PAPERS PRESENTED AT THE SALTSJÖBADEN CONFERENCE OCTOBER 2009

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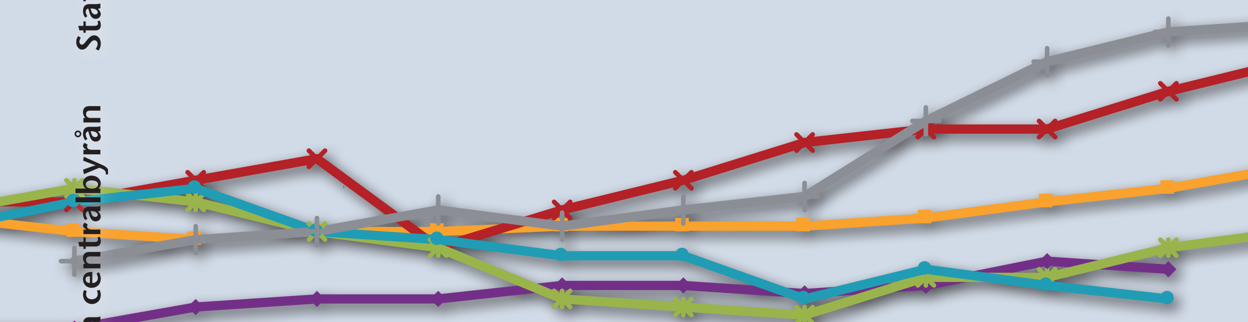

Yearbook on Productivity 2009

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Statistics Sweden
2009

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Foreword

Growth is important. Today's growth is what we have to live on tomorrow. 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. The commission's proposals were well received by the Government, which commissioned Statistics Sweden to carry out this programme, of which this yearbook is a part of. The results of this program wars presented at this year's conference.

This yearbook contains a number of productivity studies; some are more oriented towards measurement and some more towards analysis. The articles have been written by colleagues outside Statistics Sweden as well as people from our own organisation or in cooperation. This year's yearbook is the fifth one and was presented at our yearly conference in Saltsjöbaden as the coming yearbook.

We want to especially thank Anna-Leena Asikainen at Centre d'Innovation par les Technologies de l'Information (CITI), Luxembourg and Mariagrazia Squicciarini VTT Innovation Studies, VTT Technical Research Centre of Finland, John Baldwin, Ryan Macdonald and Wulong Gu at Statistics Canada, Julien Dupont, Dominique Guellec and Joaquim Oliveira Martins at the OECD and Sara Johansson at Stockholm University for their contributions. Those involved in this yearbook at Statistics Sweden include; Kaisa Ben Daher, Olle Grünewald, Caroline Ahlstrand and Hans-Olof Hagén, Project Manager.

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Contents

Innovation and the construction industry: A value-chain based definition of the sector

Anna-Leena Asikainen[1] and Mariagrazia Squicciarini[2]

The paper proposes a NACE-based definition of the construction sector aimed at encompassing the whole value chain of the industry. It does so by adding to Section F of the classification, i.e. the official construction section; class-codes of activities that depend upon or are functional to core construction activities but that are classified outside the sector. These classes relate to: "pre-production" activities intended as the provision of intermediate inputs, whether manufacturing or services activities; "support" activities; and "post production" functions, intended mainly as maintenance and management services. Using data from Finland and the Community Innovation Survey 4 (CIS4) the paper characterises core and non-core construction activities, and shows how the sector's composition, structure, value added, skills, and R&D-input and output indicators change when including non-core activities. It finally points out some policy implications of using the "wide" definition proposed.
Keywords: construction, NACE classification, core activities, innovation, pre-production, post-production.

