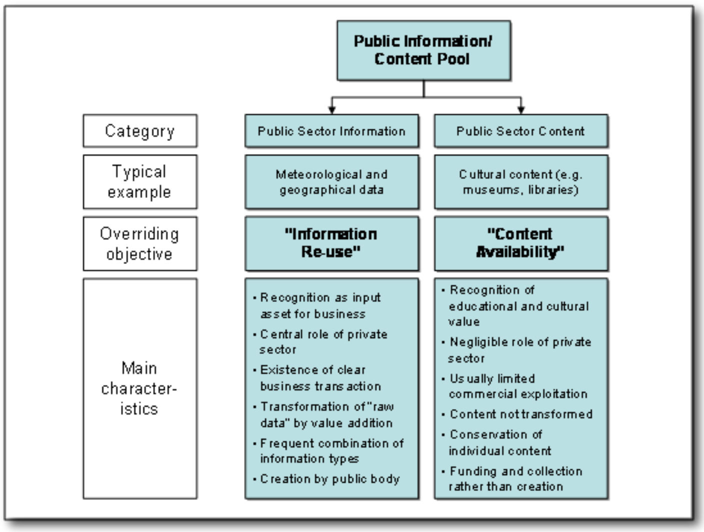
Table 1. Public sector information domains with examples

Commercial re-use of PSI	Geographic Information	cartographic information
		land use info (cadastral data)
		spatial data/geographical coordinates
		administrative and political boundaries
		topographical information
		elevation data
↑	Meterological and Environmental Information	oceanographic data
		hydrographic data
		environmental (quality) data
		atmospheric data
		meteorological (weather) data
	Economic and Business Information	financial information
		company information
		economic and statistics
		industry and trade information
	Social Information	demographic information
		attitude surveys
		data on health/illness
		education and labour statistics
	Traffic and Transport Information	transport network information
		traffic information
		transport statistics
		car registration data
	Tourist and Leisure Information	hotel information
		tourism statistics
		entertainment (local and national)
	Agricultural, Farming, Forestry and Fisheries information	cropping/land use data
		farm incomes/use of resources
		fish farming/harvest information
		live stock data
	Natural Resource Information	biologic and ecologic information
		energy resource/consumption information
		geological and geophysical information
	Legal System Information	crime/conviction data
		laws
		information on rights and duties
		information on legislation
		information on judicial decisions
		patent and trademark information
	Scientific Information and Research data	university research
		publicly-funded research institutes
		governmental research
↓	Educational Content	academic papers and studies
		lecture material
	Political Content	governmental press releases
		local and national proceedings of governments
		green papers
Making available PSC	Cultural Content	museum material
		gallery material
		archeological sites
		library resources
		public service broadcast archives
		other public archives

Source: OECD, 2006, adapted from PIRA, PSINet and other studies.

For public authorities this information has two distinct dimensions once collected and used for its initial public purpose. One comprises facilitating commercial "re-use" of public sector information (Table 1 and Figure 1). The other (public sector content) usually aims at wide diffusion and preservation of public goods for various socio-economic purposes.

Figure 1. Categorisation and characterisation of the public information pool



Source: Adapted from OECD, 2006.

2.2. Users and applications

2.2.1. Commercial re-use of public sector information

"Re-use" centres on exploiting the economic value of public information. PSI serves as "raw material" which can be used to develop new products and services. Whereas public bodies are the creators and suppliers of the original material, the private sector plays a major role as intermediary and information processor between the public source of information and end users. Payment occurs in exchange for information; private businesses pay for PSI and consumers for value-added information products and/or services. Public bodies also provide products directly to final users. There have been wide differences across countries in access and pricing approaches, but countries are increasingly making access easier, with data priced at marginal cost of storage and distribution.

2.2.2. Making available public sector content held by cultural establishments

Public institutions also invest in the preservation and dissemination of public sector content held by cultural establishments to realise social and educational goals. As the main objective is wide diffusion, this content has usually been freely available for private individuals and educational purposes, with low prices occasionally charged to recoup some costs. In most countries the private sector was only marginally involved in efforts to make content held by cultural establishments widely available. However, with increased pressures on government budgets and the growth of popular interest and access to all aspects of culture, the private sector and individuals have often expanded their role, for example, in exchange for marketing possibilities (*e.g.* private sponsoring of cultural events).

2.3. Value chains for commercial re-use of public sector information

The value chain of commercial re-use of PSI comprises: *i)* data creation and collection, *ii)* aggregation and organisation, *iii)* processing, editing and packaging, and *iv)* marketing and delivery. The Internet and software applications are supporting systems and the basis for value-creating functions. Much re-use activity only started once low-cost ICT applications and networks became available.

Creation and collection: The first stage of the PSI value chain is data creation or collection (e.g. the actual measurement of geo-spatial data). At this stage public information can be considered as "raw material". The most important PSI producing public bodies generating data as part of their public tasks are:

- Mapping agencies producing geo-spatial and geographic data.
- Meteorological services generating weather data.
- Statistical offices generating comprehensive socioeconomic data.
- Company registrars collecting corporate financial data.
- Transport agencies producing traffic data, and
- Courts and other government institutions providing legal and legislative information.

Aggregation and organisation: In the second stage the information created at local, national or international level is aggregated and organised to create more comprehensive data sets and to permit joint storage and retrieval.

Processing, editing and packaging: The third stage of the value chain includes a large variety of value-adding activities including data processing, editing, re-packaging or re-modelling. Editorial activities include the production of synopses, explanatory notes and search indexes. For example, geo-spatial data can be used to produce location maps for all kinds of end-using devices, with the major part of added value coming from combinations with other information such as demographic, traffic or environmental data.

Marketing and delivery: ICTs have augmented market reach and have transformed many traditional PSI-related marketing, distribution and delivery activities.

Overall, the changing scope and value chains for public sector information make it more widely accessible and more readily combined to produce new information goods and services for an expanding number of end-users.

The next sections explore the aggregate economic dimensions of access to and use of PSI. The literature review is divided into two parts, the first covers general market studies and estimates of PSI markets and PSI impacts, the second estimates the size of the EU27 PSI market based on extrapolations from these studies. It does not cover all of the PSI literature, particularly studies of implementation and legal aspects of PSI re-use. All information sources are listed in the Bibliography at the end of this survey.

3. GENERAL MARKET STUDIES

3.1. Open access to public sector information

Knowledge and information flows underpin creativity and innovation, and the relative scope and scale of public sector information, particularly in small economies, make public sector information important sources of raw material for innovation. The public sector is a major, even the dominant, producer and custodian of information in many domains and easier access can drive innovation and new economic activity (OECD, 2006, Vickery, 2010). Furthermore, only government and the public sector have the critical mass to create inclusive public platforms and scalable repositories in many areas (Cutler, 2007, Nilsen, 2010).

Improved access to and use of public sector information has increasingly taken centre stage from being a somewhat peripheral issue often confused with freedom of information, and extensive work has been undertaken analysing and providing policy principles for the development and use of public sector information. These principles have also taken into account that there are limits to what can be released and that legal requirements and restrictions, including effective and secure management of personal information, confidentiality and national security concerns, and fundamental principles including democracy, human rights and freedom of information (see OECD, 2006, 2008).

3.1.1. Access, equity and pricing

Re-use of publicly funded information from government activities, academic and other research areas has potential for a wide variety of new and innovative combinations (Cook, 2010). An underlying rationale for this is not so much the predictability of these new combinations as their unpredictability. As Drucker argued 'Opportunity is where you find it, not where it finds you. The potential of a business is always greater than what is actualised'. Enlarging and systematically inviting serendipity can be argued to be an aim of government information policy, making access to public sector information an important cornerstone in a comprehensive digitally driven innovation policy (see e.g. European Commission, 2010).

The supply of PSI at no charge is generally justifiable on grounds of economic efficiency where there are no clear obligations and risks related to nondisclosure. According to some, the arguments related to equity and 'user pays' are usually poorly conceived in the context of public funding of PSI and strenuous efforts devoted to the promotion of lifelong learning (Cook, 2010, Stanley, 2010).

3.1.1.1. Geospatial and weather information in the United States

Two examples of the benefits and challenges to better access to and greater use of public sector information can be drawn from experience in the United States.

Geospatial information: The volume, quality and resolution of geospatial data are increasing exponentially with sources of data including global positioning satellites, aerial photographs, distributed sensor networks, embedded devices, location-aware technologies and IT-enabled social and commercial networks. Challenges for governments include national security concerns, working out the relations between data collected for government and that from commercial providers, and how to cover the costs of preparing data for public release. Furthermore, even in the United States many state and local government organisations have continued to seek partial or total cost recovery, undermining benefits from the liberal Federal policy of making data available free or at cost of distribution with few licensing constraints (National Research Council, 2003a, National Academy of Sciences, 2009).

Weather information: The strengths of the US weather and climate system is seen as coming from the interplay of three actors: The National Weather Service (of the National Oceanic and Atmospheric Administration), responsible for protecting life, enhancing the national economy and maintaining an extensive sophisticated infrastructure; academia, responsible for advancing science and educating meteorologists; and the private sector, responsible for creating products and services for commercial use and communicating with the public. Based on free access to meteorological information, this system has developed a flourishing set of weather and weather-related services. Furthermore these services are used globally, contributing to global welfare, as well as being widely cited as an example of the benefits of free access to PSI (National Research Council, 2003b).

3.1.2. International initiatives

In addition to the EC Directive on PSI, the OECD Recommendation of the Council for enhanced access and more effective use of public sector information provides policy guidelines for greater transparency, lower pricing, simpler licensing, and enhanced competition (OECD, 2008). This Recommendation aims at increasing economic and social benefits and returns on public investments through more efficient distribution, enhanced innovation, development of new uses, and market-based competition. The Recommendation encourages greater access and use regardless of IP ownership.[4]

3.1.3. Continuing barriers to measuring markets and benefits

Despite what are seen as increasingly self-evident and growing benefits from improved lower /no cost access, there are conceptual and practical difficulties in measuring benefits and the size of related markets. These difficulties remain even in areas such as geospatial information and a considerable literature has grown up on the difficulty of measuring its "real value" of geospatial information and the importance of establishing robust theoretical and empirical user models (Genovese, 2010, de Vries and Miscione, 2010, Crompvoets, 2010).

3.2. European market studies

This section reviews the two most important earlier large-scale attempts to collect new information of the European market, followed by more partial studies of this market.

3.2.1. Total PSI in Europe. The PIRA report

The PIRA report was the first cross-European study to estimate the value of PSI markets and the contribution of PSI to economic activity (PIRA, 2000). This was based on detailed estimates for a few countries extrapolated to the EU15. The PSI market was estimated to be EUR 68 billion, with EUR 36 billion for geographical information. The geographical sector took over 37% of total investment in PSI in France, 41% in Sweden and over 57% in the United Kingdom (PIRA, 2000). The methodology is summarised in Box 1. The US information sector was estimated to be EUR 750 billion although it contains many activities unrelated to PSI. It was concluded that the US PSI market was considerably larger than the EU market, and given the rapid growth of commercial PSI re-use and the capabilities of ICTs, the economic value of public information has undoubtedly increased subsequently.

Box 1. PIRA economic valuation methodology

The PIRA study provided the first extensive economic estimates of PSI, but the methodology is not always straightforward. The study identified: *i)* investment value and *ii)* economic value of PSI.

Investment value: defined as government investment in the acquisition of PSI. The cost of acquiring the information gathered by the public sector provides a lower bound to the value of PSI.

Economic value: defined as the part of national income attributable to industries and activities that are based on the exploitation of PSI.

PIRA used a combined estimate with *i)* data on the investment value of PSI, *ii)* estimates of the value added by PSI users and *iii)* private sector expenditure on PSI. Identification and combination of information on these items is difficult, and there are four additional potential sources of error:

- Estimating the value of PSI that is given away freely.
- The allocation of government agency receipts to intermediate and final users.
- Estimating the value of information supplied to intermediate users to give a final user figure.
- Using the relative size of national economies to extrapolate to total EU PSI. France, Germany, Portugal, Sweden, the United Kingdom were estimated directly and ten extrapolated.

Source: PIRA, 2000, OECD, 2006.

[4] The OECD Recommendation was based on findings that there were major barriers to commercial and non-commercial re-use of public sector information and content. Continuing obstacles included: restrictive or unclear rules on access and re-use; discouraging, unclear and inconsistent pricing; complex and lengthy licensing procedures; inefficient distribution; barriers to development of international markets; and the unclear role of public sector organisations in competitive markets.

3.2.2. Total PSI in Europe. The MEPSIR report

Following the PIRA report in 2000, the most comprehensive subsequent analysis of European PSI markets is the MEPSIR study (MEPSIR, 2006).[5] This study developed and tested a repeatable methodology for measuring PSI re-use in Europe and a comparison with the United States. Public sector information covered: geographic information of all kinds; meteorological information; business information, including patent and trademark information and public tender databases; social data, including economic, employment, health, population, public administration, and social statistics; transport information; and legal information. It did not include scientific/research information or cultural content.

Two survey methods were used. Public information/content holders and re-users were asked to estimate the size of the domestic market in their sub-domain(s). Given the very large variation in estimations, particularly for PSI holders, the median was used as a base value, with the average as an upper boundary. Based on re-users' estimates, the overall market for PSI was EUR 26.1 billion in 2006 (median value) with an upper boundary of EUR 47.8 billion (average value). An alternative estimation of PSI markets was based on surveyed user turnover and staff numbers. The overall market size is the sum of the re-users' turnover minus costs of acquisition. The average for the minimum and maximum estimates by this method was EUR 27.6 billion, with an upper limit of EUR 46.5 billion.

The two estimation procedures for the EU25 PSI market converged, with average turnover and median respondent estimates both around EUR 27 billion, with upper limit values of the order of EUR 47 billion and lower limit values around EUR 10 billion. The value of EUR 27 billion was considered a conservative but realistic estimate, equivalent to 0.25% of European GDP, and this was used to estimate PSI markets in individual countries.[6]

3.2.3. Geographical, meteorological and legal information

An in-depth survey and case studies across the EU27 presented a picture of generally dynamic growth of PSI re-use in the geographical information, meteorological information and legal information sectors (MICUS, 2009). Some of this re-use was directly attributed to the EC Directive, but the Directive's impact varies.

Geographical information. The PSI Directive was seen to have its strongest impact on geographical information (GI). The market is growing, income of re-users is increasing (66% of respondents) and new re-users offer innovative applications. The Directive directly drives some of this growth, and other public sector holders aware of the Directive have introduced significant changes (reported by 54% of Mapping and Cadastral Agencies). Many changes are technical, dealing with data formats and modes of delivery, and GI is increasingly offered on Internet portals or via web services. Re-users confirmed that holders had improved their services, particularly the speed of delivery and formats. Although restrictive licensing and high prices are continuing barriers, the large majority (79%) of private re-users would like to access more public GI. However, GI is increasingly available from private sources, and in some areas it was considered that PSI holders should consider reviewing their public tasks.

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5 The MEPSIR and PIRA studies used entirely different approaches. The estimates of MEPSIR are based on the surveyed added value attributed to PSI re-users. The total of PIRA encompassed all firms related to PSI, based on broad estimates using national accounts data. PIRA takes the size of the information industry as an upper bound proxy, particularly for the US market.

6 The study gathered data for the US in exactly the same way as for one European country, and is thus much lower than for the EU27, and not robust enough to compare with EU27 estimates. Nevertheless, it appears that the number of US re-users per public sector content holder is higher, and the US scored high on Accessibility, Accountability and Non-discrimination, as may be expected from the more open US approach to PSI access.

Meteorological information. In the meteorological information sector the market for is also growing. The volume of meteorological data procured from the public sector between 2002 and 2007 had increased for 74% of users; 80% of National Meteorological Services reported increasing income and re-users confirmed very significant increases in income. Nevertheless on the supply side, the study suggests that relatively few PSI holders had changed their data policies based on changes in their national legislation. Re-users complain first and foremost about pricing, transparency and licensing, and particularly about discriminatory activities. As in the other sectors, the large majority of re-users would like to obtain more PSI from holders, but in many cases re-users gather information from other free sources, such as the US weather services, and would like to see unrestrictive licensing.

Legal information. The market for legal and administrative information is growing; holders reported a 40% average increase in the period 2002-07. Half of holders indicated that they changed their data policy since 2002, one third saying due to legislation and the majority (79%) offers information free of charge on the Internet. The majority of re-users recorded increasing income, and those that add value to PSI reported exceptional growth rates. In contrast to other sectors, many re-users criticise the lack of information on what is accessible and where to find it. This can be explained by decentralized jurisdictional organization, but it could also be due to the structure of the re-using side.

Comparable trends in the PSI market can be observed in all three sectors. Unmet market demand for PSI is significant, and re-users reported undiminished buying interest. It was recommended that PSI holders focus on licensing and pricing, and provide greater support for re-use. The study further recommended that regular market monitoring be introduced, for example the volume of data delivered and the income of PSI holders where data is not free.

3.2.4. Environmental impact assessments

The EU27 market for obligatory Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA) was surveyed in detail in 2009 (Craglia *et al*., 2010). The key finding is that this market is worth EUR 1 billion per year, and that improving accessibility of the information required for these studies could save up to EUR 200 million. Including sub-national assessments could increase these values by a factor of 10, saving EUR 2 billion annually.

The detailed survey indicated that the main suppliers of spatial data are local authorities/local governments and environmental protection agencies (73%) followed by mapping agencies (52%). In addition 44% of respondents produce their own data; other sources include national and regional bodies and private companies including Google Earth (Craglia *et al*., 2010). The survey clearly shows the continuing reliance of these reports on public sector sources. The survey also highlighted the continuing challenges in using spatial data. The most frequent problems relate to finding the data (59%) and low data quality (58%). These are followed by problems accessing the data (53%), integrating it (53%) and cost (48%). Only 4% indicated having none of these problems. Clearly, improved access at lower cost to better data would facilitate development of higher quality EIA/SEA reports.

3.2.5. Summary

Overall, the review shows that improved access to and use of public sector information is of major importance. It has increasingly taken centre stage from being a somewhat peripheral issue often confused with freedom of information, and there has been extensive international analysis and development of policy principles for better use of public sector information. Despite increasingly self-evident benefits from improved PSI access at lower /no cost to users, there are conceptual and practical difficulties in measuring benefits and the size of related markets, even in narrow defined areas such as geospatial information.

A number of early aggregate studies set the scene for measuring PSI markets and impacts across the EU. The PIRA report (2000) gave very large estimates of the size of the European PSI market by including a range of non-PSI related activities. The MEPSIR study (2006) estimated a EU25 PSI market around EUR 27 billion, with upper and lower limits of EUR 47 billion and EUR10 billion. A more recent in-depth survey of the geographical, meteorological and legal information sectors across the EU27 presented a picture of generally dynamic growth through 2008. Unmet market demand for PSI is significant, and it was recommended that PSI holders focus on licensing and pricing issues and provide greater support for re-use. In the sub-area of environmental impact assessments the market was worth EUR 1 billion in 2009. Improved access to information could save up to EUR 200 million per year; including sub-national assessments could increase values by a factor of 10.

3.3. National studies

3.3.1. Denmark

The Danish government launched the "Open Data Innovation Strategy" in 2009 to provide easier access to public data as a digital "raw material" for businesses. Denmark is advanced in data collection and digitisation and has considerable public sector information resources. The value of open government data was quantified in a study using interviews and workshops to identify areas where expanded access could lead to quantifiable commercial benefits and efficiency gains (Zangenberg & Company, 2011, see also de Vries, 2012).

In the banking sector, banks are working with the tax authorities and clients to give banks access to clients' payroll and pension data from the state eIncome register. Banks estimate that this extra information alone is potentially worth over DKK 500 million per year (EUR 67 million in 2010[7]) and the total potential is estimated to be billions of DKK. There are however issues with the scope of customer consent and customers' real capacity to refuse consent. The insurance industry pointed to a number of areas where the industry could use detailed data but there are the same privacy concerns as for the banking industry.

The energy sector considered that it could benefit considerably from increased access to data on residential occupants, their age, gender, income, etc. coupled with information on housing age, construction, insulation, energy, etc. These data could be used to offer high value energy-saving improvements, possibly combined with funding incentives The energy industry estimated that in conjunction with the construction industry the potential Danish market for energy improvements is DKK 4-20 billion per year (EUR 0.54-2.7 billion). The EU27 market could be worth EUR 29-143 billion using the same assumptions.

Following up on this strategy the government has opened up “unproblematic” basic data for re-use (Danish Government / Local Government Denmark, 2012). PSI is being made available in geographic, address, real property, business and personal data areas using a common data distributor. This basic data has great value for the private sector in their internal processes and for entirely new digital products and solutions, as well as being an important basis for public authorities to perform their tasks.

[7] Exchange rates from OECDStatExtracts, Financial Indicators at: http://stats.oecd.org/Index.aspx

3.3.2. France

There is relatively little data on PSI reuse in France. SerdaLAB undertakes an annual study of the professional digital information market and estimated this to be EUR 1.54 billion in 2007 and 1.57 billion in 2008, with relatively slow growth for 2009 and 2010. A large part of the information (legal, environmental, economic and financial data) is supplied by the public sector (SerdaLAB, 2009, 2010). On the PSI supply side the major government institutions providing and charging for PSI have relatively low revenues, due in part to past restrictive pricing and licensing conditions:

- Institut Géographique National (IGN): estimated 2009 revenues EUR 2 million; Cadastre (DGFiP): estimated revenues EUR 0.9 million;
- Institut national de la statistique et des études économiques (INSEE) only charges for the base “SIRENE” and for services related to delivery of data;
- Institut national de la propriété industrielle (INPI);
- Service Hydrographique et Océanographique de la Marine (SHOM);
- Méteo France;
- Direction de l'information légale et administrative (DILA): estimated 2009 revenues EUR 0.9 million.

However, a radical new policy was put in place in 2011 to open up data sources for re-use at no charge and with easy licensing mechanisms and conditions. A new body, "Etalab", was created directly under the authority of the Prime Minister (Etalab, 2011). It was tasked to create a unique public information access portal (data.gouv.fr). With this initiative, France joined other countries with single government portals and simplified access, including the United States (data.gov, May 2009), and United Kingdom (Data.gov.uk, September 2009).

3.3.3. Germany

In Germany a considerable amount of analysis has explored how PSI markets could be reshaped to provide better services at lower costs (Fornefeld, 2009). The German market for geo-information increased rapidly from EUR 1 billion in 2000 to EUR 1.7 billion in 2009, with 50% driven by the navigation market. Because of unmet demand for public map data, private alternatives emerged, with much of the new geo-information market based on “free” private data (Fornefeld, 2011). There is insufficient market transparency on the side of PSI holders, they lack market knowledge, and tend to overestimate product prices. In the meteorological market, for example, the government overpriced data and underestimated potential market growth, encouraging development of parallel private infrastructures.

This analysis estimated German government PSI revenues to be very low, around EUR 0.16 million from legal, vehicle, and meteorological data in 2007 (Fornefeld, 2009). However, analysis in 2010 suggested that revenues were around EUR 3.2 million from meteorological data (DWD) and geographical data (SenStadt), with lesser amounts from statistics (Destatis) and maps (BKG) (POPSIS, 2011).

3.3.4. Netherlands

There is a range of information on the size and structure of parts of the Netherlands PSI market, including a detailed study of the geospatial sector (see Castelein, *et al.,* below). For example, the narrow meteorological re-use market (2010) was around EUR 10 million, estimated from around 45 re-users, 5 dedicated to pure meteorological services (M. de Vries, personal communication, 2011, POPSIS, 2011). The market has grown steadily over the past 10 years due to the very liberal re-use policy of the Royal Netherlands Meteorological Institute (KNMI) that charges very low re-use costs and has no licensing restrictions.

Government revenues: the Netherlands and the United Kingdom

PSI suppliers were estimated to generate considerable revenues in 2009 (R. A. te Velde, personal communication, 2011):

- KvK (Chamber of Commerce): EUR 30 million (estimated budget EUR 165 million).
- Cadastre: EUR 17-22 million (total budget EUR 230 million, the remaining EUR 200+ million from 'legal tasks' related to its cadastral information monopoly).
- CBS (Statistics Netherlands): EUR 16 million (total budget EUR 205 million).

Thus the Netherlands' government revenues from sales of PSI by these four bodies were around EUR 68 million in 2009-10, in relative terms around one-third of the United Kingdom's GBP 400 million estimated for the UK Office of Fair Trading report (2006). Nevertheless, the Netherlands has been a country that has been fairly effective in generating PSI sales revenue (data from POPSIS, 2011).

If these values for the Netherlands are pro-rated to the whole EU27, government revenues from direct PSI sales are of the order of EUR 1.408 billion. Equivalent values based on the UK estimate would be approximately EUR 3.386 billion. Nevertheless the UK values look to be high for the EU27, as the UK has had a different system of Crown Copyright and an efficient and simple licensing system has helped generate government revenues.

Analysis of Public Sector Bodies (PSBs) providing PSI also suggests that revenues across Europe are relatively low. The United Kingdom is an upper range outlier and the Netherlands is also on the high end of revenues from PSI sales (POPSIS, 2011). In most cases revenues are less than 1% of expenditures and they are a maximum of one-fifth in a few cases -- the United Kingdom in general, the Netherlands agencies above, the Austrian Federal Office of Meteorology BEV, Spanish legal data CENDOJ. There is also evidence that dramatically increasing access and lowering prices has positive impacts on numbers of users and new uses, and that these changes provide opportunities for reviewing the role of public tasks and implementing other changes (see POPSIS, 2011).

3.3.5. Norway

Norway has reviewed the market potential, benefits and costs of increased availability of public data (Norway, 2011). It is argued that a central feature of the use of digital data is that costs are largely fixed, and the greater the use, the lower the average cost of production and delivery. Furthermore, there will be better use of public resources, improved economic and social interactions, and democracy will be supported. If the marginal cost of data publication is virtually zero, all pricing beyond marginal cost normally gives a welfare loss.

Obstacles to increased availability of public data include:

- Technical and financial constraints: There may be new costs for individual stakeholders or a different cost distribution that may outstrip expected benefits.
- Cultural barriers: Traditional public sector functions can be challenged.
- Legal provisions. Increased availability of public data should in principle not be in conflict with general social considerations and the need for protection of citizens

Two estimates of the impact of better access to PSI were undertaken.

3.3.5.1. Valuing time saved

The value of simpler and more efficient information flows in terms of time saved for individual work and leisure activities was estimated. It is assumed that each individual on average saves 2 hours per year through better access to public information. Converted to the adult population over 20 years of age, some 7.2 million hours are saved per year. Assuming that half of the savings are work-related and half for private activities, and that work-related time savings are valued at wages and salaries before tax and leisure time is valued at earnings minus taxes, the annual surplus is NOK 260 million (EUR 32.5 million) in 2010.

3.3.5.2. Effects of free data on processors, distributors and end-users

If public data is provided free, organisations that process, distribute and disseminate data will have reduced costs, but revenue streams to established distributors will be reduced. For example, Norwegian Mapping Authority revenues were NOK 72 million in 2009. If map data is freely available some "pure" distributors may also have reduced revenues, and will have to change their business models. On the demand side, direct effects on end users are likely to be greater than the simple reduction of input costs. For example, assuming linear demand with a demand elasticity of -1 a price reduction of only 10% increases demand by 10%. Consumer surplus will increase by NOK 73.5 million, i.e. NOK 3.5 million more than total government map data revenues. In addition, free map data may generate considerable gains from new market entrants, operators, and technology-based innovations.

3.3.6. Spain

The Spanish Government launched the Aporta project (www.aporta.es) in 2009 with the aim of encouraging PSI re-use in Spain. This sector was seen to have considerable potential for growth, employment and development of new products with high added value. As part of this work the "infomediary" business sector was analysed for the year 2010 (Proyecto Aporta, 2011). The sector was defined as "the set of companies that create applications, products and/or added-value services for third parties, using public sector information", including business/economic, legal, geographic /cartographic, meteorological, social data/statistics and transport data. Some 230 infomediary companies were identified to provide what was considered to be a comprehensive overview of direct PSI activities through quantitative surveys and qualitative interviews and focus groups:

- Business turnover directly associated with infomediary activities is EUR 550-650 million, 35-40% of the total company activity of EUR 1.6 billion. Infomediary turnover is equivalent to video game software development or online advertising.[8] Some 5,000-5,500 employees are involved in PSI re-use activities in the companies analysed.
- In the most recent year the number of clients increased, especially for companies with foreign customers; over 45% have EU customers and 20% have clients outside of the EU.
- Re-use fields were: business/financial 37.6%, geographic/cartographic 30.5%, legal 17.0%, transport 5.2%, social data/statistics 1.9%, meteorological 1.1%, others 6.7%.
- Information comes mostly from national agencies, but half of the companies also reuse international information.
- The main clients are companies, self-employed and some public administration activities.
- Companies largely use electronic distribution channels. Free-access and password-access models coexist with advertising in product portals/websites and payment models. Companies have a high technological level and innovation is in processing and analysis.
- Re-use policies are valued, particularly to improve the quality of information, improve the legal framework, and expand the amount and scope of information generated.

8 Source: "Annual Report on Digital Contents in Spain 2010", ONTSI. Data for 2009: video content industries EUR 8.0 billion, video games software 8%, online advertising 8.2% see www.ontsi.red.es

- Areas identified for improvement include standardisation of formats, standardisation and improvement in the regulation of licenses for re-use, and pricing of information.

3.3.7. United Kingdom

The United Kingdom has undertaken extensive review and reorganisation of its public sector information resources (see e.g. Power of Information Taskforce, 2009), and there is a growing body of independent economic analysis (see Pollock *et al.* 2008, Pollock, 2009, 2011a, 2011b). Transformation of the PSI set-up has been based on increasing recognition that PSI delivers benefits for the knowledge economy and reinforces the relationship between the public sector and citizens (The National Archives, 2011). There is increasing recognition of the international dimension of PSI. Included among national policy objectives are to promote awareness that the value of PSI is not defined by national boundaries, and to operate internationally sharing best practice.

Information and data produced by the government and the public sector is the largest and most diverse source of information in the UK, encompassing national and local legislation, statistics, local planning, transport, education, local services and tourist information. It is estimated that 15-25% of information products and services are based on information produced or held by the public sector (The National Archives, 2011, from PIRA, 2000).

As part of the drive to expand the use of PSI the May 2010 transparency agenda aimed to enable businesses and non-profit organisations to build innovative applications and websites using public data. The UK drew on analysis in Australia and New Zealand, which have policies to open up government and make PSI more readily available. The UK developed the Open Government Licence for PSI whereas Australia and New Zealand have adopted Creative Commons model licences. The main reason was that existing Creative Commons licences did not extend to licensing works protected by the database right.[9]

3.3.7.1. Estimating welfare gains

Pollock has estimated the welfare gains to UK society (overall economic gains across the whole economy) from opening up access to digital, non-personal PSI for use and reuse (Pollock, 2011a). Gains from ‘opening up’, that is moving to marginal-cost (zero) pricing for digital public sector information, are estimated using the formula Gains = $2/5F\lambda\varepsilon$ where F is revenues under average cost pricing, λ the multiplier and ε the elasticity of demand. Using total income data from sales of PSI of GBP 400 million (Office of Fair Trading, 2006): upper end estimates of gains were approximately GBP 4.5-6 billion per year (EUR 5.05-6.73 billion per year), and middle range estimates were approximately GBP 1.6-2 billion per year (EUR 1.80-2.25 billion per year) (Pollock, 2009, Pollock *et al.,* 2008).[10]

Pollock (2011a) points out a wide range of benefits from opening up access to PSI. These include development of new products built directly on PSI; development of complementary products such as new software and services; reduction of transaction costs in

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9 The Open Government Licence and a more liberal approach to PSI access and pricing replaced the previous Click-Use Licence operated by the National Archives.

10 The definition of PSI in Pollock’s study is fairly wide. It comprises digital information (data not necessarily originally collected in digital form, but that can be made available in digital form) whose marginal cost of production/dissemination may be taken to be zero. It covers non-personal information, which either contains no personal information or is at a level of aggregation and anonymisation so that personal information cannot be identified. It includes but is not restricted to: company information, vehicle registration, physical property, intellectual property, meteorological data, geospatial information, hydrographic information, socioeconomic statistics, environmental data, official gazettes, transport statistics and the like. Public sector information includes any piece of ‘information’ produced or held within the public sector, but the focus is on relatively large and coherent information sets, and does not include scientific or cultural information in general.

accessing and using such information; gains in the public sector itself, etc. He also points out that it is economically attractive in the UK to shift from largely unsuccessful user funding models to "updater" funding (Pollock, 2011b). For example, companies updating company data pay higher levies, or increased fees are paid by construction activities that change land surveys. Updater funding mechanisms would need to be supplemented with some extra government or external funding, but the extra funding is estimated to be relatively small, and very small compared with additional benefits from greater economic activity.

Although the UK PSI access and licensing system is somewhat different from other EU27 countries, estimates of the positive impacts of removing barriers to access are likely to be realistic proxies for removing barriers across the EU27. In the UK, barriers have been due to price and licensing conditions, as well as poor interoperability, different data formats, lack of knowledge of what is available etc., partly compensated by an efficient licensing system and centralisation of access procedures. In other countries, even lower pricing and easier access may be negatively offset by different licensing systems across national institutions, lack of information, poor interoperability etc. Thus the results from the Pollock studies may be reasonable proxies for EU27 welfare benefits from free access.

3.3.8. United States

Free access to public sector information has been a cornerstone of US policy and this was strengthened when the White House issued the Open Government Directive based on principles of transparency, participation, and collaboration (Office of Management and Budget, 2009). This directed executive departments and agencies to take specific actions to implement these principles and established deadlines for action. The directive made it a requirement that each department or agency make its information available online in open format, which could be retrieved, downloaded, indexed and searched by commonly used web search applications. Agencies were encouraged to proactively use modern technology to disseminate information, rather than to wait for specific requests under the Freedom of Information Act (USA) 1966. In April 2010, every Federal department published an Open Government Plan to make operations and data more transparent, and expand opportunities for citizen participation, collaboration and oversight.

3.3.9. Summary

A range of detailed national studies shows growing markets and new applications. For example in Denmark the banking, insurance and energy sectors indicated that better access to PSI could be of significant value, with the energy industry estimating that in conjunction with the construction industry the potential national market for energy improvements drawing on various government data sources is EUR 0.54-2.7 billion. The German market for geo-information increased rapidly from EUR 1 billion in 2000 to EUR 1.7 billion in 2009, and in Spain the PSI reuse sector was shown to be equivalent to the online advertising sector, with two thirds of reuse revenues derived from business and geographic data.

For the United Kingdom moving to marginal cost pricing and easier access would give estimated welfare gains of EUR 5.1-6.7 billion per year at the upper end. Although the UK PSI access and licensing system is somewhat different, estimates of the positive impacts of removing UK barriers to access are likely to be realistic proxies for values across the EU27, due to the general nature of disincentives to PSI use. At a different level, in Norway saving as little as 2 hours per person per year by making information flows simpler and more efficient was conservatively estimated to be worth around EUR 32.5 million in 2010.

In contrast, government revenues from sales of PSI are in general low, with the Netherlands and the United Kingdom being generally more effective in generating PSI sales revenue. If values for the Netherlands are pro-rated to the whole EU27, the value of EU27 government revenues from direct PSI sales are of the order of EUR 1.41 billion and for the

UK approximately EUR 3.39 billion. In most cases sales revenues are relatively much lower, usually less than 1% of expenditures and a maximum of one-fifth in a few cases. There is also evidence that increasing access and lowering prices dramatically has positive impacts on the number of users and new uses, and that changing access and pricing policies provides opportunities for reviewing the role of public tasks, and implementing other changes.

Overall, exploiting the potential in the PSI market is seen to require lower pricing and less restrictive licensing agreements. Countries including France, Denmark and the United Kingdom have radically overhauled their PSI access systems, and other countries including Norway and Spain have made access easier and less costly. There are gradations in approaches used depending on where countries are positioned in their PSI re-use activities. Policy strategies include: opening up PSI that has been difficult to access and reuse; reviewing and amending unnecessary restrictions; reviewing and redefining the public task; facilitating access to third party rights holders' material where rights holders agree. A number of countries have also stressed the international dimensions of PSI access, both in accessing international data, and developing international markets for national data.

3.4. Geospatial information

3.4.1. International benefits

Recent cross-country research shows clear firm-level benefits from free or marginal cost pricing (Koski, 2011). Analysis of 14,000 firms in architectural and engineering activities and related technical consultancy services in 15 countries in the 2000-2007 period shows that in countries where public sector agencies provide fundamental geographical information for free or at maximum marginal cost, firms grew about 15% more per annum compared with countries where public sector geographic information has cost-recovery pricing.[11] Positive growth comes one year after switching to marginal cost pricing but growth is higher with a two-year lag. Changes in policy captured in the study included reducing prices of digital cadastral maps, and free web portals for cadastral or spatial data. SMEs benefit most from cheaper geographical information, although marginal cost pricing has not generated notable growth among large firms. According to the study, switching to marginal cost pricing of PSI substantially lowers SME barriers to enter new GI-based product and service markets.

3.4.2. Australia

An Australian study of the economic impacts of spatial data and high precision positioning systems suggested that they significantly increase productivity across a range of sectors (ACIL Tasman, 2008, Australian Government, 2009). The study quantified economic impacts in the 2006-07 fiscal year, estimated the cost of inefficient access and identified factors causing inefficiencies, and considered prospects for economic, social and environmental development. The report was based on detailed case studies in 22 sectors (including agriculture, forestry, fisheries, property and business services, construction, transport, electricity, gas and water, mining and resources, resource exploration, communications, government). For each sector, two conservative scenarios of direct impacts were estimated. These were then applied to a large-scale computable general equilibrium model to calculate aggregate impacts.

It is conservatively estimated that spatial information industry revenue in 2006-07 could have been AUD 1.37 billion and gross value added around AUD 682 million. The economic footprint is considerably larger as spatial information activities are also in government, non-profit research and other industries. Furthermore, spatial information is used across the economy where it has a direct productivity impacts. General equilibrium modelling gave a

[11] Countries were: Australia, Austria, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Poland, Portugal, Spain, Sweden, United Kingdom, and the United States.

cumulative GDP gain of AUD 6.43-12.57 billion in 2006-7, equivalent to 0.6-1.2% of GDP (including the spatial information industry itself), increased household consumption by between AUD 3.57-6.87 billion on a cumulative basis, increased investment by AUD 1.73-3.69 billion on a cumulative basis, and had positive impacts on trade and real wages.

Other benefits were expected to increase significantly as spatial information systems are further integrated into the operation of water markets, carbon markets, natural resources management and environmental management and monitoring programmes. High using industries included property and services, construction, mining, transport and agriculture were seen to be major sources of the national economic benefit from spatial information. Further gains might be expected as spatial information penetrates other large sectors including retail and trade, recreation and other services, and finance and insurance (see also Koski, 2011).

The costs of inefficient access were estimated to have reduced the direct productivity impacts in certain sectors by 5-15%. It is estimated that GDP and consumption could have been around 7% lower in 2006-07 than they might otherwise have been. Increased adoption and new applications in existing sectors could increase the direct impacts in some sectors by up to 50% over the medium term. However a larger impact is likely to be in new applications, and the scale of the future contribution will be driven by the policy environment for data access and skills development, and increased awareness in government and industry.

Access to Australian spatial data has also been studied in detail more recently (see Houghton, 2011). This analysis shows that from 2002 Australian spatial data has been freely available or available at marginal cost of transfer and there are no restrictions on commercial use or value-added activities with considerable related benefits. Welfare effects of free re-use are convincing, as well as the efficiency gains from saving transaction costs.

3.4.3. Netherlands

Analysis in the Netherlands (Castelein, *et al.*, 2010) aimed at defining the geo-information sector and measuring turnover, employment and market size. The economic value of the Dutch geo-information sector in 2008 was estimated at EUR 1.4 billion, or 0.23% of national GDP, and the Dutch geo-information sector is a fast developing sector with high potential. The work was inspired by earlier US research suggesting that the geo-technology sector is likely to be one of the three most important employment growth sectors and drew on Australian (ACIL Tasman, 2008) and New Zealand (ACIL Tasman, 2009) studies.

The analysis is based on a detailed survey of the geo-information sector combined with data from government and research geo-information activities working on primary geo-information products and services. The economic value would be greater if primary geo-information activities in other sectors such as real estate, transport and logistics, banking and the ICT sector were included. The low share of consumer market activities in the survey data also suggests that estimates are conservative.

'Traditional' geo-activities such as cartography, geodata management and GIS analysis were the most common private geo-information products and services. The main activities of government employees were data collection, management and distribution, followed by systems design, field collection and management activities. In 2008, around EUR 100 million was spent on R&D on geo-information products and services with around 45% in the public sector and 55% in the private sector. The authors concluded that their definition and survey methodology provide a good basis for measuring the geo-information sector.

3.4.4. New Zealand

Land Information New Zealand and others commissioned a report on spatial information in the NZ economy in 2009 (ACIL Tasman, 2009). The study was based on detailed sector analysis, and productivity benefits were estimated using a large-scale, computable general equilibrium model. The report estimated that real GDP increased by NZD 1.2 billion in 2008 through productivity-related gains as a result of the increasing adoption of modern spatial information technologies since 1995. This is equivalent to slightly more than 0.6% of GDP. Impacts would have been higher if resource availability had been estimated. The report points out that spatial information has innumerable applications, and that impacts could increase as it spreads to sectors that are not yet major users. Other non-productivity benefits linked to the increasing use of spatial information are probably worth a multiple of this.

One of the main challenges was seen to be freeing up access to data, so that users can find new ways of exploiting spatial information. A range of barriers to adoption have constrained uptake and limited the ability to reap extra benefits. Past and current barriers include problems in accessing data, inconsistency in data standards, and a general lack of skills and knowledge relating to modern spatial information technology. Had these barriers been removed it is estimated that there would have been nearly NZD 500 million in extra productivity-related benefits, generating at least NZD 100 million in government revenue.

A government intervention representing the best 'value-for-money' is the release of basic government spatial data, i.e., enabling access at marginal cost, which would be zero where it is made available over the Internet. A broader intervention building an effective Spatial Data Infrastructure would lead to the highest overall benefits. The report estimates the benefit-to-cost ratio of such an intervention to be at least 5:1 where extra costs are NZD 100 million and only one years' benefits counted.

3.4.5. United Kingdom

In the United Kingdom, a "supply-side" study estimated market size and growth potential for geographic information products and services (Coote and Rackham, 2008). The estimated market in 2007 was GBP 657 million, or 0.06% of GDP, not taking into account human resource capital in customer organisations. This comprised software GBP 152 million, services GBP 223 million, data GBP 254 million, and hardware GBP 28 million. The results were believed to be accurate to +/- 10%. In terms of future growth, the major drivers include the integration of GI into mainstream ICT applications, public sector initiatives such as INSPIRE and the Location Strategy, and emergence of consumer market geospatial tools.