1. Introduction

Economic downturns, like the one began in 2008, emphasise the need to address structural and sectoral problems, and to identify ways to increase productivity and, more generally, competitiveness. They also stress the importance of monitoring the implementation and outcome of the policies put in place to meet these challenges. Innovation supporting policies are often seen as "the" way to improve the performance and competitiveness of industries, since consensus exists about the positive relationship characterising innovative output and productivity (among others, Crépon et al, 1998; Griffith et al., 2006; Criscuolo et al., 2008). Such a relationship proves to hold in all sectors, whether high tech industries

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like biotechnology or – traditionally considered as – scarcely dynamic sectors like construction. Designing purposely tailored sectoral policies and assessing their effectiveness hence call for a precise and systemic definition of the industry to be intervened, so that the most suitable tools may be chosen. To have greater leverage, policies in fact often need to encompass the entire the value-chain of the targeted industry. This is especially true for sectors, like construction, seeing the presence of a multiplicity of heterogeneous actors, specialties, and trades.

The present paper focuses on the construction industry and proposes a comprehensive definition of the sector that encompasses the most important activities carried out throughout the construction value chain. It arises out of a careful analysis of the content of NACE[3] divisions, groups and classes, and highlights those components of the construction industry left outside the official definition of the sector, but that we believe constitute fundamental parts of it. The definition proposed relies on 4-digit NACE classes other than and in addition to those included in the F section, i.e. the official construction section. To the best of our knowledge, the herewith proposed taxonomy is the first to explicitly attempt to translate and formalise in terms of NACE classes the wide range of activities traditionally considered as part of the construction cluster[4]. Being NACE-based, our classification has the advantage that it does not require statistical data to be gathered or aggregated in different way. Moreover, since most statistical offices worldwide rely on NACE or on equivalent taxonomies to classify economic activities, the definition of construction we propose would be immediately applicable and suitable for comparisons across countries and over time.

Using data from Finland and the Community Innovation Survey 4 the study shows the extent to which the proposed definition may change the perception and indeed the quantification of the performance of the sector. This in turn warns about the way innovation policies for construction are designed and evaluated, especially if relying on the ”strict” NACE Section F-based classification of construction. The latter in fact only encompasses the construction of buildings, civil engineering, and construction specialised activities, but completely overlooks components like e.g. the manufacture of construction products, or the architectural and engineering activities needed for construction. These activities and components are nevertheless fundamental for the functioning and the advancement of the sector, and may cause policies to fail, if left outside of their scope.

[3] *The acronym NACE stands for "Nomenclature générale des Activités économiques dans les Communautés Européennes", i.e. statistical classification of economic activities in the European Communities.*

[4] *In this respect see, for instance, the "Finnish Real Estate and Construction Cluster", www.kirafoorumi.fi*

The remainder of the paper is organised as follows. Section 2 characterises construction and its relevance, whereas Section 3 discusses construction's main features vis-à-vis the innovative behaviour of the sector. Section 4 discusses the current statistical definition of the industry and proposes an alternative value-chain based definition of the sector. Section 5 offers some statistical evidence about how much of the sector is overlooked when only NACE Section F codes are considered. Finally, the conclusions in Section 6 briefly highlight the possible implication for innovation policy making of adopting the ”wide” definition proposed.

2. Characterising construction: The industry and its relevance

Construction is a very ancient industry, dating back to the very existence of mankind and human beings' need to get sheltered. Despite being born before the advent of industry as we today conceive it, construction keeps representing a fundamental part of modern economies. According to FIEC, the European Construction Industry Federation, in the year 2008 construction accounted for a total of 3 million enterprises (EU27), the 95% of which with less than 20 workers, and contributed to about 50% of gross fixed capital formation. In 2008, construction also represented a major employer of the economy, accounting for 7.6% of total employment (EU27), which corresponds to 30% of industrial employment (FIEC, 2009). To give an idea of the sheer size of the sector, Table 1 shows the total employment figures of construction (in thousand units) during the period 1999-2007, for selected countries.

Table 1: Total employment in construction 1999 - 2007 (in thousand units)

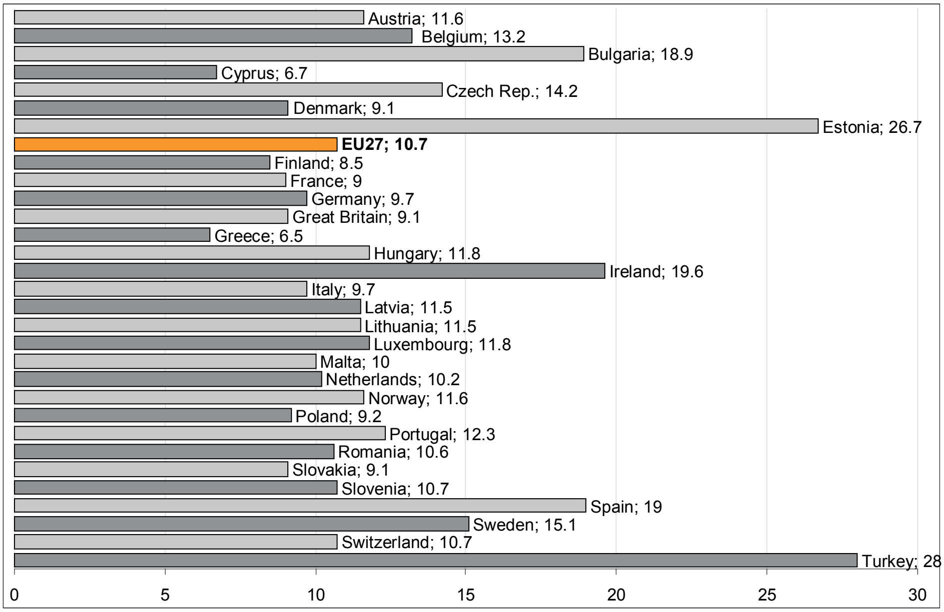
	1999	2000	2001	2002	2003	2004	2005	2006	2007
Austria	281	276	265	258	255	253	253	257	260
Germany	2,859	2,769	2,598	2,439	2,322	2,254	2,165	2,159	2,199
Spain	1,570	1,749	1,914	2,006	2,113	2,233	2,390	2,520	2,697
Finland	149	154	152	153	154	157	164	165	174
France	1,527	1,586	1,630	1,652	1,661	1,689	1,736	1,809	1,890
Great Britain	1,854	1,900	1,917	1,948	1,997	2,069	2,119	2,165	2,230
Italy	1,559	1,611	1,711	1,746	1,794	1,823	1,890	1,902	1,911
Netherlands	461	472	484	478	460	450	453	466	482
Portugal	539	596	586	622	584	548	554	553	571
Romania	270	281	262	279	378	337	363	380	420
Sweden	225	225	232	235	238	242	254	270	285
Slovakia	136	127	125	128	131	134	143	156	166
EU	13,000	13,488	13,618	13,715	13,938	14,097	14,459	14,880	15,623

Source: Authors' own compilation on data from FIEC (2008).

The construction sector is not only a major employer of all economies, but it also accounts for a quite substantial share of countries' GDP. In 2007, construction made up for the 10.7% of the EU27 GDP (FIEC, 2008), as can be seen in Figure 1. Construction's share of GDP translates into a quite remarkable contribution of the sector to the generation of value added[5]. This is true for all nations, whether industrialised nations as Europe and the US or emerging countries like India (see Figure 2).

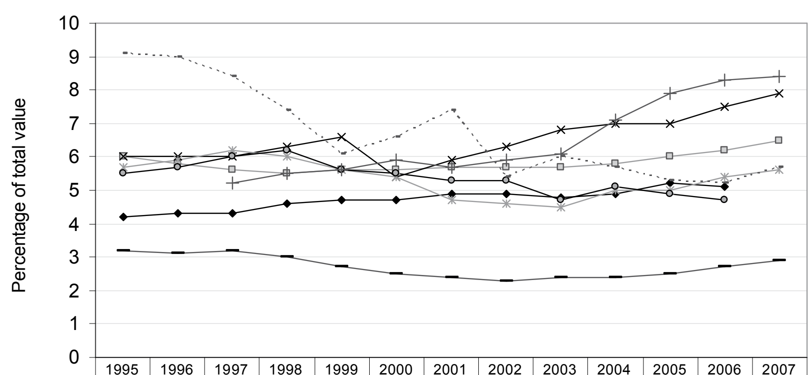
[5] *The OECD defines gross value added as output minus intermediate consumption. It equals the sum of employee compensation, gross operating surplus of government and corporations, gross mixed income of unincorporated enterprises and taxes less subsidies on production and imports, except for net taxes on products. Total value added is less than GDP because it excludes value-added tax (VAT) and other product taxes.*

Figure 1: Construction's share of GDP in 2007 (in percentage)



Source: Authors' own compilation on data from FIEC (2008).