A more recent study for England and Wales by the same group focused on local government applications (Coote and Smart, 2010, Schmid, 2010). It is considerably narrower in terms of geographical coverage but uses a computable general equilibrium model to assess overall benefits. The approach was similar to the Australian and New Zealand studies, with case studies and economic impacts of geospatial information used to estimate aggregate benefits at regional and national levels. Real output of local government was estimated to have increased by GBP 232 million as a result of productivity benefits associated with adoption of geospatial applications. GDP was estimated to be GBP 323 million higher in 2009, equivalent to around 0.02% of GDP. This was projected to grow rapidly to 2015 and with better policies the contribution would almost double to around 0.04% of GDP.

3.4.6. Summary

The geospatial industry and the impacts of geospatial information across the whole economy have received considerable attention, due to its major share in total PSI reuse and the importance of geospatial applications. The most comprehensive estimates of the impacts of geospatial information have been in Australia and New Zealand, where general equilibrium models were used to calculate aggregate economic impacts. The structural features of these two economies are somewhat different from those of the EU27 countries but the analytical approach provides a comprehensive basis for EU27 estimates.

In Australia it was conservatively estimated that annual spatial information industry revenues in 2006-07 could have been AUD 1.37 billion. The economic footprint of the spatial information industry is larger as there are spatial information activities in other parts of the economy. Based on general equilibrium modelling, aggregate economic impacts contributed cumulative GDP gains of AUD 6.43-12.57 billion, equivalent to 0.6-1.2% of GDP, with concomitant cumulative gains in other economic variables. Other benefits were expected to increase significantly with wider use. Similar results were obtained for New Zealand where economy-wide productivity-related gains due to uptake of spatial technologies increased 2008 GDP by NZD 1.2 billion, or slightly more than 0.6% of GDP.

Using a different approach, the economic value of the Dutch geo-information sector in 2008 was estimated at EUR 1.4 billion, or 0.23% of national GDP. This did not include geo-information activities outside of the core primary activities. In comparison, a more restricted United Kingdom "supply-side" assessment estimated the market for narrowly defined geographic information products and services to be GBP 657 million in 2007.

Cross-country research shows clear firm-level benefits from free or marginal cost pricing and changes in policy to provide freer and simpler access. Analysis of 14,000 firms in architectural and engineering activities and related technical consultancy services in 15 countries in 2000-2007 shows that in countries where public sector agencies provide fundamental geographical information for free or at maximum marginal cost, firms grew about 15% more per annum compared with countries where public sector geographic information has cost-recovery pricing. The impacts of changes in policies towards easier and cheaper access were significantly positive, notably for SMEs.

4. ESTIMATING EU27 MARKET SIZE AND OTHER VARIABLES

4.1. Market size and aggregate economic impacts

4.1.1. Estimating market size and aggregate economic impacts from Australian spatial data

Based on Australian estimates of spatial information industry revenues of 0.15% of GDP in 2006-07 and broader accumulated impacts of spatial information applications equivalent to 0.6-1.2% of GDP (ACIL Tasman, 2008), the estimating approach was simply to pro-rate these GDP-based estimates to give estimates of spatial information for the EU27. For the simple estimating method see Vickery, 2011, using data from EUROSTAT, 2011.[12] The EU27 spatial information industry size is EUR 17.7 billion, and the expanded size of the economic impacts of the spatial information industry is in the range of EUR 70.85-141.7 billion. It is assumed that the geospatial market is about one half of the total PSI-related market, and that one-half of the PSI-related market comes from PSI itself. [13] The total value of the narrow EU27 PSI industry is thus of the order of EUR 18 billion, and the expanded

[12] The same pro-rata estimation technique was used in the MEPSIR study (MEPSIR, 2006), but in the opposite direction. In MEPSIR, the size of the total EU25 plus Norway market was estimated from detailed survey data, and the ratio of the PSI market to GDP used to estimate national markets.

[13] Spatial information makes up about one half of all PSI according to various aggregate estimates (see e.g. PIRA, 2000, MEPSIR, 2006), and it is assumed that around one-half of spatial information is derived from government sources, and that the same ratio applies to other areas of PSI. These estimates assume that there are similar systemic, interoperability and accessibility barriers for all kinds of PSI, and that PSI markets are broadly similar in terms of their incentives and barriers.

Spanish data provides somewhat different estimated proportions, but gives similar results in terms of the ratio of spatial information to the whole PSI-based market (see Proyecto Aporta, 2011).

economic impacts from the use of PSI are of the order of EUR 70-140 billion. These estimates assume that there are similar systemic, interoperability and accessibility barriers for all kinds of PSI, and that EU27 PSI markets are structurally and operationally similar.

The same pro-rating procedure was repeated using national and EU27 data for (a) computer services spending, and (b) ICT spending by government (WITSA, 2009). This gives estimates for the EU27 in 2006-07: (a) PSI market EUR 27.0 billion (computer services spending, WITSA, 2009), (b) EUR 25.8 billion (ICT spending by government, WITSA, 2009). Averaging these data with the GDP-based estimates gives a EU27 PSI market of EUR 23.25 billion. The expanded economic impacts from the use of PSI for the EU27 are: (a) EUR 126.9–248.1 billion, (b) EUR 120.9–236.4 billion. Averaging these results with the GDP-based estimates above gives an EU27 expanded economic impacts estimate of EUR 106.2–208.7 billion, with a mid-point of EUR 157.5 billion.

4.1.2. Estimating market size from the Netherlands geo-information sector

The core geo-information sector in the Netherlands was estimated to be 0.23% of GDP in 2008 (Castelein, *et al.*, 2010), and these estimates were used to calculate EU27 values. Applying the same assumptions as for Australia above, GDP-based estimations give a EU27 geo-information sector of EUR 27 billion and a PSI-based market of EUR 27 billion. The wider economic impacts were not estimated.

The same pro-rating procedure was repeated using national and EU27 data for (a) computer services spending, and (b) ICT spending by government (WITSA, 2009). This gives estimates for the EU27 in 2008 of: (a) PSI market EUR 42.1 billion (computer services spending, WITSA, 2009), and (b) EUR 28.7 billion (ICT spending by government, WITSA, 2009). Averaging these estimates with the GDP-based estimate above gives a EU27 PSI market of EUR 32.6 billion in 2008.

EU27 PSI market estimate: Averaging the EU27 market estimate derived from Netherlands data (EUR 32.6 billion) with the EU27 estimate derived from Australian data (EUR 23.25 billion) gives an estimated PSI market around EUR 27.9 billion in 2008. Various studies have reported growth rates for PSI markets in the range of 6-18% per year (Castelein, *et al*., 2010, Coote and Smart, 2010, Fornefeld, 2011, MICUS, 2009). Taking 7% per year as a lower estimate, the EU27 PSI market would have grown to around EUR 32 billion by 2010 provided that it grew at earlier rates and was not dramatically affected by the recession.

4.1.3. Estimating aggregate economic impacts from NZ spatial information

Productivity-related benefits from the use and re-use of spatial information in New Zealand were approximately 0.6% of GDP (NZD 1.2 billion) in 2008. Removing barriers and improving the infrastructure could have added another NZD 500 million (ACIL Tasman, 2009). Applying these data to EU27 2009 GDP (EUROSTAT, 2011), gives approximately EUR 71 billion in productivity-related gains in 2009 based on improvements in the use of spatial information, plus a potential addition of a further EUR 28 billion if barriers were removed and the infrastructure improved. This makes about EUR 99 billion in total. This is probably an underestimate given the rapid growth rates reported for this industry.

Using GDP-based estimates and the same assumptions as above, the size of EU27 benefits from PSI are around EUR 70 billion, with an extra EUR 25-30 billion if barriers are removed and the data infrastructure improved. The same pro-rating procedure was repeated as for Australia using national and EU27 data for (a) computer services spending, and (b) ICT spending by government (WITSA, 2009). This gives estimates for the EU27 in 2008 of the expanded economic impacts (productivity gains) from the use of PSI for the EU27 of: (a) EUR 154.8 billion (computer services spending, WITSA, 2009), and (b) EUR 159.7 billion

(ICT spending by government, WITSA, 2009). Averaging these data with the GDP-based estimates above gives an estimate for the EU27 of EUR 128.5 billion.

EU27 aggregate economic impacts estimate: Averaging the EU27 estimate derived from Australian data (EUR 157.5 billion) with the EU27 estimate derived from New Zealand data (EUR 128.5 billion) gives estimated aggregate economic impacts around EUR 143 billion in 2008. There could be approximately EUR 56 billion of additional gains if barriers were removed and the data infrastructure was improved as described in the New Zealand study. That is, if PSI was opened up, barriers were removed and the infrastructure worked better, aggregate direct and indirect economic benefits for the EU27 economy could have been of the order of EUR 200 billion (1.7% of GDP) in 2008, and more in 2010.

4.1.4. Estimating total welfare gains from open access to PSI in the UK

Estimates of gains from opening up access to digital, non-personal, public sector information are based on estimates for the UK (Pollock, 2011a). The estimated ranges were pro-rated to the EU27 economy to give an approximation of the size of the annual gains from moving from an average cost / cost recovery pricing model to marginal cost pricing for digital public sector information (for the simple estimating method see Vickery, 2011, GDP data from EUROSTAT, 2011). The values for the EU27 for 2009 can be estimated to be EUR 38.1–50.8 billion for the upper range of estimates, or alternatively EUR 13.5–16.9 billion for middle range estimates. These ranges assume that the pricing models across the EU27 are similar to the United Kingdom (average cost / cost recovery pricing in many cases) and the average structure of public sector information and related markets are similar.

The same pro-rating procedure was repeated as for Australia using national data for (a) computer services spending, and (b) ICT spending by government (WITSA, 2009). This gives the following estimates of total welfare gains of moving to open access models across the EU27 in 2009: (a) EUR 29.1–38.9 billion for the upper range of estimates and EUR 10.4–12.9 billion for the middle range estimates (computer services spending, WITSA, 2009), (b) EUR 38.8-51.7 billion for the upper range estimates and EUR 13.8-17.2 billion for the middle range estimates (ICT spending by government, WITSA, 2009).

Averaging with the GDP-based estimates gives an upper range for EU27 welfare gains of EUR 35.3-47.1 billion, and a value of EUR 40 billion is adopted in this survey.

4.1.5. Summary

The results in this part of the survey are based on using the most viable aggregate studies available to estimate plausible values for the PSI market, potential gains from freeing up access, and wider economic impacts that could accrue from using PSI across the economy. National estimates were pro-rated to give EU27 totals based on the averages of national : EU27 ratios for GDP, computer services spending, and ICT spending by government.

In the case of estimates based on geospatial data, it is assumed that the geospatial market/impact is about one half of the total PSI-related market/impact, and that one-half of the PSI-related market/impact comes from government PSI. Both assumptions give conservative estimates. Geospatial information may be considerably less than one half of all PSI, and governments are the basic source of information for probably more than one-half of all PSI-like activities. Furthermore, estimated values within and across different sources were reasonably comparable, suggesting that the averages in this part of the review provide reasonable low estimates of the economic features of PSI markets and the impacts of PSI use.

The EU27 PSI market was estimated to be around EUR 27.9 billion in 2008 based on values for the Netherlands and Australian geospatial markets. The EU27 PSI market could have grown to EUR 32 billion by 2010 provided that PSI markets continued growing at earlier rates and were not dramatically affected by the recession.

Aggregate EU27 economic impact of PSI-related applications and use was estimated to be around EUR 143 billion in 2008 based on Australian and New Zealand geospatial impacts. There could have been approximately EUR 56 billion of additional gains if barriers to use were removed, skills enhanced and the data infrastructure improved. Estimated values are comparable for the two countries, and the averages are intuitively reasonable. It is however urged that similar studies using general equilibrium modelling or similar techniques be undertaken in European countries to confirm these results. It is further suggested that estimates based on studies of consumer surplus be undertaken to provide a picture of consumer benefits from better access to and use of PSI.

EU27 welfare gains from moving from an average cost / cost recovery pricing model to marginal cost pricing for digital public sector information are estimated to be EUR 35.3-47.1 billion in the upper range, and EUR 40 billion is adopted in this survey. Although the UK PSI access and licensing system is somewhat different, the positive impacts of removing barriers to access are likely to be realistic across the EU27, due to widespread disincentives to use, lack of information, poor interoperability etc. that have stifled easy use of PSI.

4.2. Other estimates

4.2.1. Other estimates of market size

Market size estimates were also undertaken on the basis of other studies, but the original data is less suitable for the estimating method used. Estimates based on the German geo-information market give a narrow GDP-based EU27 PSI market of around EUR 8.3 billion (from Fornefeld, 2009, 2011). Estimates based on the Spanish "infomediary" sector give a narrow GDP-based EU27 PSI reuse market of core direct re-users of around EUR 6.7 billion (from Proyecto Aporta, 2011). Estimates based on a UK supply-side assessment of the geographic information market give a GDP-based EU27 market size of EUR 7.2 billion (from Coote and Rackham, 2008). All of these are likely to be under-estimates due to prior difficulties or costs in obtaining public sector data.

4.2.2. Estimates of the value of time savings

The value of improved time allocation can be estimated from data for Norway where a minimum of 2 hours per citizen per year could be saved through better access to public information (Norway, 2011). A simple GDP-based pro-rata calculation for the EU27 gives EUR 1.395 billion for the annual value of individual time saved.

4.2.3. The European environmental impact assessment market

European Law requires environmental impact assessments and strategic environmental assessments. The European assessment market has been estimated to be EUR 1 billion per year for national assessments (Craglia, *et al.,* 2010). Improving accessibility of the information required could save up to EUR 200 million per year for these assessments. Including sub-national assessments values could be 10 times higher, i.e. a EU27 market of EUR 10 billion, with potential savings from better information of EUR 2 billion.

4.2.4. Improved access to research results

Estimates of the benefits from improved access to scientific research results are included, although they are not directly comparable with market size and impacts estimates (Houghton 2009, OECD, 2005). The potential increase in returns to R&D due to Open Access are estimated using a modified Solow-Swan model (Houghton and Sheehan, 2009).

With a 20% return on R&D and a 5% increase in accessibility and efficiency from Open Access (both very conservative assumptions), recurring annual gains from the effect of one year's EU27 R&D are of the order of EUR 4.85 billion for Gross Expenditures on R&D (GERD) and EUR 1.15 billion for Higher Education Expenditures (HERD) (Table 2). Total EU27 public expenditure on R&D (GOVERD + HERD) in 2009 was EUR 87.275 billion, giving EUR 1.79 billion recurring annual benefits from open access. If a shift to open access publishing is permanent these gains can be converted to growth rate effects.

Table 2. EU27: Increase in returns to R&D due to increases in accessibility and efficiency arising from Open Access, estimates for 2009

EU27					
Gross Expenditure on R&D	Rate of return to R&D				
EUR 236,553 million	20%	30%	40%	50%	60%
Per cent change in accessibility and efficiency	Recurring annual gain from increased accessibility & efficiency (million)				
1%	951	1,426	1,902	2,377	2,853
2%	1,911	2,867	3,823	4,778	5,734
5%	4,849	7,274	9,699	12,123	14,548
10%	9,935	14,903	19,870	24,838	29,806
Higher Education Expenditure on R&D	Rate of return to R&D				
EUR 56,024 million	20%	30%	40%	50%	60%
Per cent change in accessibility and efficiency	Recurring annual gain from increased accessibility & efficiency (million)				
1%	225	338	450	563	676
2%	453	679	905	1,132	1,358
5%	1,148	1,723	2,297	2,871	3,445
10%	2,353	3,530	4,706	5,883	7,059

Source: Houghton, personal communications, 2011, 2012, EUROSTAT, 2011.

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Are Newly Exporting Firms more Innovative? Findings from Matched Spanish Innovators

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Abstract:
The prevalence of Internet-based sales was highlighted by the World Bank (Ferro, 2011) associating state-of-art technology with exporters. We use propensity score kernel matching with difference-in-differences to reveal export selection and evidence of 'technology upgrading' through higher exporter innovation rates.

Keywords: exporting, innovation, Propensity-Score Matching, technology-upgrading

JEL classification: F14, F23, O3

1 Background

In a study of the hypothesized productivity dip for firms quitting export markets, Girma et al. (2003) observe a surprising persistence in productivity growth rates for such exporters and conclude that [1]: '.....the benefits from exporting are due to exposure to *best practice technology* (our italics), rather than scale economies or competition effects' (pp.186)

The reasoning is based on symmetry: exporters stand to make productivity gains vs. non-exporters as their costs get spread over expanded output. Having quit their export markets, these efficiency gains should disappear unless caused by long-lasting technology improvements.

Is there direct evidence that firms improve their way of doing things (technology) as a result of exporting? While there is recent evidence on how pre-exporting firms upgrade their *products* by investing more in quality or R&D (Iacovone and Javorcik, 2010; Bustos, 2011), the literature is largely silent on *technology* upgrading (i.e. *process* innovations).[2] Yet, the positive productivity growth of newly exporting firms or adjustments to keep costs competitive or foreign customers satisfied, hints at changes in how these firms produce and sell their products before and after the transition to exporting (e.g. Delgado et al., 2002; Clerides et al., 1998; Lachenmaier and Wößmann, 2006)

But does upgrading cause firms to select into export markets? And do newly exporting firms subsequently adjust their products and processes? What is the timing of any upgrading? These questions are what we set out to answer.

To address these questions we uniquely apply a combination of propensity score matching with difference-in-differences to a cohort of newly exporting Spanish firms in 2006.[3] Our dual methodology follows Girma et al., allowing us tackle both endogenous exporting where 'better' firms select into exporting ('learning-to-export' /'product upgrading') whilst neutralizing the bias of common macroeconomic shocks (difference-in-differences).[4] Additionally, we sidestep problems of sunk exporting costs flagged up in other studies (Bustos, 2011; Caldera, 2010).

Unsurprisingly, we find that the most productive and high-tech firms select into exporting. Uniquely, our kernel estimations reveal that newly exporting firms are 11 percent more likely than non-exporters to report changes in their manufacturing processes in the year that they switch to exporting. One year later, these differences disappear.

Our paper is organized as follows. The next section summarizes the methodology. Then follows a short description of our data, our analysis and finally a concluding section.

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[1] Wagner (2002) and Girma et al., (2004) both show the positive productivity impacts for new exporters

[2] The exception being Caldera (2010) who uniquely estimates selection into exporting as a function of innovation in a framework which recognizes the potential endogeneity of innovation. However, she does not distinguish between product and process innovation in this instrumented analysis.

[3] Wagner (2002) and Girma et al. (2004) both apply matching methodologies to discern ex-post productivity changes for exporting firms

[4] See Blundell and Costa Dias (2000) for an excellent review of this approach.

2 Methodology

In attempting to look at the innovation/exporting nexus, we face the ubiquitous selection problem where:

'If today's export starters are 'better' than today's non-exporters (and have been so in the recent past), we would expect that they should, on average, perform better in the future even if they do not start to export today'. (Wagner, 2002, p288)

Here a lack of statistically relevant and intuitively compelling instruments for a firm's innovation makes it difficult to deal with self-selection unless we isolate from our sample the group of newly exporting and non-exporting firms. Following Heckman et al. (1997) we can calculate the average effect of exporting as:

$$E\{y^1_{t+s} - y^0_{t+s} | EXPORT_{it} = 1\} = E\{y^1_{t+s} | EXPORT_{it} = 1\} - E\{y^0_{t+s} | EXPORT_{it} = 1\}$$

where the last expression term is needed in order to infer the innovation propensity rates for the group of firms that did not switch to exporting. To get this term, we match each firm that switched to exporting with a derived counterfactual, constructed over the distribution of non-exporting firms. We apply the STATA propensity score routine, *psscore*, based on Rosenbaum and Rubin (1983). Specifically, the first-stage Probit captures the likelihood that firms become exporters based on observable pre-exporting attributes of the firm (firm size and age, R&D status, technology status and productivity). Both control (never-exporters) and treatment (newly exporting firms) firm groups are then assigned to strata according to the propensity score and the balancing property checked for each stratum.[5]

In our model, productivity is measured alternatively as sales per worker and total factor productivity, size as number of employees, age as the number of years a firm has been in existence, R&D as a dummy variable for whether a firm conducts R&D and the industry fixed effect is a technology index where higher values denote a high-tech industry.[6] Finally, innovation is broadly defined binary variable denoting the introduction of products/ processes which are new to the firm.

In estimating innovation rates, we opt for the STATA *attk* procedure proposed by Heckman et al. (1998) which builds on traditional pairwise matching by using the full distribution of firms falling

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[5] We assume that the assumption of conditional independence holds: i.e. that firms in the control and treatment group largely select into exporting based on these observable pre-exporting attributes. Specifically, their differing ability to bear sunk exporting costs. The implication being that both productivity and firm size play a key role in informing the decision (Wagner, 2002; Bernard and Jensen, 1999; Clerides, Lach and Tybout, 1998) and firm age (Barrios, Görg and Strobl, 2003). R&D capacity (Caldera, 2010) should also play a role in co-determining the export decision

[6] Total factor productivity was used as our preferred productivity measures in earlier estimations. Although showing a positive effect on selection into exporting (as expected), estimates were biased for having overrepresented large firms who reported values for capital stock

under common support in the pre-exporting Probit.[7] The nonparametric matching estimator constructs a match for each newly exporting firm using a kernel-weighted average over multiple non-exporting firms. Assuming that the common support conditions hold, we now have a consistent estimator of the propensity of exporter switchers to innovate, had they not decided to export: $E\{y^0_{t+s}|EXPORT_{it} = 1\}$

Finally, we apply a further correction is to difference out time varying external shocks (e.g. exchange rate movements) by applying Difference-in-Differences to the innovation outcomes.