Figure 2: Construction's share of value added 1995 – 2007 (selected countries)

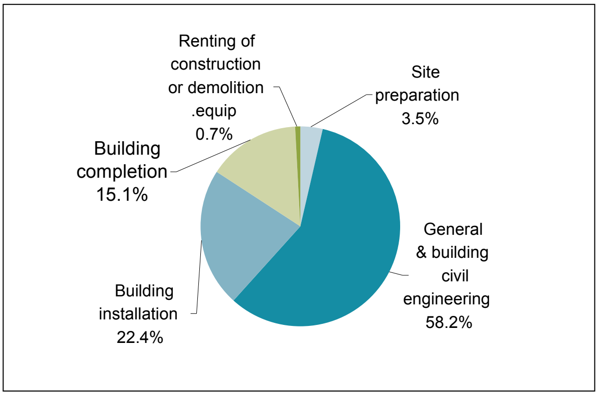


	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
United States	4.2	4.3	4.3	4.6	4.7	4.7	4.9	4.9	4.8	4.9	5.2	5.1	
EU27 total	6	5.8	5.6	5.5	5.6	5.6	5.7	5.7	5.7	5.8	6	6.2	6.5
Australia	6	6	6	6.3	6.6	5.4	5.9	6.3	6.8	7	7	7.5	7.9
Turkey	5.7	5.9	6.2	6	5.6	5.4	4.7	4.6	4.5	5	5	5.4	5.6
Brazil	5.5	5.7	6	6.2	5.6	5.5	5.3	5.3	4.7	5.1	4.9	4.7	
India			5.2	5.5	5.6	5.9	5.7	5.9	6.1	7.1	7.9	8.3	8.4
Russian Federation	9.1	9	8.4	7.4	6.1	6.6	7.4	5.4	6	5.7	5.3	5.2	5.7
South Africa	3.2	3.1	3.2	3	2.7	2.5	2.4	2.3	2.4	2.4	2.5	2.7	2.9

Source: Authors' own compilation on data from OECD Factbook 2009.

According to Eurostat (2009), more than half of the total value added of the construction sector is generated by general building and civil engineering activities (58.2%). These are followed by building installation (22.4%) and building completion (15.1%), as can be seen in Figure 3 below.

Figure 3: Construction's value added by activity



Source: Eurostat (Structural Business Statistics), 2009.

If on the one hand construction contributes importantly to the employment, GDP, value added, and capital stock creation of all countries, it nevertheless makes massive use of and has a very strong impact on natural resources. More than 50% of all the materials extracted from the earth are in fact transformed into construction materials and products. Moreover, construction and the built environment are accountable for the largest share of greenhouse gas emissions in terms of energy use, and the sector produces one of the largest waste streams - even though a significant part of it is renewable or re-usable (COM(2007)860-final).

3. Construction's main features vis-à-vis innovative behaviour

Construction is generally held as a low-productivity low-technology sector, a scarcely dynamic industry that underperforms compared to other industries (Manley, 2008). The sector is characterised by low R&D investment (Gann, 2001[6]), very long economic cycles, and strong cyclical variations in both demand and profits. These accentuate the financial risks associated to R&D investment in the sector (Blackley and Shepard III, 1996), and ultimately stiffen the innovative capacity of the sector. Construction generally suffers from a lack of the necessary financial resources for innovation, which in part depends on the low profitability and small average size of firms in the industry. Furthermore, construction activities are mainly project-based, and lack of the skills required to conducting R&D and innovation activities. This ultimately makes construction firms suffer from a short term perspective, and may lead them to suboptimal behaviours (Gann, 1996) that impinge upon enterprises' ability to innovate and develop technically (Dubois and Gadde, 2000).