3 Data

The data we use is for newly exporting firms in 2006 for which we have information on innovation outputs. The firms are extracted from the annual *Spanish Business Strategy Survey* (SBSS), a public database containing survey data for a representative panel of manufacturing firms with at least 10 employees. Pre-exporting data for 2005 contains key correlates for export market entry. Also available is data for 2007, the year following entry.

Important for propensity score matching is a valid control group for the 3 yearly cross-sections. There are just over 600 of such non-exporting firms (non-exporting in 2005, remaining non-exporting in 2006-2007). This means that for 2006 we record 38 newly exporting firms over a total of 646 non-exporters. This breakdown (circa 6 percent) is in line with Girma et al. (2004) who, using data for UK firms, similarly report that only 6 percent of non-exporters became new exporters. This fact they attribute to sunk exporting costs.

Consistent with the evidence that exporting firms are 'better' than their non-exporting peers, Table 1 shows how the newly exporting cohort in the year before they commenced exporting. They are older, larger, are more likely to carry out R&D, belong to a high-technology sector and have higher labor productivity. Also clear is that newly exporting firms are more likely to report an innovation outcome in the period following the transition to exporting.

4 Analysis

The descriptive statistics reveal differences between the control and treatment groups. But are these differences significant? For this we first conduct a simple Probit with a dummy variable denoting whether the firm transitioned to exporting in 2006.[8] Consistent with Bustos (2011) there is a significant correlation between the switch to exporting and the appearance of newly introduced products / manufacturing processes contemporaneous with the switch. Uniquely, we also find that the

[7] We use the Stata default Gaussian kernel with bandwidth 0.06. Smith and Todd (2005) give an excellent summary of this and other matching techniques. An advantage of this matching technique is that it reduces the asymptotic mean squared error found in traditional pairwise matching.

[8] For a fuller discussion of the Probit results see accompanying working paper by Hanley and Monreal-Pérez (2011)

positive effect carries through to the year following the transition, *t+1*. Regarding marginal effects for innovations in *t+1*, we see some similarities with the descriptive statistics reported in Table 1. Setting baseline probabilities at the average values of the continuous variables and setting all dummy variables to 0, we can report the impacts of a move to exporting on a firm's innovation. For 'export switchers' the probability of product innovation rises to 7 percent from a baseline probability of 2.9 percent. The corresponding change for process innovation is an increase to 45.7 percent from a baseline of 21.8 percent.[9] Clearly, new processes are introduced with greater regularity than are new products.

Clearly, the simple Probit is not set up to deal with endogenous exporting. We therefore turn to the estimates from the propensity scored and matched kernels, reporting first the related balancing tests in Table 3.[10] The 465 'never-exporters' and 38 new exporters are first allocated to 4 blocks by the STATA procedure *psscore* on the basis of their employment size, age, R&D intensity, productivity and technology level. Balancing implies that the group ('never-exporters' and 'export switchers') averages for selection variables such as R&D intensity in each block are statistically equivalent. Only once the 4 blocks have been satisfactorily balanced can we report the estimates for the first-stage Probit selection in Table 3 followed by the kernel estimates in Table 4.

From the first-stage probit we see firm evidence of firm selection into exporting, most notably in the case of productivity (Table 3). Here, the most productive firms who can afford the sunk costs of exporting are also the most likely to switch to exporting. Similarly, firms from the highest-tech sectors. R&D which also played a positive and significant role in the bivariate Probit, remains positive as expected but insignificant.

Turning to the kernel estimation in Table 4, we see little evidence of returns to a firm's innovation from exporting. The exception being an 11 percent increase in the rate of process innovations for newly exporting firms in the year that they transition to exporting. It appears therefore, that when we decompose the innovation-exporting nexus into the selection effects (i.e. exporting propensity conditioned on pre-export attributes) and contemporaneous/ex-post innovation, there is little residual variation between the exporting and non-exporting group.

5 Conclusions

What are the policy implications of our findings? Most interesting is the significantly higher incidence of production upgrading (improved manufacturing *processes*) in the lead up to, and contemporaneous with, the move to export markets. Specifically, a 11 percent higher innovation rate. Not so for the impact of exporting on a firm's product upgrading. We confirm Iacovone and Javorcik's (2010)

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[9] We recall from the descriptive statistics (see Table 1) the values were 24 and 42 percent for newly exporting firms.

[10] The Stata balancing rule is at the 0.01 level of significance.

finding that new 'product discoveries' is a small numbers game. Overall, only 6 percent of firms record these introductions. The transition to exporting does not significantly increase this low incidence.

Why the differences in process innovation rates? Overseas exporters may have to align production to help meet the myriad needs of overseas markets and reduce costs (Lachenmaier and Wöβmann, 2006). One example of this realignment: The introduction of Internet product-tracking helping new exporters to transact over a greater geographic and cultural distance, analogous to the production improvements recently highlighted by the World Bank (Ferro, 2011). Clearly, exporting 'raises the bar' for firms who may be forced into more imaginative and cost-efficient ways of producing and selling product overseas.

Table 1 Comparisons for export starters and non-exporters

	Non-exporters						
	t+1		*t-1*				
	product innovation	**process innovation**	**employees**	**age (years)**	**R&D carried out**	**high-tech sector**	**productivity**
mean	0.05	0.19	64	20	0.09	0.54	2.86
sd	0.22	0.39	234	16	0.29	0.46	0.55
median	0	0	22	16	0	0.41	2.82
N	646	646	474	467	473	642	474
	Newly exporting firms						
	t+1		*t-1*				
mean	0.24	0.42	108	27	0.18	0.71	3.13
sd	0.43	0.50	167	24	0.39	0.65	0.57
median	0	0	27	20	0	0.43	3.17
N	38	38	38	37	38	38	38

Table 2 Selection into Exporting (Propensity Scoring)

1st stage Probit: Firm switches to exporting (Stata '*psscore*')		
	coefficient	SE
Small firm	0.16	(.247)
Age:		
1st tercile	-0.33	(245)
2nd tercile	-0.26	(.242)
R&D carried out	0.30	(.271)
Productivity:		
1st tercile	-0.50**	(.234)
2nd tercile	-0.56***	(.220)
High-tech sector:		
1st tercile	-0.42*	(.219)
2nd tercile	-0.66***	(.239)
constant	-0.67	
Observations		503
Pseudo R2		0.0849
Percentiles (Propensity score):		
P50		0.05
P25		0.03
P75		0.09
Final # blocks		4

Table 3 Exporting and innovation (Kernel Matching)

Second stage: Kernel Treatment with Difference-in-Differences (Stata command 'attk')		
	Average treatment effect of switch to exporting	SE
	Process innovation	
t	0.11*	0.068
t+1	0.065	0.119
	Product innovation	
t	0.02	0.05
t+1	-0.093	0.075

Notes: All estimations applying common support assumption bootstrapped standard errors, common support assumption applied for all kernel estimates

Acknowledgements

We would like to thank the Fundación SEPI and Michaela Rank for assistance with the data. Also to Sourafel Girma for his unstinting support with the analysis.

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Are ICT users more innovative? Analysing ICT-enabled innovation in Manufacturing and Services

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Abstract

This paper provides a comparative analysis of the impacts of information and communication technologies (ICT) on the likelihood of innovating among firms in Manufacturing and Services. For this purpose I use a rich data set of Norwegian firms covering the period 2002–2008. The results are consistent with ICT having a positive impact on firm innovation activity, in particular on marketing and organisational innovation and on innovations in services. These results hold even after taking into account persistency of innovation. However, I did not find any evidence that ICT use increases the capability of a firm to cooperate with other firms/institutions in their innovation activity nor that ICT intensive firms have higher capacity to introduce "more innovative" (new-to-the-market) products. These results suggest that ICT enable rather adoption of innovation than developing of truly new products.

Key words: Innovation, ICT, Persistency of innovation, Manufacturing and Services

1. Introduction

Business innovation is regarded as a potentially important driver of productivity growth both at the firm and at the national level. At the micro level, business innovation has the potential to increase consumer demand through improved product or service quality and simultaneously decrease production costs (see, for instance, Crépon, Duguet and Mairesse, 1998; Griffith *et al.*, 2006; Parisi, Schiantarelli and Sembenelli, 2006). More importantly, strong business innovation at a macro level increases multifactor productivity thus lifting international competitiveness, economic growth and real per capital incomes (see, for instance, Van Leeuwen and Klomp, 2006). Therefore, it is of great interest to businesses and policy makers alike, to identify those factors which stimulate innovation and to understand how these factors interact.

Information and communication technology (ICT) is one of the most dynamic areas of investment as well as a very pervasive technology. The possible benefits of ICT use for a firm include among others savings of inputs, general cost reductions and greater flexibility of the production process. This technology may also stimulate the innovation activity in the firm leading to higher product quality and creating of new products or services. Its use has the potential to increase innovation by improving communication possibilities and speeding up the diffusion of information through networks. For example, technologies that allow staff to effectively communicate and collaborate across wider geographic areas will encourage strategies for less centralized management leading to organisational innovation. Previous analysis confirms that ICT play an important role for firm performance, *e.g*. Brynjolfsson and Hitt (2000), Gago and Rubalcaba (2007), Crespi *et al.* (2007), Van Leeuwen (2008), OECD (2004) and Polder *et al.* (2009). These studies evaluating effects of ICT use and innovation on productivity, however, do not directly focus on the link between ICT use and innovation.

Both R&D and ICT investment have been identified as sources of relative innovation underperformance in Europe vis-à-vis the United States. For example, Van Ark et al. (2003) point to the differences in industrial structure, specifically the smaller ICT producing sector as the main cause of lower productivity growth in Europe. The same argument use O'Sullivan (2006), Moncada-釘Paternò-Castello et al. (2009) and Hall and Mairesse (2009) in explaining lower R&D intensity in Europe. It is also true that the R&D investment and ICT investment shares in GDP by firms in all sectors are lower in Europe than in the United States and the ICT gap is somewhat larger than that for R&D (see Figure 1 in Hall et al., 2012). These findings raise a question about necessity of stimulating of ICT investments in European countries. At the same time Norway, as other Scandinavian countries, is among forwards in implementation of ICT technologies.[1] This fact is one of the reasons why the current paper directs its attention to data on Norwegian firms. Could more intensive ICT-use in the forms stimulate their innovation activity?

The aim of this study is to assess the effects of ICT as an enabler of innovation in Norwegian firms. Do effects differ for different types of innovations? Four types of innovations are under investigation: a new (or improved) product, a new (or improved) production process, an organisational innovation and a new marketing method. One obviously important factor behind innovations is R&D, but it is not the only one. The availability of high–skilled workers is another

[1] Almost all firms in 2006 ICT-survey (more than 97 %) had access to Internet and more than 70 % of firms had access to broadband.

important factor. Both these factors I control for in the analysis. Moreover, the effects of ICT use can vary depending on the firm's size and industry. To investigate this variation I control for the firm size and provide the analysis for manufacturing firms and firms in services separately.[2]

The research consists of a set of testable hypotheses about the effects of ICT use on innovation, grouped under 3 themes:

- Innovation capabilities;
- Trajectories in innovation;
- Cooperation in innovation.

For the analysis, I use Norwegian microdata covering firms included in the 2004, 2006 and 2008 innovation surveys. Innovation surveys contain information on the inputs and outputs of firms' innovative activities. By supplementing these data with constructed ICT capital measure, ICT-use indicators and information from different registers, I obtain three series of cross sections partly repeated.

The paper is organized as follows. Section 2 summarizes the main findings by previous studies. Section 3 presents the dataset and variables used in this paper while Section 4 discusses the research questions and the methodology. Section 5 presents the results and Section 6 draws the main conclusions and makes suggestions for further work.

2. Previous findings

Several previous analyses confirm that ICT plays an important role in business success. One of the first attempts to estimate the role of IT assets on the firm performance in the form of productivity was made by Brynjolfsson and Hitt (1995). Since then a broad variety of empirical studies has emerged exploring the impacts of ICT on the firm performance.[3] Most of these studies employ a production function framework to estimate the elasticity of output with respect to ICT capital, controlling for the amount of other inputs among them innovations. However, none of them focus on the direct link between ICT use and innovation.

As Koellinger (2005) puts it "ICT makes it possible to reduce transaction costs, improve business processes, facilitate coordination with suppliers, fragment processes along the value chain (both horizontally and vertically) and across different geographical locations, and increase diversification". Each of these efficiency gains provides an opportunity for innovation. For example, technologies that allow staff to effectively communicate and collaborate across wider geographic areas will encourage strategies for less centralized management leading to organisational innovation.

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[2] OECD (2008) concludes that insofar as innovation activity is weak in Norway, the weakness seems to be in the manufacturing sector, i.e., there is not much R&D spending, particularly in high-technology manufacturing, and very low sales of new-to-market products in this sector. Hence, it is important to provide a separate analysis for different sectors.

[3] See, for example, recent studies by Atrostic and Nguyen (2002), Biscourp et al. (2002), Bresnahan et al. (2002), Brynjolfsson and Hitt (2003), Crespi et al. (2207), Hall et al. (2012), Hempell (2005) and OECD (2004).

ICT enable also closer links between businesses, their suppliers, customers, competitors and collaborative partners, which are all potential creators of ideas for innovation (see Rogers, 2004). By enabling closer communication and collaboration, ICT assists businesses to be more responsive to innovation. For example, having broadband Internet, web presence and automated system linkages, assists businesses to keep up with customer trends, monitor competitor's actions and get rapid user feedback, thereby assisting them to exploit opportunities for all types of innovations.

Gretton, Gali and Parham (2004) suggest following two reasons why business use of ICT encourages innovative activity. Firstly, ICT is a “general purpose technology” which provides an “indispensable platform” upon which further productivity-enhancing changes, such as product and process innovations, can be based. For example, a business which establishes a web presence sets the groundwork from which process innovations, such as electronic ordering and delivery, can be easily developed. In this way, adopting general purpose ICT makes it relatively easier and cheaper for businesses to develop innovations. Secondly, the spillover effects from ICT usage, such as network economies, can be sources of productivity gains. For example, staff in businesses which have adopted broadband Internet are able to collaborate with wider networks of academics and international researchers more closely on the development of innovations.

Another line of literature motivates the importance of ICT for organisational innovation (see Brynjolfsson and Hitt, 2000, for a survey and Bloom *et al.*, 2009, for a recent study). Case studies reveal that the introduction of information technology is combined with a transformation of the firm, investment in intangible assets, and of the relation with suppliers and customers. Electronic procurement, for instance, increases the control of inventories and decreases the costs of coordinating with suppliers, and ICT offers the possibility for flexible production: just-in-time inventory management, integration of sales with production planning, et cetera. A lack of proper control for intangible assets is seen as a possible candidate for explaining the differences in productivity growth that are observed between Europe and the US.

The available econometric evidence at firm level shows that a combination of investment in ICT and changes in organisations and work practices facilitated by these technologies contributes to firms’ productivity growth. For instance, Crespi *et al.* (2007) use Innovation surveys data for the UK and find a positive effect on firm performance of the interaction between IT and organizational innovation.

Gago and Rubalcaba (2007) find that businesses which invest in ICT, particularly those which regard their investment as very important, or strategically important, are significantly more likely to engage in services innovation. Van Leeuwen (2008) shows that e-sales and broadband use affect productivity significantly through their effect on innovation output. Broadband use, however, only has a direct effect on productivity if R&D is not considered as an input to innovation. This approach is further developed by Polder *et al.* (2009). Their study finds out that ICT investment is important for all types of innovation in services, while it plays a limited role in manufacturing, being only marginally significant for organisational innovation. Cerquera and Klein (2008) find controversially that a more intense use of ICT brings about a reduction in R&D effort in German firms. Hall et al. (2012) find for Italian manufacturing firms that ICT investment intensity is associated with product and organizational innovation, but not with process innovation, although not having any ICT investment is strongly negative for process innovation.

These few recent papers, which investigate R&D and ICT investment jointly, have produced conflicting results on ICT impact on innovation. In addition, the observed industry differences suggest that new ICT applications, such as broadband connectivity and e-commerce, are more important in services than in manufacturing. In this paper I explore the effects of ICT use on different types of innovation in manufacturing firms and firms in services separately.

3. Data and definition of main variables.

For the analysis, I use Norwegian microdata covering firms included in the 2004, 2006 and 2008 editions of Community Innovation Survey (CIS). These data are collected by Statistics Norway as a part of the annual R&D survey (we refer to them as *R&D statistics*). They contain information on the inputs and outputs of firms' R&D and innovative activities, e.g., how much firms spent on R&D in the year of survey, whether firms have introduced different types of innovation over the three-year period before each survey and whether they cooperated with other firms/institutions in their innovation activity. These data then are supplemented by ICT capital measure constructed from Structural statistics for the years 2002-2008 and by information on ICT use from 2002–2008 Business ICT surveys. The design of the Business ICT survey is to show how good the access to ICT is and how these technologies are used in the firms. Its questionnaire covers a broad range of activities such as access to and use of IT (PCs, workstations and Internet), use of online purchasing and sales, use of computer networks and network systems for the operation of orders and purchases, etc. Finally, by supplementing these data with information on firms and employees from different registers, I obtain three series of cross sections partly repeated.[4] Table 1 presents an overview of the main variables and the data sources applied in our study. The data sources are described in more detail in Appendix A.

Five types of innovations are under investigation: a new (or improved) product for the firm, *inpdt*, a new (or improved) product for the market, *inmar*, a new (or improved) production process, *inpcs*, an organisational innovation, *inorg*, and a new marketing method, *inmkt*. The definitions of these types of innovation comply with the recommendations of the Oslo manual (OECD, 2005). For definitions and examples of different types of innovations see Appendix B. Firms are asked in the Innovation survey to answer whether the firm has introduced a given type of innovation during the last three years with "yes" or "not" options. The corresponding dummy variables are measures of how innovative the firm is and are considered as dependent variables in the analysis.

The two variables, *coopf* and *coopu*, indicate if the firm cooperated with another firm (*coopf*) or with a university or research institute (*coopu*) when carrying out R&D during the last three years.

[4] About 60 percent of manufacturing firms and 70 percent of the firms in services are represented only once in the sample. I prefer keeping all available observations to the panel data construction in order to check for persistency of innovation. However, since I have repeated observations, I adjust standard errors for the intrafirm correlation.

Table 1.
Overview over variables and data sources.

Variable	Definition	Data source(s)
inpdt	1 if firm has introduced a new product for the firm in the given subperiod, 0 else	R&D statistics
inmar	1 if firm has introduced a new product for the market in the given subperiod, 0 else	R&D statistics
inpcs	1 if firm has introduced a new production process in the given subperiod, 0 else	R&D statistics
inorg	1 if firm has introduced an organizational innovation in the given subperiod, 0 else	R&D statistics
inmkt	1 if firm has introduced a new marketing method in the given subperiod, 0 else	R&D statistics
coopf	1 if firm cooperated with another firm in R&D in the given subperiod, 0 else	R&D statistics
coopu	1 if firm cooperated with a university or research institute in R&D in the given subperiod, 0 else	R&D statistics
R	R&D investment in the given year	R&D statistics
RK	R&D capital stock at the end of the given year	R&D statistics
rk	R&D capital intensity: *RK*/man-hour	R&D statistics/REE
ICTK	ICT capital stock at the end of the given year	Structural statistics
ictk	ICT capital intensity: *ICTK*/man-hour	Structural statistics/REE
skill	Share of man-hours worked by employees with academic education (18 or more years of education)	REE/NED

Note: Subperiod includes the last three years.

R&D investment, *R*, is annual R&D investment as it is reported in the questionnaire, deflated by the R&D deflator used in the national accounts[5]. The volume of R&D capital stock at the end of a given year *t*, RK_t, is computed by the perpetual inventory method (PIM) using all available data on R&D investments from R&D statistics.[6] R&D capital intensity, *rk*, is calculated as the R&D capital stock per man-hour, where the latter is the sum of all man-hours in the firm.

While definitions of innovation and R&D variables are pretty clear, the definition of ICT use by firm is much less clear. Computer use — the criterion often used in the earlier literature — is not a relevant criterion any longer, as virtually all firms in Norway use the computer.[7] Given the dominance of IP-based networks, one may reasonably argue that Internet use, particularly broadband Internet, is what makes a firm an ICT user. Some recent studies (e.g. Eurostat, 2008) have pointed out that the percentage of broadband connected employees is a better measure of the intensity of ICT use by firms. However, using of those measures of ICT requires linking the ICT

[5] More than 60 percent of total R&D expenditures are made up of labour costs.
[6] Although the final sample analyzed in this paper is restricted to the firms in 2004, 2006 and 2008 editions of CIS, I use all available data on the firm's R&D investments from the biannual 1993–1999 R&D surveys, and the annual 2001–2008 R&D surveys for R&D capital construction, if available for the given firm (for details on construction procedure see Cappelen et al., 2012).
[7] The usage of the computer is a quite common feature for Norwegian firms, i.e., more than 97 percent of the firms and more than 57 percent of the firms' employees in average used PC in 2002–2008.

survey and the Innovation survey at the firm level. Traditionally, surveys have been designed to estimate representative "averages" for the population and for selected groups of the population. In order to reduce the burden on the respondents, samples for different surveys have been designed as to reduce overlapping between them.[8] This fact raises an issue of representativeness of the joint ICT-Innovation sample, which is likely to be biased towards large firms that are usually included in both surveys in each year.