Construction owes its composition, dynamics, performance and innovative behaviour to the very characteristics of the output it produces. Whether directed to the residential, non residential or infrastructure markets[7], construction output differs in many ways from other manufactured goods. It is generally represented by large and immobile goods, and entails a high degree of complexity and interdependence in terms of number and range of resources and components involved, as well as number and degree of interactions needed[8]. Construction output is meant to be more durable and is usually more expensive than other manufactured goods, with a life-cycle of several decades or more. It further features a slow replacement rate of the building stock, and an even lower rate of demolition.

3.1 Technical interdependence and organisational independence

Construction is characterised by technical interdependence and organisational independence (Crichton, 1966), i.e. by the fact that many independent and heterogeneous actors are needed for construction (multi-inputs) goods to be obtained. The many specialisations / tasks that make up the sector can be seen in Table 2, which shows data from the United Kingdom (Construction Skills Network, 2009).

[6] *Country-specific differences nevertheless exist, with R&D investments in the construction sector in France, Japan and Scandinavia that are not as low as in other countries Gann (2001).*

[7] *These are the markets envisaged in the COM(2007) 860 final.*

[8] *Gann (1996) highlights that cars are on average assembled from around 20,000 items, whereas houses might require 200,000 components.*

Table 2: United Kingdom total employment in construction by occupation

	2009	As % of SIC 45 ^	As % of SIC 45 & 74.2^
Senior, executive, and business process managers	98,010	4.37	3.87
Construction managers	219,080	9.77	8.64
Non-construction professional, technical, IT, and other office-based staff	282,340	12.60	11.14
Wood trades and interior fit-out	281,150	12.54	11.09
Bricklayers	88,160	3.93	3.48
Building envelope specialists	92,590	4.13	3.65
Painters and decorators	135,660	6.05	5.35
Plasterers and dry liners	48,300	2.15	1.90
Roofers	46,520	2.08	1.83
Floorers	38,050	1.70	1.50
Glaziers	41,740	1.86	1.65
Specialist building operatives nec*	56,170	2.51	2.22
Scaffolders	24,260	1.08	0.96
Plant operatives	46,750	2.09	1.84
Plant mechanics/fitters	27,060	1.21	1.07
Steel erectors/structural	28,330	1.26	1.12
Labourers nec*	116,590	5.20	4.60
Electrical trades and installation	177,880	7.94	7.02
Plumbing and HVAC Trades	176,920	7.89	6.98
Logistics	32,280	1.44	1.27
Civil engineering operatives nec*	59,660	2.66	2.35
Non–construction operatives	123,930	5.53	4.89
Total (SIC 45)	2,241,430	100.00	88.40
Civil engineers	52,300		2.06
Other construction professionals and technical staff	143,930		5.68
Architects	40,550		1.60
Surveyors	57,280		2.26
Total (SIC 45 and 74.2)	2,535,490		100.00

Legend: * nec - not elsewhere classified
^ SIC, Standard Industrial Classification[9]

Source: Authors own compilation on data from the Construction Skills Network, 2009.

As can be inferred from having a look at the distribution and type of tasks accomplished by the construction workers, the sector is characterised by an on average low education of its workforce. This often leads to firms exhibiting little absorptive capacity, and to encounter many construction trades where learning is neither organised nor widespread. Such features are worsened by the fact that the sector suffers from a high turnover of human resources, with the 12%–13% of all workers in the EU27 reporting just one year or less of service (EFILWC, 2007).

[9] *The United Kingdom Standard Industrial Classification of economic activities (UK SIC) is used to classify business establishments and other standard units by the type of economic activity in which they are engaged. The UK SIC is equivalent to NACE to the four digit level.*

3.2 Project-based organisations

Construction companies are normally structured as project-based organisations rather than as functionally organised enterprises, and supply clients with custom-designed products and services on a project base (Blindenbach-Driesses and van den Ende, 2006). Construction activities entail varying degrees of uniqueness and are normally carried out on site, rather than being produced in factories and then transported to the market, as it instead happens in the majority of industries. Due to the impossibility of producing a test piece, everything has to be done right the first time (MacLeod et al., 1998; Koivu et al., 2001). Moreover, it can be difficult and expensive to test a product that should last for decades and to ex-ante foresee all the changes it might undergo. In addition, since barriers to entry are low in the sector, firms tend to compete in prices, and not even newcomers need to rely on innovations to enter the market.

Construction projects' phases are generally divided into well-defined and discrete work-packages, which are normally accomplished in a sequential and commonly known order by purposely contracted specialists. The complexity of the supply chain relationships may vary greatly and very much depends on the type of project carried out. Each contractor is ultimately responsible only for its own contribution, and this almost inevitably leads to workflows that face major interruptions, possible conflicts, as well as time and cost over-runs and quality problems (see Barlow, 2000, for a detailed account). In project-based production all activities, including innovative ones, are usually conducted in collaboration with other firms, whether clients, suppliers, project partners, etc.. Despite their different backgrounds, they all need to be engaged in the process for innovation activities to be successful (Bayer and Gann, 2007).

Project-based production significantly undermines the learning processes essential for innovations. Although learning in the context of a particular project may indeed take place, it is uncertain whether this information ever becomes available to and accessible from other projects or the firm as a whole (Brady and Davies, 2004). This is true even if certain types of innovations may be project-specific and therefore not repeatable. In addition, it might happen that if project partners do not work together again, they might not be able to exploit the knowledge gained while collaborating. Hence, despite projects representing flexible systems of production that enable the coordination of loose networks of firms (DeFilippi, 2001), they rarely make firms able to integrate, further develop, and transform into organisational capabilities the knowledge thus acquired (Davies and Brady, 2000; Acha et al., 2005).

3.3 Incremental and "hidden" innovations

Being or getting engaged in R&D and innovation is relatively expensive for construction firms, since the risks related to innovation, also"hidden"innovation (Barrett et al., 2007), are allocated to the producers and not to the users (Widèn et al., 2007)."Hidden"innovations are those that remain undetected by conventional measures, for example project-level innovation activities, organisational, and design innovations (Barrett et al., 2007). In this multi-tech sector successful innovations are often based on hitching and matching several existing technologies, and on implementing systemic innovation, aimed at improving the whole production process (Koivu et al., 2001).

All this might also explain why the innovations occurring in construction are typically incremental in nature, and lead to dramatic transformations only over the long term. Innovation in the construction sector is generally characterised by the adoption of new practices and advances in both technological and business processes. Although major innovations do occur in the industry, they rarely imply a major or sudden shift, but rather take the form of (gradual) refinements over a long time frame (Lansley, 1996). Examples of the radical transformations happened since 1950 are the changes in materials, the introduction of standardisation and pre-fabrication, the use of information technologies (IT) in both design and construction, as well as the introduction of automation, robotics and the changes in the supply chain management that the sector has experienced (Miozzo and Ivory, 2000).

3.4 Standards and regulations

Construction is a highly regulated sector. In Europe as well as elsewhere a vast range of Directives, regulations and legislations directly and indirectly affect practically every activity and aspect of the construction industry, being this safety, energy, or environment-related. Construction is influenced by a number of regulations that govern products and processes; as well as by planning and environmental regulations governing finished products; and labour market regulations governing the welfare of the workers taking part in the construction work (Dewick and Miozzo, 2002).

Although standardisation and regulations may enable the widespread deployment of novel technologies and processes, the possibly excessively stable system they determine may ultimately hinder innovation. Certification practices, whether related to products or to the firm itself, may also discourage innovation efforts and investments in small firms, for the additional costs and the delay they imply.

The degree of stability at the core of standardization, which is needed to let improvements get embedded in operational processes, may impinge upon the continuous changes implied by innovation (Edum-Fotwe et al, 2004), fact also acknowledged by the European Commission COM(2007)374. If standards may facilitate the uptake of new technologies and help making the results of R&D reaching their target markets, they can nevertheless stiffen technological change and the development of new technologies and products.

4. Redefining construction: a Value-chain based "wide" definition of the sector

The elements offered to characterise the sector and its main features all underline the very much eclectic nature of the industry, a sector whose innovativeness mainly stems from research and innovation activities carried out in other sub-sectors and industries. From a statistical point of view, the latter are typically classified as belonging to the manufacturing or service sectors.