Table 2. Descriptive statistics on key variables.

Manufacturing	Obs	Mean	Std. Dev.	Min	Max
inpdt	3109	.3293664	.4700588	0	1
inmar	3109	.1605018	.3671298	0	1
inpcs	3109	.2444516	.4298307	0	1
inorg	3109	.2087488	.4064799	0	1
inmkt	3109	.2688968	.4434575	0	1
coopf	3109	.1450627	.3522207	0	1
coopu	3109	.0845931	.27832	0	1
rk	3109	.0996787	.4973447	0	20.05326
ictk	3109	.0084379	.0500912	0	1.315943
skill	3109	.0307911	.083216	0	.9
Services					
inpdt	3848	.2817048	.4498886	0	1
inmar	3848	.1507277	.3578297	0	1
inpcs	3848	.2138773	.4100945	0	1
inorg	3848	.1730769	.3783629	0	1
inmkt	3848	.2588358	.4380521	0	1
coopf	3848	.0725052	.2593563	0	1
coopu	3848	.0309252	.1731375	0	1
rk	3848	.1858315	.6783265	0	11.72094
ictk	3848	.0262185	.2882459	0	13.12568
skill	3848	.1253442	.202746	0	1

The ideal measure capturing the economic contribution of capital inputs in a production theory context is flow of capital services (see Draca et al., 2007). In very few studies the authors construct a measure of ICT capital based on information about investments in hard- and software (e.g., Hempell, 2005; Farooqui, Sh. and G. van Leeuwen, 2008). Since 2002, Statistics Norway has collected micro level information on investment expenditures on ICT, i.e., on purchased hardware and purchased and own account software. This type of information on ICT flows over consecutive time periods has the clear benefit of providing a direct measure of investment that can be quite easily used for building measures of ICT stocks, *ICTK*, following PIM as in the case with R&D capital stock (see, Rybalka, 2009, for details of ICT capital construction procedure).[9]

[8] Only about 25 % of firms that responded to the Innovation surveys also responded to the ICT surveys in the relevant years. To reduce this problem I use ICT business surveys for 2003, 2005 and 2007 for supplementing information from ICT business surveys for 2004, 2006 and 2008 respectively, assuming that the firm's ICT facilities did not change dramatically in one year. As a result the shares have increased to 31-38 % in different editions of CIS.

[9] Again I use all available data on the firm's ICT investments from annual 2002–2008 Structural statistics for ICT capital construction.

Another benefit of these data is that their linking to Innovation survey data does not reduce the sample dramatically (information on ICT capital is available for 80 % of firms in the Innovation surveys). Then by analogue to R&D capital intensity, ICT capital intensity, *ictk*, is calculated as the ICT capital stock per man-hour.

Finally, for each firm, I distinguish between two types of employees: those with academic education (corresponding to a Master or PhD level of education) and those without. I assume that the former group is particularly relevant to the R&D activity in the firm. The variable *ac* is defined as the number of man-hours worked by employees with academic education divided by the total number of man-hours in the firm.

The 2004, 2006 and 2008 innovation surveys include 4655, 6443 and 6012 firms, respectively. After merging them and excluding firms with incomplete information on the variables of interest, I obtain a reduced unbalanced panel of 3109 firms in Manufacturing and 3848 firms in Services. Table 2 contains descriptive statistics for the key variables for these samples.

While an ICT capital is a general measure of ICT in the sense that it accumulates information on firm's ICT investments, it does not show what kind of equipment the firm has invested in and how intensively this equipment is used. As an alternative measure of ICT that takes into account the intensity of ICT use, I explored the correlation between innovations and a set of potential indicators for ICT use available from the ICT business survey: the number of web facilities; the number of automatic IT links; the share of employees with a broadband connection to the Internet; the value of e-sale; the value of e-purchasing; the presence of a firm's web page; the first factor from a factor analysis of all the above indicators; the simple average of the above indicators.

The number of automatic IT links turned out to have the highest correlation to innovation. The number of automatic IT links is based on the answers to the following questions from the ICT business survey:

Did your enterprise's IT systems for managing orders link automatically with any of the following IT systems, during January 'year'?

a) *Internal system for re-ordering replacement supplies*
b) *Invoicing and payment systems*
c) *Your system for managing production, logistics or service operations*
d) *Your supplies' business systems (for suppliers outside your enterprise group)*
e) *Your customers' business systems (for customers outside your enterprise group)*

Firms are asked to answer all questions with yes or not. Therefore, the indicator varies between 0 (firms has no automatic IT link) to 5 (firms has all automatic IT links).

Strictly speaking, this indicator is not a direct measure of the intensity of ICT use by firms. It is rather a measure of the sophistication or scope of ICT use. However, this indicator is correlated to the intensity of use. Adding a new automatic link to the firm's IT system is costly and a firm would not do undertake such an investment if it did not use it. Clearly, firms with the same automatic IT links may use them differently and this indicator would not capture these differences. In addition, IT links seem to be biased towards the use of ICT for e-commerce and e-business but they may be a poorer proxy for other ICT-enabled activities relevant for innovation, e.g., communication. Bearing these limitations in mind, in the rest of this study I regard the number of automatic IT links as a measure of the intensity of ICT use by firms.

4. The model

The aim of this research project is to assess the effects of ICT as an enabler of innovation. ICT has the potential to increase innovation by speeding up the diffusion of information, favouring networking among firms, reducing geographic limitations, and increasing efficiency in communication. These effects can be analysed by looking at whether the use of ICT in firms is associated to:

1. higher probability to innovate;
2. specific features of innovation; and
3. higher probability to cooperate in innovation.

To answer these questions I test a set of following hypotheses, grouped under 3 themes:

1. Innovation capabilities: *The probability to innovate increases with the intensity of ICT use.* This hypothesis is tested for any type of innovation and for four types of innovation separately.

2. Innovation trajectories: *Among all firms introducing a new product, the probability to introduce a product new-to-the-market increases with the intensity of ICT use.* The introduction a new product by a firm may result from the adoption of an existing product, *i.e.* new-to-the-firm, or by the invention of a truly new product, *i.e.* new-to-the-market. If ICT use increased the invention capabilities of a firm, one may expect new products by ICT intensive users to be new-to-the-market more often than new-to-the-firm.

3. Cooperation in innovation: *Among all innovative firms, the probability to innovate in cooperation with other firms or institutions increases with the intensity of ICT use.* Information and communication technologies enable closer links between businesses, their suppliers, customers and competitors, making communication and collaboration easier.

The above hypotheses have been tested through a series of logistic regressions, where the dependent variable, Y_t — a binary variable that either takes the value 1 (“success”) or 0 (“failure”) — is regressed on a vector of explanatory variables, X_t:

$$\Pr(Y_t = 1 \mid X_t) = \frac{1}{1 + \exp(-X_t \beta)}. \qquad (1)$$

That is, (1) is a logit model, where $\Pr(Y_t = 1 \mid X_t)$ denotes the probability of “success” (either introduction of an innovation with specific features, *e.g.*, product, marketing, new-to-the-market, etc., or cooperation with others in the innovation activity) for a given firm in period *t* given X_t.

X_t is a (row) vector of independent variables (covariates) and β is the corresponding (column) vector of regression coefficients. The vector X_t contains:

- *ICT* variable, i.e., ICT capital stock intensity at the beginning of the corresponding 3-years period, *ictk*, or the number of IT links in the alternative specification, *itlink*;
- R&D capital stock intensity at the beginning of the corresponding 3-years period, *rk*;
- a proxy of employees' skills (share of employees with academic education), *skills*;
- the firm's characteristics, *size, age and location dummies*[10];
- time dummies, *d_2006* and *d_2008.*

The date of the continuous regressors in X_t refers, in most cases, to the beginning of subperiod *t*. For example, the R&D capital per man-hour, *rk*, and ICT capital per man-hour, *ictk*, in subperiod *t = 1* (2004 edition of CIS) refer the beginning of this subperiod, i.e., 2002. I choose this dating to reduce the potential endogeneity problem that occurs if the right-hand side variables can be adjusted as a consequence of changes in the dependent variable, Y_t. For example, if the firm increases its R&D investment or initiate a joint research project with another firm as a consequence of an innovation. The one exception to this dating convention regards the skills proxy, *skills*, which is the share of total man-hours by employees with academic education in the observed year *t*.

One shortcoming of specification (1) is that it does not take into account the persistence of innovation activities at the firm level; that the dependent variable, Y_t, may depend on Y_{t-1} (given the explanatory variables X_t).[11] For example, we expect, *ceteris paribus*, that the probability of innovating in the second subperiod ($Y_2 = 1$) is larger for firms that innovated in the first subperiod ($Y_1 = 1$) than for those that did not ($Y_1 = 0$).

In the second econometric specification, I attempt to address this concern by assuming that

(2) $$\Pr(Y_t = 1 \mid X_2, Y_{t-1}) = \frac{1}{1 + \exp\{-(X_2\beta + Y_1\alpha_1)\}}.$$

Thus, I model the probability of success in subperiod *t* (the probability that $\mathrm{Y}_t = 1$) conditional on the explanatory variables in subperiod *t*, X_2, *and* the dependent variable in subperiod *t-1*, Y_{t-1}.

As mentioned above the ICT capital measure does not take into account the intensity of ICT use. To explore whether the intensity of ICT use matters for the firm's innovation activity, I use an

[10] Intervals for the number of employees: [10,20), [20,50), [50,150) and ≥ 150 with reference interval [1,10); Intervals for the firm age: [0,2], [3,5], [6,9] and [10,14] with reference interval ≥ 15 years; "Economic regions": East coast, East inn, South, West, Central and North with Capital region as reference one.

[11] Earlier studies have shown that innovation is a quite persistent feature of firms cf. Peters (2009).

alternative measure of ICT, i.e., the number of IT links, *itlink*. [12] However, if firms that have a high *a priori* probability of being successful in their innovation activity also have a high intensity of ICT use, *ICT* will be an endogenous variable. In order to control for the endogeneity of ICT variable in that case, I used and Instrumental Variable (IV) approach. I tested a number of ICT variables which are expected to be correlated to ICT use but not to innovation, i.e., variable indicating the speed of Internet, dummy for whether the firm uses e-government service and the lagged ICT variable. The variable indicating the speed of Internet, *int_speed*, turned out to be a valid instrument and is used as an IV in the further analysis.[13]

In more formal terms, the model can be presented as follows:

$$Y_{it}^{*}=\beta_0+\beta_1 rk_{it}+\beta_2 skills_{it}+\overline{\beta}\,\overline{X}_{it}+\sum \gamma_j D_{j,it}+u_{it}$$

(3) $$ICT_{it}=\delta_0+\delta_1 rk_{it}+\delta_2 skills_{it}+\delta_3 IV_{it}+\overline{\delta}\,\overline{X}_{it}+v_{it}$$

$$Y_{it}=1 \; if \;\; Y_{it}^{*}>0; \; Y_{it}=0 \; otherwise$$

$$D_{j,it}=1 \; if \;\; ICT_{it}=j; \; D_{j,it}=0 \; otherwise$$

where *i = 1, 2, …., N* indicates the firms; *j = 1, 2, … 5* the frequency of ICT use (number of IT links); $\overline{X}_{it}$ contains firm's characteristics (size, age and location) and time dummies; and (u_{it}, v_{it}) is assumed to have a zero mean, bivariate normal distribution and to be independent of all exogenous variables in (3).

If u_{it} and v_{it} are correlated, *ICT* is endogenous and the Probit estimates of all variables in (1) are biased. Under the assumption of joint normality of (u_{it}, v_{it}) , one can write

$$u_{it}=\theta v_{it}+\varepsilon_{it}$$

where $\varepsilon_{it} \sim N[0, \; Var(u_i) - Cov(u_i, v_i)]$.

Therefore, the above model (3) can be rewritten as:

(4) $$Y_{it}^{*}=\beta_0+\beta_1 rk_{it}+\beta_2 skills_{it}+\overline{\beta}\,\overline{X}_{it}+\sum \gamma_j D_{j,it}+\theta \hat{v}_{it}+\varepsilon_{it}$$

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[12] This part of the analysis is based on framework used in the OECD research project "ICT-enabled innovation in OECD firms" where nine different countries have participated (Canada, Italy, Luxembourg, Nederland, Norway, Spain, Sweden, Switzerland and UK), see OECD (2012).

[13] This variable has three values, i.e., 1 (firms with speed of Internet <144 Kb/s), 2 (firms with speed of Internet 144 Kb/s – 2 Mb/s) and 3 (firms with speed of Internet > 2 Mb/s).

where $\hat{v}_{it}$ are the OLS residuals of equation ICT equation in (3)[14].

This model was estimated through a two-stage conditional maximum likelihood (Rivers and Vuong, 1988) with adjustment of standard errors for the intrafirm correlation and the Average Partial Effects (APEs) were computed as the average of the Partial Effects (PEs) across $\hat{v}_{it}$.

This model can be interpreted as a simultaneous model, where the decision to innovate and to use ICTs is taken jointly. In this sense, the model does not predict that ICT use is the *cause* of innovation, rather that ICTs are an *enabler* of innovation, i.e., firms use ICT as a tool or a “platform” for innovation.[15]

5. Empirical results

5.1 Estimation results for innovations and ICT capital

Table 3 shows the results for model (1), i.e., estimates of the effects of R&D and ICT intensity, use of skilled workers and different firm characteristics on the probability of innovation for the manufacturing firms and firms in services. While Table 4 shows the corresponding results for model (2), which in addition to explanatory variables in model (1) takes into account persistency of innovation (this model is not estimated then for cooperation variables).

Innovation capabilities

The results in Table 3 show that ICT intensity, measured as ICT capital per man-hour, has little effect on innovations in manufacturing firms (i.e., a significant positive effect is found only for the new production process), and no effect in services. However, when the persistency of innovation is taken into account, ICT intensity becomes important for organizational innovation in manufacturing and it has a significant positive effect for all types of innovation in services (see Table 4). One explanation to such a change is that in the latter case the sample is reduced to the firms that are represented in at least two Innovation surveys, which exclude many small firms. At the same time all medium and large firms (those with more than 50 employees) are included in the each survey. Hence, for them these findings confirm that ICT are an important enabler of capturing and processing knowledge in the innovation creating process. However, the observed industry differences suggest that ICT are more important for innovations in services than in manufacturing.

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[14] As *ICT* is a discrete variable, the OLS estimates of $\hat{v}_{it}$ are not consistent. Nonetheless, they lead to consistent estimates of equation (6) because they are orthogonal to all exogenous variables (see, for instance, Heckmann, 1978).
[15] Since only about 35 percent of the firms in this already heavily reduced sample (see footnote 8) have two or more observations, I do not estimate the version of this model with persistency of innovation, i.e., when the dependent variable, Y_t, depends on Y_{t-1}.

Table 3. Estimation results for innovations and ICT capital

Variables	inpdt	inpcs	inorg	inmkt	inmar	coopf	coopu
	Innovation capabilities				Trajectories	Cooperation	
Manufacturing firms (5310 obs., 3109 firms)							
rk	0.248***	0.171***	0.210***	0.083	0.228***	1.009***	0.206**
ictk	-0.034	1.031*	0.148	0.419	-0.235	-6.000**	-1.564
skill	3.545***	1.205***	1.828***	1.409***	2.504***	1.443***	3.831***
1-9 empl.	-1.477***	-1.007***	-8.010	-1.298***	-1.706***	-2.212***	-3.186***
10-19 empl.	-1.229***	-1.023***	-1.165***	-0.503***	-0.750***	-1.505***	-1.969***
20-49 empl.	-0.805***	-0.572***	-0.582***	-0.327***	-0.535***	-0.964***	-1.381***
50-149 empl.	-0.635***	-0.377***	-0.400***	-0.260***	-0.342***	-0.663***	-1.039***
firm age 0-2	-0.040	-0.023	0.118	-0.082	0.000	-0.111	0.058
firm age 3-5	0.062	0.075	0.176**	0.080	-0.056	0.050	0.087
firm age 6-9	-0.143	0.016	0.039	-0.062	-0.177*	-0.126	-0.119
firm age 10-14	0.059	-0.006	0.050	0.229***	0.096	-0.030	0.094
Firms in services (5431 obs., 3848 firms)							
rk	0.561***	0.347***	0.253***	0.248***	0.406***	0.523***	0.580***
ictk	-0.141	-0.068	-0.012	-0.089	-0.042	0.081	-3.341*
skill	1.221***	0.570***	0.708***	0.374***	0.994***	0.838***	2.403***
1-9 empl.	-0.086	-0.330***	-8.974	-0.459***	-0.555***	-1.381***	-2.000***
10-19 empl.	0.077	-0.295***	-0.814***	0.100	0.113	-0.624***	-0.877***
20-49 empl.	0.197	-0.254***	-0.243***	-0.005	0.259**	-0.282*	-0.363
50-149 empl.	-0.079	-0.183*	-0.144*	0.029	-0.112	-0.096	-0.155
firm age 0-2	0.121	0.113	-0.006	0.099	0.165	0.103	-0.188
firm age 3-5	0.380***	0.288***	0.177**	0.216***	0.343***	0.226*	-0.416*
firm age 6-9	0.483***	0.225***	0.204***	0.220***	0.404***	0.277**	-0.165
firm age 10-14	0.306***	0.254***	0.140*	0.184**	0.330***	0.194	-0.233

legend: * p<.1; ** p<.05; *** p<.01
Economic regions and time dummies are included in the analysis but not reported here.

Table 4. Estimation results for innovations and ICT capital, with persistency in innovation

Variables	inpdt	inpcs	inorg	inmkt	inmar
	Innovation capabilities				Trajectories
Manufacturing firms (1400 obs., 700 firms)					
l_y	2.107***	0.690***	0.369***	0.701***	1.134***
rk	-0.016	0.025	0.084	-0.130	0.011
ictk	-3.726	3.493	9.634*	1.287	-6.690
skill	3.919***	1.358**	1.456**	1.889***	2.193***
1-9 empl.	-0.120	-0.529	-7.635	-1.001*	-1.166*
10-19 empl.	-0.611**	-1.001***	-1.711***	-0.119	-0.273
20-49 empl.	-0.164	-0.300***	-0.520***	-0.111	-0.145
50-149 empl.	-0.437***	-0.323***	-0.430***	-0.107	-0.243**
firm age 0-2	1.084	-0.005	0.132	0.322	-0.278
firm age 3-5	0.360	0.214	0.163	0.087	0.168
firm age 6-9	-0.338*	0.074	0.107	0.107	-0.263**
firm age 10-14	0.267	-0.026	0.049	0.331***	0.136
Firms in services (878 obs., 439 firms)					
l_y	1.123***	0.867***	0.504***	0.663***	0.938***
rk	0.149**	0.049	0.004	-0.073	0.127*
ictk	2.852***	2.668***	1.723*	1.434*	1.891**
skill	0.314	0.134	0.774***	0.084	0.577*
1-9 empl.	6.476	-0.329	-6.709	-6.477	-7.165
10-19 empl.	0.752***	0.630***	-0.262	0.772***	0.691***
20-49 empl.	0.535***	0.213	0.063	0.310**	0.486***
50-149 empl.	0.085	-0.021	-0.156	-0.072	0.062
firm age 0-2	0.053	-0.792**	0.123	-0.626**	-0.142
firm age 3-5	-0.141	-0.040	0.026	-0.096	-0.196
firm age 6-9	-0.054	-0.052	0.004	-0.107	-0.161
firm age 10-14	-0.172	0.056	0.028	-0.114	0.214

legend: * p<.1; ** p<.05; *** p<.01
Economic regions and time dummies are included in the analysis but not reported here.

Trajectories in innovation
The introduction of a new product by a firm may result from the adoption of an existing product, *i.e*. new-to-the-firm, or by the invention of a truly new product, *i.e*. new-to-the-market. If ICT intensity increased the invention capabilities of a firm, one may expect new products by ICT intensive users to be new-to-the-market more often than new-to-the-firm. Against this expectation, I found that higher ICT intensity does not increase the probability to introduce a product new-to-the-market – as opposed to new-to-the-firm. Service firms are the only ones to show a higher probability to introduce a new-to-the-market product, although only in the case when persistency of innovation is taken into account (see Table 4).

Cooperation in innovation
In general, I found no support for the hypothesis that firms with higher ICT intensity are more likely to cooperate in innovation with other firms or research institutions.

The estimates regarding such variables as R&D intensity and skills of employees are in line with results well established elsewhere in the empirical literature: firms having higher R&D intensity and with higher share of skilled employees have a higher probability of innovating than other firms and higher probability of cooperating with others in their innovation activities. The firm size seems to matter more for innovating in manufacturing and firm age in services (see Table 3). However the latter effect is neglected when persistency of innovation is taken into account (see Table 4).

5.2 Estimation results for innovations and ICT-use intensity

A key role in this estimation is assigned to the variable *int_speed*, which is an exclusion restriction in model (3) and contributes to identifying the effects of the endogenous ICT use variable, *itlink.* The identification, of course, requires that the speed of Internet has no direct effect on innovation probability. The results of the first stage of a two-stage conditional maximum likelihood estimation identified highly significant and positive relation between ICT intensity and the variable *int_speed* both for manufacturing firms and firms in services. [16] A plausible explanation is that the high speed Internet allows firms to use available IT and communication facilities faster. On the other hand, there is little reason to believe that heterogeneity in the speed of Internet in the firms has a direct effect on the probability of innovation. I do not find that *int_speed* is significant in any of the innovation equations. Thus, the speed of Internet seems to have no direct effect on the probability of innovating and is a valid instrument for the ICT intensity variable.