4.1 NACE classifications and the construction sector

Statistical offices generally collect and present data related to economic activities following NACE classifications. Currently, two NACE classifications coexist: NACE Revision 1.1 (NACE Rev. 1.1), which has been in force since 2002 and has been used until the end of the year 2007; and NACE Revision 2 (NACE Rev. 2; EU, 2008). The latter has been introduced at the beginning of the year 2008 and is to be fully adopted after a transition period ending in 2011. From time to time NACE codes are in fact revised in order to better capture the prevailing structure of the economy. Mirroring such an effort, the latest NACE Revision pays more attention to services, as well as to some emerging industries and production processes, and offers a more detailed classification of economic activities in general[10]. NACE nomenclatures are divided into: i) sections, denoted by a letter, ii) divisions, denoted by 2-digit codes; iii) groups, denoted by 3-digit codes; and iv) classes, characterised by 4-digit codes[11].

In both NACE Revisions 1.1 and 2 the activities carried out within the construction sector are accounted for under the heading"Section F". In NACE Rev. 1.1 section F coincides with division 45, whereas NACE Rev. 2 section F is subdivided into divisions 41, 42, and 43.

Substantial differences also exist with respect to the number of groups and classes contained in the section. From NACE Rev. 1.1 to NACE Rev. 2 the sector's number of groups and classes has increased from 5 to 9 and from 17 to 22, respectively. These changes mirror the attention that the recently revised classification pays to the details of the production process, and to the different technologies used in the sector. Moreover, in NACE Rev.1.1 groups are divided according to the various stages of the construction process - from site preparation to renting and demolition activities -, whereas NACE Rev. 2 classifies the sector according to the outcome obtained.

[10] *Among the newly created divisions there is, e.g., the"Manufacture of basic pharmaceutical products and pharmaceutical preparations" and the "Manufacture of computer, electronic and optical products".*

[11] *We use the word code in a general sense, in order to refer to any level of the nomenclature.*

Table 2: Statistical classification of activities in the Construction sector

NACE Rev. 1.1 (2002) - Section F codes		NACE Rev. 2 (2008) - Section F codes	
45	Construction	41	Construction of buildings
		41.1	Development of building projects
45.1	Site preparation	41.2	Construction of residential and non-residential buildings
		42	Civil engineering
45.2	Building of complete construction or parts thereof; civil engineering	42.1	Construction of roads and railways
		42.2	Construction of utility projects
45.3	Building installation	42.9	Construction of other civil engineering projects
		43	Specialised construction activities
45.4	Building completion	43.1	Demolition and site preparation
		43.2	Electrical, plumbing and other construction installation activities
45.5	Renting of construction or demolition equipment with operator	43.3	Building completion and finishing
		43.9	Other specialised construction activities

Source: Authors own elaboration on Eurostat data
Note: NACE Rev. 1.1 and Rev. 2 divisions and groups are listed in numerical order. No correspondence is meant among the codes considered.

Table 2 shows the construction sector's divisions and groups of both NACE Rev. 1.1 and Rev. 2 classifications. In NACE Rev. 2 (right hand side of Table 1) division 41 covers the complete construction of buildings; division 42 relates to the complete construction of civil engineering works, and division 43 deals with specialised construction activities, if carried out only as a part of the construction process. The greater number, type and level of details characterising NACE Rev. 2 vis-à-vis NACE Rev. 1.1 mirror the willingness to better and more comprehensively account for the wide range of activities carried out by construction firms. Such an aim is expressly stated in the metadata published by Eurostat (2008), which also highlight a number of activities that should have been included in section F, but were excluded from it to ensure the general consistency of the classification[12].