Table 5 shows the results of model (4) estimation, i.e., estimates of the partial effects of intensity of ICT use on the probability of innovation for the manufacturing firms and firms in services, where the intensity of ICT use is measured as the number of automated IT links (0 to 5). [17]

[16] Focusing on the results for the ICT use intensity variable, I do not report the full set of results for the estimation of ICT and innovation equations here. These results can be provided by request.
[17] The estimates regarding such variables as firm size, R&D intensity and skills of employees are in line with earlier estimations: firms with more employees, doing R&D and with higher share of skilled employees have a higher probability of innovating than other firms. These results are not presented here and can be provided by request.

Innovation capabilities

The main results show that intensity of ICT use has little effect on innovations in manufacturing firms (i.e., a significant positive effect is found only for the new marketing method), whether it has a significant positive effect for all types of innovation in services. For example, for a representative firm in services, a change in the number of automated IT links from 0 to 5 increases the probability of introducing a new product by 18 percent, a new process by 24 percent, a new organisation by 15 percent, and finally, a new marketing method by 20 percent.

These findings confirm that ICT are an important enabler of capturing and processing knowledge in the innovation creating process. However, the observed industry differences suggest that ICT are more important for innovations in services than in manufacturing.

Trajectories in innovation

If intensive ICT use increased the invention capabilities of a firm, one may expect new products by ICT intensive users to be new-to-the-market more often than new-to-the-firm. In contrast to this expectation, I found that more intensive ICT use does not increase the probability to introduce a product new-to-the-market – as opposed to new-to-the-firm. Manufacturing firms are the only ones to show a higher probability to introduce a new-to-the-market product (17 %), although only in the case of changing number of automated IT links from 0 to 5.

Table 5. Partial effects of ICT use intensity on the probability of innovating

	Manufacturing					Services				
Dependent variable	it_link1	it_link2	it_link3	it_link4	it_link5	it_link1	it_link2	it_link3	it_link4	it_link5
Innovation capabilities										
1:Any innovation	0.02	-0.01	**0.08**	0.02	0.00	**0.15**	**0.13**	**0.11**	**0.14**	**0.22**
New product	0.01	0.04	0.06	-0.03	0.01	0.11	0.07	**0.17**	**0.10**	**0.18**
New process	0.05	0.05	-0.01	-0.04	-0.01	0.03	0.04	**0.08**	**0.12**	**0.24**
New organisation	-0.03	0.01	0.05	0.00	0.05	**0.11**	0.04	**0.08**	0.07	**0.15**
New marketing	-0.05	0.06	**0.07**	**0.12**	**0.11**	0.02	0.05	**0.10**	**0.17**	**0.20**
Trajectories in innovation										
2: New-to-the-mkt	0.11	-0.01	0.01	0.01	**0.17**	0.13	0.17	0.08	0.15	0.01
Cooperation in innovation										
3: Coop	0.12	0.04	0.06	0.04	0.09	0.01	0.01	0.05	-0.02	0.01
No. of obs			1697					1273		
No. of firms			1232					980		

Bold: significant at 5 %; underlined: significant at 1 %

Cooperation in innovation

Again, I found no evidence for the hypothesis that ICT intensive users are more likely to cooperate in innovation with other firms or institutions.

6. Conclusions and some ideas for further research

This study has tried to assess the effects of information and communications technologies (ICT) as an enabler of innovation in Norwegian firms in two sectors, i.e., Manufacturing and Services. The element of novelty of approach used in the paper is that I treat ICT in parallel with R&D as an input to innovation allowing existence of possible complementarities among different types of innovation inputs. The results support the hypotheses that ICT act as an enabler of innovation, in particular for marketing and organisational innovation and for innovations in services. However, I did not find any evidence that intensive ICT use increases the capability of a firm to cooperate with other firms/institutions in their innovation activity nor that ICT intensive firms have higher capacity to introduce "more innovative" (new-to-the-market) products. These results suggest that ICT enable rather adoption of innovation than developing of truly new products.

In interpreting these results, one should bear in mind that they are based on some "imperfect" measures of ICT use by firms. While an ICT capital is a general measure of ICT in the sense that it accumulates information on firm's ICT investments, it does not show what kind of technologies the firm has implemented and how intensively these technologies are used. An alternative measure of ICT that takes into account the intensity of ICT use, i.e., the number of automatic IT links, is not perfect either. Firms with the same automatic IT links may use them differently and constructed indicator would not capture these differences. In addition, this indicator seems to be biased towards the use of ICT for e-commerce and e-business but it may be a poorer proxy for other ICT-enabled activities relevant for innovation, e.g., communication. Hence, the obtained results cannot be directly compared to the results if an alternative indicator of ICT is used.

The possible direction for further research would be to link the present results to an analysis of productivity at the firm level. Do ICT-enabled innovations have a different impact on productivity as compared to other types of innovation? Do they act through different channels? This line of research requires introducing ICT variables into a broader productivity model.

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Appendix A. Data sources

R&D statistics: R&D statistics are the survey data collected by Statistics Norway every second year up to 2001 and annually later on. These data comprise detailed information about firm's R&D activities, in particular, about total R&D expenses with division into own-performed R&D and purchased R&D services, the number of employees engaged in R&D activities and the number of man-years worked in R&D. The 2001, 2004, 2006 and 2008 editions are combined with Community Innovation Survey (CIS) and contain information on whether firms have introduced different types of innovation over the three-year period before each survey. In each wave the sample is selected with a stratified method for firms with 10-50 employees, whereas the firms with more than 50 employees are all included. Strata are based on industry and firm size. Each survey contains about 5000 firms, although not all of them provide complete information.

The Structural statistics: The term “structural statistics” is a general name for the different industrial activities statistics, such as Manufacturing statistics, Building and Construction statistics, Wholesale and Retail trade statistics, etc. They all have the same structure and include information about production, input factors and *investments* at the firm level. The structural statistic are organized according to the NACE standard and are based on General Trading Statements, which are given in an appendix to the tax return. In addition to information about operating revenues, operating costs and operating result and labour costs, the structural statistics contain data about purchases of tangible fixed assets and operational leasing. Since 2002, Statistics Norway has also collected micro level information on investment expenditures on ICT, i.e., on purchased hardware and purchased and own account software. These data were matched with the data from the R&D statistics. As the firm identification number here and further I use the number given to the firm under registration in the Register of Enterprises, one of the Brønnøysund registers, which is operative from 1995.

The Register of Employers and Employees (REE): The REE contains information obtained from employers. All employers are obliged to send information to the REE about each individual employee's contract start and end, working hours, overtime and occupation. An exception is made only if a person works less than four hours per week in a given firm and/or was employed for less than six days. In addition, this register contains identification numbers for the firm and the employee, hence, the data can easily be aggregated to the firm level.

The National Education Database (NED): The NED gathers all individually based statistics on education from primary to tertiary education and has been provided by Statistics Norway since 1970. I uses this data set to identify the length of education. For this purpose, I utilizes the first digit of the NUS variable. This variable is constructed on the basis of the Norwegian Standard Classification of Education and is a six-digit number, the leading digit of which is the code of the educational level of the person. According to the Norwegian standard classification of education (NUS2000), there are nine educational levels in addition to the major group for “unspecified length of education”. The educational levels are given in Table A1.

Table A1. Educational levels in the NUS2000

Tripartition of levels	Level	Class level
	0	Under school age
Primary education	1	1^{th}-7^{th}
	2	8^{h}-10^{th}
Secondary education	3	11^{th} -12^{th}
	4	13^{th}
	5	14^{th}
Post-secondary education	6	14^{th}-17^{th}
	7	18^{th}-19^{th}
	8	20^{th}+
	9	Unspecified

Appendix B. Definitions and examples of different types of innovation

The Oslo Manual defines an 'innovation' as:
“...the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organisation or external relations.” (OECD, 2005, p. 46)

A product innovation is the introduction of a good or service that is significantly improved with respect to its characteristics or intended uses and includes significant improvements in technical specifications, components and materials, incorporated software and user friendliness or other functional characteristics (OECD, 2005, p. 48). Design changes which do not involve a significant change in the product's functional characteristics or intended use, such as a new flavour or colour option, are not product innovations. Product innovations in services can include significant improvements in how the product is provided, such as home pick-up or delivery services, or other features which improve efficiency or speed.

A process innovation is a new or significantly improved production or delivery method, including significant changes in techniques, equipment and/or software (OECD, 2005, p. 49). For example, introduction of a new automation method on a production line, or in the context of ICT, developing electronic system linkages to streamline production and delivery processes, are both process innovations.

With respect to services, it is often difficult to distinguish a product and process innovation. The Oslo Manual (OECD, 2005, p. 53) contains the following guidelines to distinguish these two types of innovation:

- if the innovation involves new or significantly improved characteristics of the service offered to customers, it is a product innovation;
- if the innovation involves new or significantly improved methods, equipment and/ or skills used to perform the service, it is a process innovation.

An organisational or managerial innovation is the implementation of a new or significantly improved method of the firm's business practices, workplace organisation or external relations. It requires more than mere organisational change or restructure. In fact, the organisational method must not have been previously used by the business and must be the results of strategic decisions taken by management (OECD, 2005, p. 49). Examples include implementation a new method for distributing responsibilities and decision making among employees, decentralising group activity, developing formal or informal work teams, new types of external collaboration with research organisations or the use of outsourcing or sub-contracting for the first time (OECD, 2005, p. 52).

A marketing innovation is the implementation of a new or significantly improved marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. The marketing method must not have been previously used by the firm and must be part of a new marketing concept or strategy representing a significant departure from the firm's existing methods (OECD, 2005, p. 50).

Does Enterprise Software Matter for Service Innovation? Standardization versus Customization[§]

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May 2012

Abstract
This paper analyzes the relationship between service innovation and different types of enterprise software systems, i. e. standardized enterprise software designed to fit one certain business sector and enterprise software specifically customized for a single firm. Using recent firm-level data of a survey among information and communication technology service providers as well as knowledge-intensive service providers in Germany, this is the first paper which empirically analyzes whether the use of sector specific or customized enterprise software triggers innovation. The results based on a knowledge production function suggest that customized enterprise software is related to the occurrence of service innovation. However, there is no relationship between sector specific enterprise software and innovation activity. The results stay robust to several different specifications and suggest that the causality runs from customized software usage to service innovation.

Keywords: enterprise systems, service innovation, customized enterprise software, sector specific enterprise software, service sector
JEL Classification: L10, M20, O31

[§] We would like to thank Irene Bertschek, Daniel Cerquera, Francois Laisney, Pierre A. Mohnen, Ashok Kaul and Michael R. Ward for helpful comments and suggestions. All errors are our own.
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1. Introduction

A large range of enterprise software products nowadays supports day-to-day business operations, controls manufacturing plants, schedules services or facilitates decision-making. The purpose of these software applications is, in general, to automate operations reaching from supply management, inventory control or sales force automation to almost any other data-oriented management process. Especially in many fields like semiconductors, biotechnology, information and telecommunication or other knowledge-intensive industry branches, employees might be able to observe, measure or even envision certain phenomena only by using specific enterprise software applications. SAP, the largest global enterprise software vendor, estimates the adressable market for enterprise software applications to be roughly $ 110 billion in 2010[1].

Overall, enterprise software can be categorized into three types, as users distinguish between generic applications such as an enterprise resource planning system purchased in standardized form from the vendor[2], software systems or special modules specifically designed to fit one business sector[3] or completely customized enterprise software packages developed for a single firm in particular and adopted to its specific needs[4]. Thus, customized enterprise software systems are usually unique.

Although the usage of information and communication technology (ICT) applications in general is suspected to enhance firms' innovative activity (Hempell and Zwick 2008; Engelstätter 2012; Brynjolfsson and Saunders 2010), the potential impact of sector specific or completely customized enterprise software on innovation performance in particular is still not investigated. The literature in this field is scarce, offering only a few studies which examine the benefits of enterprise software for innovation activity, see e. g. Shang and Seddon (2002). Empirical evidence is even scarcer, provided only by Engelstätter (2012) who outlines the impact of three common generic enterprise systems on firms' ability to realize process and product innovations. However, being more general based on the available sample, Engelstätter (2012) does not picture the impacts of enterprise software on specific service innovations. Those service innovations might be driven by other characteristics such as enhanced knowledge handling or contact to customers compared to mainly research driven innovations in manufacturing. However, to succeed in realizing innovations in dynamic, information-rich environments like the service sector a firm should engage in a combination of different practices like promoting information absorption and diffusion, knowledge handling or development of an extended intra- and inter-organizational network (Mendelson and Pillai 1999). Engaging in these practices, however, is expected to be facilitated with advanced knowledge handling and storing capabilities of utilized enterprise software. In light of this research gap, the current study provides the first empirical

[1]See SAP presentation, available at:
http://www.sap.com/about/investor/presentations/pdf/WB_DB_London_8Sep2010.pdf, last visited June 29th 2012.

[2] E. g. SAP Business One or Oracle E-Business Suite.

[3] Examples for sector specific enterprise software contain computer aided design or manufacturing programs, e. g., solutions offered from Sage.

[4] Examples here are completely designed software solutions like applications from firms as, for instance, Supremistic or Jay Technologies Inc. In addition, firms could also augment generic solutions like SAP packages with custom-made modules.

evidence of the impact of business sector specific or customized enterprise software on firms' innovative performance for the specific case of service firms.

Our study relies on a unique database consisting of 335 German firms from ICT and knowledge-intensive service sectors. As analytical framework we employ a knowledge production function for our empirical analysis. Based on a probit approach, the results indicate that service firms relying on customized enterprise software have a higher probability of realizing service innovations compared to firms not using customized software packages. Concerning sector specific enterprise software we find no evidence of a positive impact on service firms' innovative activity. These results stay robust to many specifications controlling for different samples sizes and several sources of firm heterogeneity like size, age, workforce structure, competitive situation or former innovative experience.

The paper proceeds as follows: Section 0 presents the methodological framework. Section 0 introduces the dataset. The estimation procedure is derived in section 0 and section 0 presents the estimation results. Section 0 concludes.

2. Methodological and Theoretical Framework

2.1 Background

In brief, this study relates to the literature picturing the impacts on firm performance and innovation activity of ICT in general and of enterprise software in particular. Supporting the optimization of firms’ business processes ICT is expected to enable productivity and performance gains, see e.g. Brynjolfsson and Hitt (2000). A crucial prerequisite for these productivity gains, however, is the firms’ innovation activity (Crépon et al. 1998; Hall et al. 2009). In general, the link between ICT and innovation is not as extensively studied in the empirical literature as the relationship between ICT and productivity. Studies investigating the effects of ICT investments on innovative performance at the firm level usually report a positive and significant impact which may emerge directly, see e. g. Gera and Gu (2004), or indirectly via complementary assets as shown in Bresnahan et al. (2002) or Hempell and Zwick (2008).

For the literature focusing on enterprise software in particular the picture is similar to general ICT literature as there are many studies extensively examining the performance impacts of the software and nearly no analysis examining potential innovation impacts. In general, enterprise software can be roughly categorized in three types: generic applications, business sector specific software packages and lastly software specifically designed or customized for a single firm. Possible impacts of unspecific generic enterprise software systems, like, e. g., enterprise resource planning, on firm performance are extensively covered in the literature . In these performance analyses a wide range of performance measures is concerned, e. g. several return measures like return on equity, investment, assets or sales (Hunton et al. 2003; Hunton and Wier 2007; Hendricks et al. 2007) as well as labor productivity, net profit margin or value added (Hitt et al. 2002; Shin 2006; Wieder et al. 2006). Thereby, the reported positive performance impacts are linked to the benefits the enterprise software systems provide to a utilizing firm, e. g. enhancing operational and business planning capabilities, facilitating financial transaction handling or procurement. As for the impacts of generic enterprise software on innovation performance, Engelstätter (2012) empirically shows that different types of enterprise software systems enhance the using firms' innovative activity resulting in more realized process respectively product innovations. However, analyses of potential innovative impacts of sector specific or customized enterprise software packages, are completely missing in the literature at the moment. Our study aims at filling this research gap starting out by picturing the impacts of these specific software packages on firms' innovation activity. For our analysis, we rely on firms from ICT and knowledge intensive service sectors as business sector specific software packages are incomparable between manufacturing and service firms.

2.2 Service Innovations in General

In general, the nature of services complicates the use of traditional economic measurements for innovations as this field is very heterogeneous due to features like intangibility, interactivity and coterminality (Gallouj and Weinstein 1997). In detail, services turn out to be intangible, because they are hard to store or transport and can sometimes not even be displayed to a customer in advance (Hipp and Grupp 2005). Interactivity is constituted in high communication and coordination needs between client and supplier as in most cases both have to be present for the transaction. Coterminality captures the fact that services are often produced and consumed at the same place and time. Accordingly, service innovation might focus exclusively on these three typical features (Miles 2005, 2008) blurring the lines between product, process and organizational innovations in service sectors.

For service innovation, key elements are, in particular, internal knowledge within the firm and its employees and the external network of the firm including customers and other businesses (Sundbo 1997). Human capital, especially personal skills like experience or extensive consumer contact, and knowledge about markets, consumer habits and tastes are important for realizing innovations in a service company (Meyer 2010). In addition, sources of information like consumers and suppliers of equipment can provide essential clues for service enhancement and advancement.

The analysis of the relationship between ICT and service innovations is, in general, structured in two different approaches. The first one interprets the introduction of technical equipment or ICT directly as a service innovation or at least as a starting point for it. The second group of studies, in turn, deals with non-technical, service-oriented innovation (Meyer 2010). Analyzing the relationship between ICT-use, e. g. enterprise software, and service innovation, the current study takes on the second approach as ICT is not purely meant to provide already established services. In contrast, ICT is intended to improve and enhance knowledge processing as well as the connections of the information sources needed to realize service innovations positively impacting innovation performance.

2.3 Enterprise Software and Service Innovations

Each type of enterprise software may impact the firms' innovation activity through different channels, either directly on the benefits provided or indirectly if the software fosters the introduction of organizational enhancements improving the innovation process. Overall, all software types share enhanced information handling and processing thereby facilitating communication, knowledge transfer and contact maintenance between employees or consumers and partners. Sharing internal knowledge and connecting to the external network of firms the enterprise software packages can directly be expected to contribute to the realization of service innovations. Besides these basic features the examined types of enterprise software offer additional features potentially impacting innovative activity. Accordingly, the following section starts out highlighting the impacts of sector specific and customized enterprise software on firms' innovation performance and continues picturing indirect impacts on innovation performance both types of enterprise software share.

2.3.1 Sector Specific Enterprise Software

Business sector specific enterprise software, whether employed as a module enhancing a generic system or a standalone package, is expected to facilitate the knowledge handling, storing and accumulation of a firm. Offering and presenting information in an adequate manner and providing frequently updated real-time databases, sector specific software might function as a "softer" source of innovation according to Tether (2005) and can be expected to improve innovative performance in service firms. Empirical evidence of these positive impacts of sector specific enterprise software is provided by Thomke (1998) who shows that the use of specific computer simulation software in the automotive industry is associated with overall better R & D output. However, some industry branches like e. g. biotechnology, semiconductors or architects need sector specific enterprise software packages like computer aided architecture or manufacturing to complete even the simplest business tasks. In this case, sector specific software can be viewed as a necessary working tool which is not associated with innovation and not intended to shape the innovation process. Therefore, it may also be the case that this kind of software has no impact on firm's innovative performance at all as it is a standard working tool obtained and used as soon as possible mitigating any impact on innovative performance.

2.3.2 Customized Enterprise Software

If a firm instead or additionally employs enterprise software, which is specifically designed for the own company, all the potential benefits mentioned due to enhanced knowledge processing can even be expected to increase. Having influence on the development of this software, a firm can incorporate long-term experience and knowledge in the software application, making it perfectly suitable for fulfilling all requirements for their specific business resulting in shortened reaction times. Taking part in the software development may be particularly useful for firms in the dynamic service sector where firms face a high degree of heterogeneity. For this turbulent firm environment Pavlou and El Sawy (2006) show that the ability to effectively use IT functionalities is associated with competitive advantages in new product development. However, dynamic capabilities implying the ability to reconfigure the functionalities are needed to achieve these advantages. This necessary reconfiguration turns out to be more feasible if the employed software system is customized with regard to effective execution and reconfiguration of operational new product development processes.

Being able to directly construct and shape the employed enterprise software in a way that includes and reflects all needed business processes and tasks, a service firm might be able to quickly deliver information where it is needed. Besides enhanced knowledge processing and strengthened connections between sources of information, customized enterprise software could equip the firm with forecasting and detection instruments enabling it to check for potential changes in its external operating environment or benefits and costs of innovations ahead of time. With shortened response times to such changes or cost and benefit analyses due to quick information delivery and enhanced communication structures utilizing firms exhibit an increased external focus which is hypothesized to increase the returns on information technology (Tambe et al. 2011). Tambe et al (2011) also show that in combination with decentralization and the use of sophisticated information technology like, e. g., enterprise software solutions the external focus leads to improved innovation performance. The necessary decentralization, however, is associated with customized enterprise software usage (Gronau 2010). In a case study Malhorta et al. (2001) offer first evidence of the positive impacts of customized enterprise software on firms' innovative performance as they show that virtual teaming yields crucial innovations at Boeing-Rocketdyne. The enterprise software the team needs for collaboration was explicitly developed and customized by a third party in response to a list of specified requirements offering the team a technology suited to their pre-defined needs.

2.3.3 Enterprise Software in General

Besides these direct effects, each type of enterprise software in general might also indirectly increase innovation activity as the software applications may help to realize some organizational enhancements which have been proven to facilitate the realization of more innovations. Thus, Tsai (2001) proclaims that business units become more innovative once they reach a more centralized network position that allows them to retrieve new knowledge generated by other units and also necessary information from them faster. Business sector specific enterprise software rightly fits into this context as the software applications advance the intern network and knowledge processing capabilities of the firm, e. g., by providing a centralized database with access for all employees and business units, fastening connections between them. Additionally, customized software can be expected to picture the adequate organizational structure of the utilizing firm thereby enhancing the firms' communication methods. With communication between employees and business units accelerated and broadened in this way the innovation activity of the firm might, according to Tsai (2001), also increase.

Criscuolo et al. (2005) argue that firms generate more innovations with established upstream/downstream contacts to suppliers and customers. This relation especially holds for service innovations as customers and suppliers can be providers of essential guidelines and ideas for enhancement and advancement of provided services. Roper et al. (2006) even support this argument as they stress the high value of backwards and horizontal knowledge linkages for innovations. Facilitating not only firms' internal communication, enterprise software also offers applications to enhance the communication structure outside the boundaries of the firm, making maintaining current and generating new contracts with suppliers and customers far easier, especially if the firms employ customized software with specifically developed components for communication, like customized or modified customer or supplier relationship management systems. Accordingly, firms with enterprise software in use firms have access to a large pool of knowledge, which can be expected to be helpful in creating more innovations.

Based on the literature and the expected benefits of enterprise software systems we carefully hypothesize that sector specific as well as customized enterprise software positively impact firms' innovative performance.

3. Description of Data

The data we use in this study is taken from the quarterly business survey among the "service providers of the information society" conducted by the Centre for European Economic Research (ZEW) in cooperation with the credit rating agency Creditreform. The sector "service providers of the information society" comprises nine sectors, three of information and communication services sectors and six knowledge-intensive services sectors[5]. Every quarter, a one-page questionnaire is sent to about 4.000 mostly small and medium-sized companies. The sample is stratified with respect to firm size, region (East/West Germany) and sector affiliation. The survey achieves a response rate of about 25 % each wave and builds a representative sample of the German service sector. The interviewed candidates may choose between responding via pen and paper, fax or online. The questionnaire consists of two parts. In the first part of the questionnaire, companies complete questions on their current business situation with respect to the previous quarter as well as their expectations for the next quarter. The second part is dedicated to questions concerning diffusion and use of ICT and further firm characteristics like innovative activities or training behavior. The questions in the second part change every quarter but might be repeated annually or biyearly. Details on the survey design are presented in Vanberg (2003). Overall, the survey is constructed as a panel with different waves of it being employed in several different empirical setting as, e. g., in Bertschek and Kaiser (2044) or Meyer (2010).

In the survey the questions covering enterprise software usage were only included in the second quarter of 2007. The questions about innovative activities were asked in the second quarter of 2009. Thus, a panel data analysis cannot be provided in this paper. Accordingly, we focus on a cross-section analysis by merging the second wave of the year 2007 to cover enterprise software usage and the second wave of the year 2009 to cover firms' innovative activity thereby forming a well-defined temporal sequence[6]. Considering item non-response for enterprise software and innovation, a sample consisting of 336 firms remains.

[5] For further details on the nine sectors, see Table 3 in the appendix.

[6] The exact wording of the questions covering service innovations and enterprise systems are outlined in the appendix.

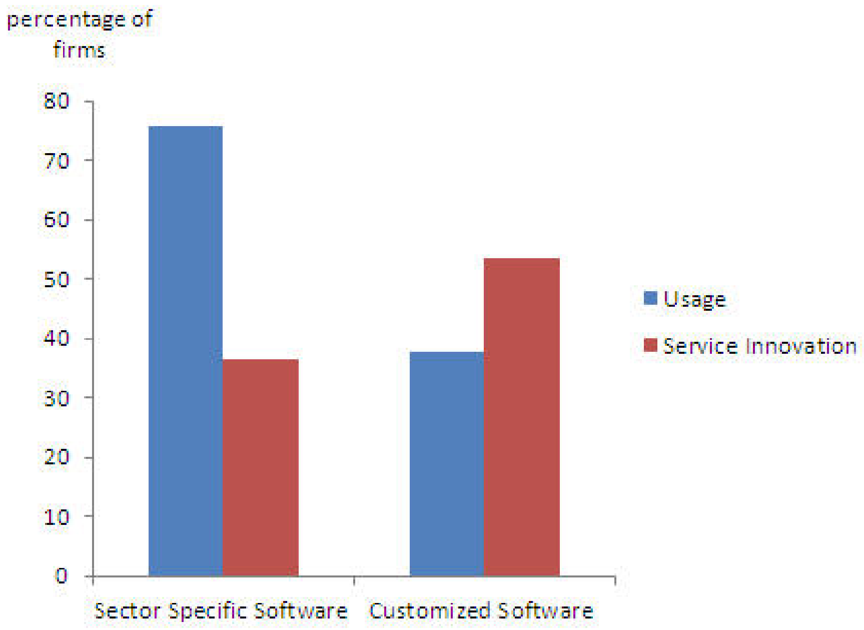
According to the OECD (2005) we define service innovations in our analysis as a completely new service or an essential improvement[7] to an existing service that has been introduced between June 2008 and June 2009. Service innovation performance representing the dependent variable in our empirical analysis is accordingly measured as a dummy variable that takes the value one for firms realizing a service innovation and zero otherwise.

In the survey, the firms were asked about using two types of enterprise software, i. e. sector specific software and customized software. The variables capturing the use of enterprise software are dummy variables which take the value one if a firm uses the respective type of enterprise software in June 2007 and zero otherwise. Figure 1 shows that more than three quarters of the service firms use sector specific software and 38 percent of the firms use customized software. However, both software types are non exclusive. Hence, some firms also have customized as well as sector specific software systems running (27 percent, not reported).

Overall, 39 percent of the firms in our sample reported realizing a service innovation between June 2008 and June 2009[8]. For a first illustration Figure 1 also pictures the share of firms which realized a service innovation and also use enterprise software. Concerning sector specific enterprise software the according share amounts to 37 percent. In contrast, more than half of the firms using customized enterprise software realized service innovations in the covered time period. This relatively high share yields first descriptive evidence for our hypothesis that the use of customized enterprise software seems to foster the innovative activity in service firms. However, for sector specific enterprise software there is no descriptive evidence for a positive innovative impact.

[7] Based on such improvements firms might also realize productivity gains placing this study also in the literature of IT and productivity. However, as these improvements are determined as service innovations (OECD 2005) we refrain from the IT and productivity literature branch focusing only on the innovative impacts of IT.
[8] See the summary statistics pictured in Table 1.

Figure 1: Usage of Enterprise Software and Service Innovation



For a further overview, Table 1 provides summary statistics for our employed sample. We describe the construction of each variable and its relationship to service innovations in the next section in detail. However, it stands out that our representative sample of the German information service sector contains mostly small and medium sized enterprises with 38 employees at mean. Nevertheless, it seems like bigger firms are more eager to employ customized enterprise software solutions as the mean size amounts to 52 employees for firms using customized software (not reported). The appropriate mean in size for firms relying on sector specific software systems, in contrast, turns out to be smaller (36, not reported). Two different reasons might explain this issue. First, large firms generally tend to have the financial infrastructure to implement big and complicated customized software solutions. Secondly, the firm structure and business processes in large service firms might, in comparison to the situation in small firms, reach such a high level of complication and integration a simple generic enterprise software solution might be unable to handle. Accordingly, large firms may rely on customized software systems suited for their specific needs more frequently. As one might argue that those large firms could possibly drive the results of our empirical analysis we conduct appropriate robustness checks in the following.

Table 1: Summary Statistics

Variable	Mean	Mind.	Max.	N
service innovation	0.386	0	1	336
sector specific software	0.758	0	1	336
customized software	0.380	0	1	336
number of employees	38	1	449	334
log (number of employees)	2.718	0	6.107	334
firm age	20	2	108	310
log (firm age)	2.851	0.693	4.682	310
0-5 competitors	0.243	0	1	312
6-20 competitors	0.304	0	1	312
more than 20 competitors	0.451	0	1	312
share of employees working with PC	0.786	0.01	1	324
share of highly qualified employees	0.435	0	1	316
share of medium qualified employees	0.159	0	1	303
share of low qualified employees	0.383	0	1	311
share of employees younger than 30 years	0.194	0	1	308
share of employees between 30 and 55 years	0.656	0	1	318
share of employees older than 55 years	0.160	0	1	307
former service innovation	0.414	0	1	258
former process innovation	0.437	0	1	265
East Germany	0.405	0	1	335

Source: ZEW Quarterly business survey among service providers of the information society, own calculations.

4. Analytical Framework and Estimation Procedure

Introduced by Griliches (1979), this study will be based on a knowledge production function, following the basic assumption that the output of the innovation process represents a result of several inputs linked to research and ongoing knowledge accumulation, such as, e. g., former innovative experience or human capital (Vinding 2006). Following Engelstätter (2012), we include enterprise software in the knowledge production function, providing first insights into the relationship between business sector specific or completely customized enterprise software usage and the firm's innovation activity. This yields the following innovation relation:

$$SI_i = f\,(ES_i, L_i, C_i, FA_i, FS_{i,-1}, FP_{i,-1}, controls)$$

with SI_i covering service innovation for firm *i*, ES_i enterprise software used by firm *i*, L_i the labor input, C_i the competitive environment and FA_i the age of the firm. Former service and process innovations $FS_{i,-1}$ and $FP_{i,-1}$) as well as controls like sector classifications and region dummy are also included. The employed explanatory variables and their temporal sequence are explained in detail below. The endogenous variable we use as measure for innovation contains the information whether the firms are service innovators or not. As this dependent variable is a dummy and we assume a normally distributed error term, the widely established probit model as, e. g., introduced in Greene (2003) is used for inference.

The labor input L_i consists of firm size, qualification structure of employees, age structure of employees and IT-intensity. We control for firm size by the logarithm of the number of employees. Larger firms tend to have more lines of activity and therefore more areas in which they can innovate. This is valid for both the manufacturing and the service sector, see, e. g., Meyer (2010) or Leiponen (2005) for further information. Firm size is reported for the year 2008.

We also consider the qualification structure of the workforce by creating three control variables: the share of highly qualified (university or university of applied science degree), medium qualified (degree in technical college or vocational qualification) and low qualified (other) employees. All shares are measured in June 2009. The share of low qualified employees is taken as the reference category. In general, qualification pictures the suitable know-how and human capital which is essential for starting and enhancing innovations. Without suitable know-how, neither is successfully possible (Meyer 2010). Therefore, we assume that the higher the qualification of employees, the higher the innovative activity.

We control for the age structure of the employees with three variables. The first one represents the share of employees younger than 30 years and builds our reference category. The second variable captures the share of employees between 30 and 55 years whereas the third variable encompasses the share of employees over 55 years. Overall, the age structure of the employees is expected to drive the firms' innovative behavior. Börsch-Supan et al. (2006) point out that on the one hand, the process of aging leads to a cutback of fluid intelligence which is needed for new solutions and fast processing of information. Due to this fact an aging workforce could be more innovative. On the other hand, older workers may resist innovations as their "human capital" depreciates. Thus, the effect of the age structure of employees on innovative activity is an ambiguous issue. The age structure was measured in June 2009 in our survey.

Following, e. g. Engelstätter (2012), we proxy the IT-intensity of firms by the share of employees working with a computer in June 2007. Licht and Moch (1999) mention that IT can improve the quality of existing services, in particular customer service, timeliness and convenience. Moreover the productive use of IT is closely linked to complementary innovations (Hempell 2005).

The effect of firm age on innovation activity is still an ambiguous topic subjected to discussion. Koch and Strotmann (2006) mention that innovative output is higher in younger firms than in older ones. However, it is lowest in the middle-aged (18-20 years) firms and raises again with an age of over 25 years. On the one hand, firms could lose their adaptability to the environment with an increasing age or, on the other hand, organizational aging increases innovativeness due to learning processes. Firm age is also measured in the year 2008 in our sample.

The competitive situation is another relevant driver of innovative activity. We created three dummy variables representing the number of main competitors in June 2009 according to the firms' self assessment. The first one includes zero to five competitors, the second one six to twenty competitors which is our reference category and the last one more than 20 competitors. The relationship between innovation and competition is supposed to look like an inverted U curve (Aghion et al. 2005). A monopolist has less incentives to innovate as he already enjoys a high flow of profit. In a competitive situation, there are less incentives to innovate if there is no possibility to fully reap the returns of the innovation (Gilbert 2006).

There are several reasons for taking former innovation into account in our analysis. One of them is that innovative experience plays an important role in explaining innovations as successful innovations in the past lead to a higher probability for innovative success in the future (Flaig and Stadler 1994; Peters 2009). Another reason is a potential endogeneity bias our result might face, as it is not clear whether enterprise software leads to innovations or if innovative firms apply enterprise software merely as a diffusion channel for innovations. Both enterprise software variables were collected in June 2007 whereas the innovation variable was measured between June 2008 and June 2009. Accordingly, there is actually a time shift between the dependent and independent variable already forming a well-defined temporal sequence. Nevertheless, it is still possible that firms strategically purchased their enterprise systems in June 2007 or earlier simply for the diffusion of new innovated services starting out in June 2008. This may result in an upward bias of our estimated enterprise software coefficients. However, by controlling for former innovative activity we capture the overall innovativeness of a firm to some extent. If enterprise software shows no significant impact on today's innovation any more when controlling for former innovation, we can expect that the software was employed only because the firm is already innovative. A significant impact of the enterprise software in this case, however, would point towards a causality running from the adoption of the software to the realization of new service innovations as the employed software still has an impact on recent innovations with firms' overall innovativeness controlled for[9]. We use two dummy variables to control for former innovations. The first one is former service innovation that takes the value one if the firm realized at least one new or essentially improved service between March 2006 and March 2007. The second dummy variable is former process innovation that takes the value one if the firm implemented new or essentially improved technologies during the same time period. We control for both types of former innovations as service and process innovations are dynamically interrelated.

In addition, we use nine sector dummies to control for industry-specific fixed effects. A dummy variable for East Germany accounts for potential regional differences.

[9] The endogeneity bias due to commonly unobserved shocks affecting our sample as well as unobserved heterogeneity should also be reduced due to the large set of control variables we employ. However, without an available instrument we cannot exclude a potential bias completely.

5. Results

5.1 Main Results

Table 2 shows the average marginal effects of the probit estimation of equation (1)[10]. In the first model specification we estimate the raw effect of both enterprise software types on service innovation. The results indicate that sector specific software has no impact on service innovation. Firms using customized enterprise software instead seem more likely to innovate than firms which do not use this type of enterprise software. Based on a high significance level the probability to innovate is about 24.2 percentage points higher for firms using customized enterprise software.

In the second specification we include firm size, firm age and IT-intensity. The impact of sector specific and customized software on service innovation remains qualitatively unchanged in this specification suggesting that firms using customized software still face a probability of innovating that is 22.8 percentage points higher compared to firms not using this type of enterprise software. Furthermore, we observe that larger firms seem to have a higher probability of innovating as the marginal effect is significant at the five percent level. Firm age and IT-intensity appear to have no effect on service innovation. The insignificant impact of IT-intensity suggests that the significantly positive impact of customized enterprise software pictures not only an overall positive IT-effect but the real effect of this type of enterprise software.

In the third specification further variables capturing competitive situation, qualification structure and age structure of employees are added. The impacts of both enterprise software systems do again not change compared to former specifications indicating that the probability of realizing service innovations is higher for firms utilizing customized software. Older firms seem less likely to innovate, based on an estimated marginal effect significant at the five percent level. The age structure of the workforce reveals some interesting results. Firms with a higher share of employees between 30 and 55 years as well as employees over 55 years are less likely to innovate compared to firms with a higher share of younger employees. The impact of employees between 30 and 55 years is significant at one percent while the impact of employees over 55 years is only significant at ten percent.

In the fourth specification, we include dummy variables measuring former service and process innovations in our analysis. Based on a high significance level the average marginal effect suggests that the probability to innovate is larger for firms which have already realized service innovations in the past. The average marginal effect of customized software remains positive and significant proposing that customized software could indeed lead to service innovation instead of being employed simply because utilizing firms are already innovative as argued in section 0. However, the incorporation of former service innovation weakens the impact of customized software by reducing its significance level from one to five percent. In contrast to former service innovations, former process innovations seem to have no impact on current service innovations.

[10] Sample averages of the changes in the quantities of interest evaluated for each observation. Table 4 in the appendix contains the coefficient estimates.

The impact of firm age and employees between 30 and 55 years and employees over 55 years turns insignificant once we include former innovations into the estimation specification.

In summary, our results suggest that firms using customized enterprise software experience a higher probability of innovating compared to firms without this type of enterprise software or sector specific enterprise software. This result stays robust across all specifications and supports our hypothesis that customized enterprise software applications tailored to specific firms' needs helps to enhance service innovation activity. Additionally, our results also indicate that sector specific enterprise software solutions seem to have no impact on service firms' innovative performance.

Table 2: Probit Estimation Results: Average Marginal Effects

dependent variable: dummy for service innovation

	(1)	(2)	(3)	(4)
sector specific software	-0.055	0.026	-0.011	-0.003
	(0.060)	(0.064)	(0.073)	(0.081)
customized software	0.242***	0.228***	0.264***	0.182**
	(0.054)	(0.060)	(0.065)	(0.075)
log. firm size		0.047**	0.026	0.020
		(0.020)	(0.023)	(0.025)
log. firm age		-0.065	-0.150**	-0.098
		(0.055)	(0.063)	(0.072)
IT-intensity		0.056	-0.065	0.063
		(0.110)	(0.131)	(0.155)
competitors 0 - 5			-0.028	0.018
			(0.078)	(0.089)
competitors > 20			-0.055	-0.040
			(0.071)	(0.077)
highly qualified employees			0.026	-0.002
			(0.124)	(0.137)
medium qualified employees			0.018	-0.128
			(0.165)	(0.178)
employees 30 – 55 years			-0.468***	-0.184
			(0.172)	(0.194)
employees > 55 years			-0.368*	-0.189
			(0.221)	(0.244)
former service innovation				0.259***
				(0.080)
former process innovation				-0.033
				(0.074)
dummies		Sector	Sector	Sector
		East	East	East
observations	336	298	240	179
Pseudo R^2	0.046	0.103	0.147	0.206

Significance levels: *: 10%, **: 5%, ***: 1%.
Reference categories: competitors 6-20, unqualified employees, employees <30 years.

5.2 Robustness Check

To ensure the validity of our results obtained we also conduct several robustness checks[11]. First, as firms could adopt sector specific in conjunction with customized enterprise software, we also

[11] All tables of the regressions performed as robustness checks are available from the authors upon request.

estimate the model with an interaction term of the two enterprise software systems added. However, the interaction effect is not significant in all specifications and does not change the other results qualitatively.

The consideration of former innovations reduces our sample to the very low size of 179 observations. Due to the insufficient panel structure, we decide to estimate all specifications with this reduced sample size as another robustness check to ensure that our results are not driven by observation loss[12]. As a further robustness check, we also estimate all specifications without the industry and regional fixed effects. The results regarding the use of sector specific and customized enterprise software do not change qualitatively in all these robustness checks.

Our last robustness check covers the firm size in our sample. As it could be the case that especially some big enterprises drive the results we decide to restrict our sample to those enterprises with a number of employees at or below the mean in size for the complete sample, i. e. 37 employees or less. As this robustness check reduces our sample to 262 small and mediumsized enterprises (SMEs) we estimate all specifications as before except the last one controlling for former innovations. Adding former innovations to this reduced sample results in a number of observations too small for the model to achieve convergence. The results generated from analyzing our SMEs sample do not change qualitatively compared to the results obtained before. Accordingly, we suspect that big enterprises do not drive our empirical results indicating that customized enterprise software is useful for innovative activity in firms of any sizeclass.

6. Conclusion

This paper analyzes the relationship between different types of enterprise software systems and innovation in services. In the service sector, enterprise software is an essential tool for providing services. Therefore, it may represent a crucial contribution to a firm's innovation performance. We analyze the innovative impact of two different kinds of enterprise software, i. e. business sector specific and completely customized enterprise software. In essence, sector specific enterprise software is off-the-shelf software designed and standardized for certain industries whereas customized software is designed and adopted to the needs of a single firm thereby implying unique features. The analysis is based on a knowledge production function constituted by an innovation equation with data of German firms in ICT- and knowledge-intensive service sectors.

Our results suggest that ICT- and knowledge-intensive service firms using customized enterprise software that fulfills their specific requirements realize positive impacts in innovative activity. The results stay robust to several specifications and robustness checks proposing that not only big enterprises drive this positive impact but SMEs may also realize gains in innovative performance. However, it is important to mention here that customized enterprise software can only support service innovation if it is developed and applied properly, if the firm has complete knowledge of its organizational structure and processes and is aware of the goals it wants to achieve by using

[12] Table 5 in the appendix pictures the results of this robustness check.

customized enterprise software. These facts ensure an enterprise software system that is perfectly suitable for all business requirements. Only given these circumstances, service firms are able to profit from the quick delivery of information, enhanced knowledge processing, the strengthened connections of information sources or reflection of all needed business processes customized enterprise software is linked to. Another benefit that arises for firms using customized enterprise software is the increased IT know-how, especially when developing the software themselves. This know-how is an essential tool for innovation which is especially useful to ICT-intensive service providers as these firms could generate benefits out of it given that software development, for instance, is a major task in these industries.

In contrast, firms that use sector specific enterprise software cannot exploit the benefits outlined. Although this type of enterprise software is very supportive by providing frequently updated databases or presenting information in an adequate manner, these advantages by themselves seem, based on our results, insufficient to support service innovation. Accordingly, relying on off-the-shelf software applications seems to be no adequate strategy when aiming for innovations. Hence, managers should consider investing in developing and customizing the needed software systems to realize service innovations.

However, the current study is not without limitations, one of these being the establishment of a causality relationship as already mentioned above. Restrained to the available data, we also have no information about other unobserved factors potentially influencing the software adoption decision like management quality or implementation problems and costs of the enterprise systems installed. Accordingly, we have to use dummy proxy variables instead, possibly resulting in unobserved heterogeneity the estimation procedure cannot completely account for. Future availability of new data might offer the opportunity to control even for these special cases of firm heterogeneity and allow for further research exploiting in detail the determinants driving the adoption of different types of enterprise software.

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Appendix

Table 3: Distribution of Industries in the Sample

Industry	**Observations**	**Percentage**
software and IT services	43	12.80
ICT-specialized trade	33	9.82
telecommunication services	13	3.87
tax consultancy and accounting	56	16.67
management consultancy	37	11.01
architecture	54	16.07
technical consultancy and planning	34	10.12
research and development	38	11.31
advertising	28	8.33
sum	336	100

Source: ZEW Quarterly business survey among service providers of the information society, own calculations.

Table 4: Probit Estimation Results: Coefficient Estimates

dependent variable: dummy for service innovation

	(1)	**(2)**	**(3)**	**(5)**
sector specific software	-0.151	0.078	-0.036	-0.022
	(0.164)	(0.191)	(0.226)	(0.277)
customized software	0.633***	0.630***	0.767***	0.586**
	(0.144)	(0.166)	(0.194)	(0.234)
log. firm size		0.139**	0.082	0.071
		(0.060)	(0.072)	(0.087)
log. firm age		-0.192	-0.463**	-0.337
		(0.164)	(0.201)	(0.251)
IT-intensity		0.166	-0.203	0.216
		(0.325)	(0.405)	(0.531)
competitors 0 - 5			-0.088	0.063
			(0.245)	(0.300)
competitors > 20			-0.170	-0.136
			(0.219)	(0.263)
highly qualified employees			0.082	-0.008
			(0.383)	(0.468)
medium qualified employees			0.058	-0.438
			(0.512)	(0.610)
employees 30 – 55 years			-1.445***	-0.629
			(0.554)	(0.667)
employees > 55 years			-1.136	-0.646
			(0.692)	(0.839)
former service innovation				0.816***
				(0.250)
former process innovation				-0.114
				(0.259)
constant term	-0.426***	-0.410	1.794*	0.520
	(0.156)	(0.667)	(0.929)	(1.119)
observations	336	298	240	197
pseudo R^2	0.046	0.103	0.147	0.206

Significance levels: *: 10%, **: 5%, ***: 1%.

Reference categories: competitors 6-20, unqualified employees, employees <30 years.

Table 5: Probit Estimation Results: Average Marginal Effects, Reduced Sample

	dependent variable: dummy for service innovation			
	(1)	**(2)**	**(3)**	**(4)**
sector specific software	-0.040	0.007	-0.001	0.003
	(0.079)	(0.083)	(0.084)	(0.081)
customized software	0.290***	0.250***	0.239***	0.182**
	(0.071)	(0.074)	(0.074)	(0.075)
log. firm size		0.030	0.026	0.020
		(0.025)	(0.026)	(0.025)
log. firm age		-0.167**	-0.158**	-0.098
		(0.069)	(0.072)	(0.072)
IT-intensity		0.108	-0.096	0.063
		(0.139)	(0.157)	(0.155)
competitors 0 - 5			-0.048	0.018
			(0.094)	(0.089)
competitors > 20			-0.014	-0.040
			(0.078)	(0.077)
highly qualified employees			0.007	-0.002
			(0.142)	(0.137)
medium qualified employees			0.065	-0.128
			(0.181)	(0.178)
employees 30 – 55 years			-0.285	-0.184
			(0.199)	(0.194)
employees > 55 years			-0.279	-0.189
			(0.251)	(0.244)
former service innovation				0.259***
				(0.080)
former process innovation				-0.033
				(0.074
dummies		Sector East	Sector East	Sector East
observations	179	179	179	179
pseudo R^2	0.071	0.145	0.157	0.206

Significance levels: *: 10%, **: 5%, ***: 1%.

Reference categories: competitors 6-20, unqualified employees, employees <30 years.

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Measuring Innovation and Investment in Intangible Assets

Introduction

Not everything that counts can be counted,
and not everything that can be counted counts. (Cameron, 1963)

This quote, sometimes attributed to Einstein though actually coined sometime after his death by William Bruce Cameron, can be taken, in the context of intangible investment[1], as both a challenge and a warning. Intangible assets are difficult to measure but their importance is beyond question, thus despite the inherent difficulty, we must develop methods to accurately quantify them.

To extent the quote somewhat, and admittedly risk its elegance, I would add that *not everything we want to count can be counted*[2]. By this I mean that we, as a national statistical agency, must temper the desire to attempt to collect information on everything with the restraints of budgets, respondent burdens and the ability of respondents to accurately provide information.

In December 2011, Statistics Sweden received a directive from the Swedish government to "Develop existing and, where deemed relevant, new indicators for innovation". The directive is one of the many measures taken by the government to strengthen the innovation capacity of the country. The task is to be carried out within four years, with a final report to be presented in February, 2016.

The directive points to the importance of developing indicators that reflect the connection between innovation activities and productivity and growth. Investment in intangible assets is also mentioned as an innovation activity of special interest; as an important driver and enabler of innovation. It is, however, an area that is currently under-measured because of the focus on tangible assets.

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[1] The OECD Frascati Manual defines intangible investment as all non-capital expenditures on non-routine marketing, training, software and some other similar items, in addition to current expenditure on R&D which is expected to give a return over a longer period than the year in which it is incurred (2005).
[2] My own addition

Statistics Sweden’s main role as a government agency is to supply customers with statistics for decision making, debate and research. In relation to investments in intangible assets, our main job is, therefore, to look at how we can gather data and produce statistics in such a way to facilitate research and analysis in the area.

The purpose of this paper, and the accompanying presentation, is to problematise investment in intangible assets from the perspective of the innovation statistics project and to provide the basis for discussion and input at Saltsjöbadskonferensen, regarding the measurement of intangible investments and the development of indicators for analysis of their impact.

We begin by giving a outlining of the main features of the Corrado, Hulten and Sichel framework and the work by Harald Edquist in applying it in a Swedish context. Thereafter, we briefly summarise the attempts to measure investments in intangible assets in the Community Innovation Survey, and the difficulties in using it as an instrument for measurement. This will be followed by a general discussion about the difficulties in measuring intangible investments and analysing their impact. Finally, the paper concludes with questions raised by the project.

Corrado, Hulten and Sichel (CHS) Framework

One of the most accepted and widely used methods of calculating investment in intangible assets is the expenditure based methodological framework developed by Corrado, Hulten and Sichel (2006). Intangible assets are grouped in the three following categories:

- Computerised information (software, computerised databases)
- Innovative property (scientific R&D, mineral explorations, copyright and licence cost, product development in financial industries, design, R&D in social sciences and humanities)
- Economic competencies (brand equity, vocational training and organizational capital)

The CHS framework is based on the premise that "any use of resources that reduces current consumption in order to increase it in the future qualifies as an investment" (2006, p. 9). Accordingly, many items previously considered to be expenses in the national accounts should be classed as investment along with plant and equipment. It follows then that this expanded definition of capital includes all investments in human capital (not just outlays by government and not-for-profit institutions on education), R&D expenditure, and indeed any expenditure in which a business devotes resources to projects designed to increase future rather than current output, whether it is intangible or tangible (Mortensen & Piekkola, 2011). Objective valuation of these assets remains however difficult in some cases, as is the accurate separation of some investments which retain a current cost component. Problems regarding "verifiability[3], visibility[4], non-rivalness[5], and appropriability[6]" (Corrado, Hulten, & Sichel, 2006, p. 9) persist when attempting to disentangle intangible investment from tangible investment.

CHS in Sweden

This re-evaluation of what is considered an expense vs. investment also goes some way to explaining the decreased investment in tangible assets, which many lament as a negative trend. Rather than decreased total investment, we see a shift from expenditure in tangible to intangible investment as developed countries move from manufacturing to knowledge-based economies. The CHS framework was applied in Sweden by Harald Edquist (2011). Edquist estimates investment in intangibles in 2006 to 288 billion SEK or 10 percent of GDP. The figure for physical capital in the private sector was 382 billion SEK. He also found that TFP accounted for 47 percent of economic growth and 50 percent of labour productivity growth when intangibles were excluded. With the inclusion of intangible investment, however, the TFP component decreased substantially.

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[3] Many intangible assets are produced and used in-house therefore, there is no arms-length market to quantify and value the asset.
[4] Given intangibles lack of physical embodiment they are, by definition, more difficult to account for.
[5] May be used by multiple users without diminishing the usefulness to a single user.
[6] The full benefit of the investment may not be captured by the firm. Especially in the case of training which is tied to the employee rather than the firm.

Expenditure on computerised information

Figures on *expenditure on computer software* and *computerised databases* are produced by Statistics Sweden and part of Sweden's official statistics. A sample of enterprises with 10 or more employees is used.

Innovative Property

Scientific R&D statistics are Statistics Sweden's data and are part of Sweden's official statistics. Here, R&D expenditures for design, market research and other R&D that is not scientific in nature are excluded. In addition to this, Edquist removed R&D spending on computers and related activity to avoid double counting software figures. *R&D in social sciences and humanities* is the turnover of R&D in the social science and humanities industry (SIC 732)[7]which Edquist doubles to capture own account spending.

Figures relating to *mineral exploration* are sourced from the Geological Survey of Sweden. They cover expenditure in prospecting for new ore deposits the aim of which is to capture R&D in the mining sector.

*Copyright and licens*e data on expenditure in the development of creative originals is from Screen Digest in 2005. These figures are extremely difficult to evaluate. Due to the lack of data for radio, television and sound recording these costs are estimated at 5 times that of the development costs of motion pictures. Missing from this are costs related to licensing and purchasing for patents.

How can patent figures relating to purchase and licensing be incorporated?

Product development in the financial services industry was sourced from the EUKLEMS database. The absence of input output tables did not allow Edquist to adjust for the fact that intermediate spending, according to Marrano and Haskel (2006), includes the purchase of advertising, software, consulting services and architectural and engineering activities which is accounted for elsewhere in the spending calculations. It is consequently measured as 20 percent of total intermediate spending by the financial industry. This method of estimation is arbitrary in nature and would benefit greatly from further research.

How can estimates for product development in the financial services industry be improved?

[7] Standard Industrial Classification (SIC) 732 is roughly equivalent to the Statistical Classification of Economic Activities in the European Community (NACE) 72.2. Both are forms of industrial classification.

Design was calculated by CHS by using 50% of the total turnover of the architectural and engineering design (AED) industry to estimate purchased and own-account expenditure. Edquist used a more sophisticated approach. For purchased AED, the output of the Architectural activities and technical consultancy industry (SIC 742)[8] was used. The wage bill of designers working in other industry groups was used to estimate own-account expenditure.

Economic competences

Brand equity is divided into *advertising* and *market research*. Advertising as measured by the Swedish Institute for Advertisement excluding expenditure for classified ads and public sector expenditure. Market research expenditure is estimated from data from Statistics Sweden. It is calculated as twice the turnover of the Market and consumer research industry (ISIC 7413)[9] as it is assumed that in-house expenditure equals purchased market research.

Firm-specific human capital is estimated with data produced by Statistics Sweden with the Continuous Vocational Training Survey (CVTS). At the moment the data used in this indicator is of poor quality as the survey has been plagued by low response rates[10], so much so that Statistics Sweden declined to release the results of the survey in 2005. As Marrano and Haskel (2006) point out, collecting data on employee training is further complicated by the fact that the employer incurs not only the cost of providing training but also the opportunity cost of the employee's time whilst undergoing training.

Organisational structure expenditure is made up of both *purchased* and *in-house*. The data for the purchased portion was sourced from Statistics Sweden using the turnover of the "business and other management consultancy activities[11]" industry and Swedish business magazine Affärsvärlden that conducts an annual survey.

In-house expenditure is estimated as 20 percent of managers' compensation. This is at best a guess, as all researchers in the field will freely admit, and more research is necessary to better estimate this figure.

How can in-house organizational structure expenditure estimates be improved?

[8] SIC 742 is roughly equivalent to NACE 71.1.
[9] The International Standard Industrial Classification of All Economic Activities (ISIC) is the international reference classification of productive activities by the UN (United Nations, 2008).
[10] CVTS had a response rate of 42 percent.
[11] NACE 70.22

Community Innovation Survey (CIS)

The Community Innovation Survey is a biennial EU-regulated survey which aims to measure innovation activity in the private sector. CIS asks respondents about their enterprise's innovations and innovation activity in products, processes, organisational and/or marketing methods.

A relatively small but important component of CIS is the section regarding expenditure in conjunction with innovation activity. The questions ask respondents to indicate if they have engaged in various activities relating to the firm's innovation such as R&D, training, acquisition[12], marketing and design.

While CIS provides valuable insight into spending on intangible assets during the process of innovation, CIS is not, in its current form, an appropriate tool to measure the full extent of intangible investment for the following reasons:

- Respondents are asked to only include spending made specifically in the innovation process. Therefore, a significant portion of spending is excluded. Enterprises with no innovation activity are also excluded.
- Some questions do not differentiate between intangible and tangible asset investment. On spending for the acquisition of machinery, equipment and buildings[13], software is also included.
- This section focuses solely on product and process innovation. Organisational innovation, for example, is not included, thus an extremely important intangible investment component (Piekkola, 2011) is missing in the calculation.
- The survey method requires self reporting and to some extent subjective estimation of expenditures which can lead to a reduction in the reliability of the statistics. Cognitive tests have shown that this is partly due to the difficulty respondents have in understanding concepts such as design and partly due to the difficulties in calculating the cost relating to innovation activity.

Would expanding the number of expenditure categories in CIS help research into the utilization of intangible assets in the innovative process?

[12] Includes acquisition of machinery, equipment, software and building as well as existing knowledge from other enterprises or organisations.
[13] Buildings is included in the proposal for CIS2012 and may be subject to change.

Problems and Challenges

The following is a brief discussion of a few of the many problems and challenges facing attempts to measure investment in intangible assets. For a more comprehensive cataloguing of the issues see the third assessment paper covering ICT R&D and intangibles from the OECD's ICTNET conference[14].

Investing vs. Spending

According to the CHS framework the difference between spending and investment and the degrees between the two is best described as arbitrary. More research is needed to arrive at more accurate methods of estimation.

Take the example of advertising. Some advertising is purely for the purpose of improving brand image and could, therefore, be considered as investment. However, this is seldom the case. Rather, advertising is more often than not closely related to the selling a specific product or service or for some short term publicity goal. However, given that it is difficult to advertise a product without mentioning the brand, advertising expenditure is part cost, part investment. The definitions and ratios between the two are, as yet, ultimately arbitrary and extremely subjective. While economic research suggests that gains from advertising are generally short-lived, Landes and Rosenfield (1994) found that more than half has a service life of at least one year and one-third makes a cut-off of three years. Accordingly, Corrado et al estimate 60% advertising as being investment.

Organisational rejuvenation expenditure versus investment is also extremely difficult to differentiate. As with advertising, the difference between short-term spending and long-term investment is not always clear or distinguishable. The CHS framework uses 20 percent of executive compensation to estimate this figure. They hypothesise that, although executive do perform duties relating to organisational rejuvenation, they also complete administrative tasks that are short-term in nature. Using a blanket 20 percent is at best arbitrary however a better alternative is not yet apparent. A study by Mariagrazia Squicciarini and Marie Le Mouel (2012), however, using a task-based approach with US data found that "estimates of investment in organisational capital appear on average 90% higher than the estimates of CHS." Further research in this area is needed to improve estimation.

Could creating sector estimates, as Landes and Rosenfield (1994) *attempted, be a better way to get closer to the true ratio?*

Moreover, using executive compensation to estimate the amount of investment in organisation rejuvenation is, even with improvements using a task-based approach, not applicable for international comparison. Executive compensation has risen, for example, in the US to a far greater extent than Sweden. It could not,

[14] https://community.oecd.org/docs/DOC-38254

however, be argued that US executives are performing more tasks relating to organisation rejuvenation than Swedish executives or that productivity is necessarily higher in the US which is reflected in the compensation gap.

The CHS framework used an estimate of 100% of firm-specific human capital to be considered investment. However, according to Mortensen and Piekkola, training is not controlled by the firm and, therefore, if an employee leaves after being trained, the expenditure should be considered as a current cost. Given however, that the employee does not leave the labour force or is made unemployed, rather finds a new job and that the training received is not specific only to the firm, the investment made by the original firm may not be entirely lost. In terms of macro accounting, where the employee works is irrelevant, however, on a micro level there is a difference. The first firm has made a poor investment and is not able to benefit from the training. The new firm will benefit from the employee given that the training received is of use to the new firm. The new firm will compensate the employee thus transferring the gains from the old firm to the employee. The degree of specificity in the training will be a factor in determining the extent of the loss when the employee changes jobs.

More than just measuring

What we are currently doing then, if we follow the CHS framework, is measuring the amount of investment in intangible assets. This is an important start; however it is only a piece of the puzzle. Next we must investigate how these investments are used and to what extent and how much this utilisation results in gains in productivity and growth. We must also understand how these are assets are most effectively utilised and what levels of investment are optimal. That is, we must understand if an investment in one asset must be matched with investment in another asset or assets to maximise the benefits to productivity and growth.

Complementarities

This study of complementarities looks at the interplay and interdependence between different investments. If there is a complementarity between two assets then investment in both will yield higher gains than an equally large investment in either asset separately. Computer equipment and computer training for staff is an obvious example. Equipment without capable users a wasted investment as is newly computer savvy employees with no computers. An initially less obvious complementarity is between IT investment and changes in organisational practices. Brynjolfsson, Hitt and Yang (2002) found that firms that enact “a specific cluster of organizational characteristics, including greater use of teams, broader distribution of certain decision rights, and increased worker training” [...] “and have a large computer capital stock have disproportionately higher market valuations”. Indeed, Bresnahan, Brynjolfsson, and Hitt (2000) found that “firms that implement only one complement, without the others, are often less productive than firms which

Which complementarities would be interesting to study, were it not for a lack of data?

implement none at all".

How can current data be used to study intangible assets utilisation?

ICT investment is an example of an intangible asset with which innovative activity is often linked. Statistics Sweden produces annual statistics on the enterprise's ICT expenditure as well as data on enterprises' ICT usage. By linking these two data sets we would be able to see changes in ICT usage as in terms of money invested. By also linking data related to IT training, we would be able to see if enterprises invest in training staff or hire ready-trained staff to complement increases in IT.

Public Investment in Intangible Assets

In Edquist's calculations using the CHS framework, public sector investment was excluded. Public sector investment is nonetheless believed to be of great importance especially in Sweden, whose public sector is relatively large. Edquist suggests that "comparisons of intangible investment in the private sector expressed as a percentage of total GDP might be affected" when public sector spending is excluded." The CHS framework has, as yet, not been applied to public sector investment. The private sector is motivated to make effective use of intangible assets in order to maximise profit. A manager in the public sector is also interested in effective use however, for better or worse, the profit motive is not in play. Given then that the public sector is driven by other factors than profit and shareholder wealth, which are relatively easily measured, the CHS framework may require significant development and adjustment before being used in the public sphere.

What, if anything, needs to be changed within the CHS Framework for it to be effectively applied in the public sector?

What is Statistics Sweden’s and the Innovation Statistics Project’s role?

Our role in this picture is to gather data and produce statistics in such a way as to facilitate new research which can in turn lead to superior government policy and social welfare gains. Our job is to provide the means to measure the amount of investment in intangible assets but also to be able to link these investments with actual benefits to individuals, enterprises and society as a whole.

Intangible investment is a prioritised area for our project. We will begin by looking at how intangible investments can be more accurately measured. We see Harald Edquist’s and other’s work in the area as a good starting point and working to improve the underlying data as an important step in the process. We continue to follow developments in academia and elsewhere that assist us in producing comprehensive and useful measurements.

Another important area for the project is investigation into leveraging current data stocks and improving the surveys we already conduct is also a priority for the project. We strive to develop a high quality database that not only benefits Swedish research and decision making but that is also in line with international development such that comparisons and bench marking is possible.

Questions:

How can patent figures relating to purchase and licensing be incorporated?

How can estimates for product development in the financial services industry be improved?

How can in-house organizational structure expenditure estimates be improved?

Would expanding the number of expenditure categories in CIS help research into the utilization of intangible assets in the innovative process?

Could creating sector estimates be a better way to get closer to the true ratio between spending and investment in advertising?

Which complementarities would be interesting to study, were it not for a lack of data?

What, if anything, needs to be changed within the CHS Framework for it to be effectively applied in the public sector?

How important is measuring intangible assets in the public sector?

Are aggregated figures regarding intangible assets useful in research into innovative activity?

Special thanks to Elif Köksal-Oudot from the OECD, whose enthusiastic discussion of this paper at the Saltsjöbaden conference provided valuable insight and answered many of the questions posed in this paper.

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ISSN 1654-0506 (Online)

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