4.2 From a "strict" to a "wide" definition of the construction sector

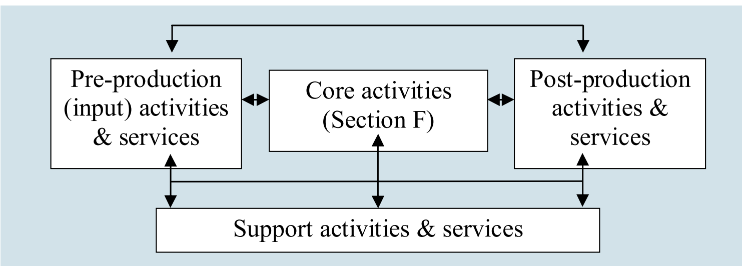
Despite the attempt of NACE Rev. 2 to achieve a broader definition of construction, many are the activities left outside the sector that we deem should have been part of it. This is why we here propose a "wide" classification that builds on NACE classes and adds "non-core" codes to the activities listed in section F. By non-core codes

[12] *See the metadata provided by the Eurostat web: ec.europa.eu/eurostat, accessed on 10 February 2009.*

we mean activities currently not contemplated in section F but that exclusively or preponderantly belong to the construction value chain.

Figure 1 summarises the main activities, phases, and components of the construction value-chain. The schematisation centres around construction activities intended as building and civil engineering, including soil and water-related constructions (i.e. "core" activities in Figure 4). The chart attempts to capture not only the construction value-chain, but also the time sequence in which core and non-core activities take place. When saying "core" activities no difference is made with respect to whether the buildings and civil engineering relate to newly-built or renovated constructions, carried out by a private or public firm, or by private individuals.

Figure 4: Construction value chain, based on NACE codes



Source: Authors' own compilation

By pre-production activities we mean upstream activities – mainly manufacturing ones – whose output constitutes an input into construction's core activities, as well as services preceding the construction core phases. Examples of input activities are the manufacture of construction products like concrete, cement and plaster, bricks, tiles, etc.. These manufacturing activities basically take care of producing all those components and systems (or kits of components) that are used in a permanent way in the construction works (see also PRC, 2006). These input suppliers are normally classified as belonging to industries other than construction, being these chemicals, forest, concrete, or else. Examples of pre-production services are instead architectural and engineering services, i.e. services preceding core construction activities. Examples are geodetic surveying, building design, and drafting.

When saying post-production activities we refer to downstream activities normally carried out afterwards and in connection to a building or civil engineering work. Among these there are the maintenance of buildings, as well as real estate selling and letting services, and facility management.

Finally, by support activities and services we mean a broad range of production and service activities, from wholesale of construction materials, to renting machinery and equipment, to recycling waste and scrap. In the present taxonomy we consider as support activities also public services like area and urban planning, steering, inspections, certification, market surveillance, research, etc, as well as construction-related finance and insurance, facility management and services.

Table 3 illustrates the NACE section, divisions, groups and classes we contemplate within the wide definition proposed. The NACE Rev.1.1-based wide classification is shown on the left and side of the table, whereas the corresponding NACE Rev. 2-based one is displayed in the column on the right. Under the heading"Section F - Construction - core codes"are shown Section F codes of both NACE Revisions. The bottom part of the table, entitled"non core codes", instead lists the codes we add to the core ones to obtain a more systemic - and we deem more policy relevant - definition of construction. Codes and activities are listed following NACE Rev 1.1 order (on the left hand side), every time showing the corresponding NACE Rev. 2 group/class on the right hand side. Finally, whenever repeated due to the official correspondence NACE Rev. 1.1 – NACE Rev. 2, codes are shadowed in grey.

Table3: The construction sector: a "wide" definition[13]

NACE Rev. 1.1 (2002)*		NACE Rev. 2 (2008)^	
Section F – Construction - core codes			
45	Construction	41	Construction of buildings
		41.1	Development of building projects
45.1	Site preparation	41.2	Construction of residential and non-residential buildings
		42	Civil engineering
45.2	Building of complete construction or parts thereof; civil engineering	42.1	Construction of roads and railways
		42.2	Construction of utility projects
45.3	Building installation	42.9	Construction of other civil engineering projects
		43	Specialised construction activities
45.4	Building completion	43.1	Demolition and site preparation
		43.2	Electrical, plumbing and other construction installation activities
45.5	Renting of construction or demolition equipment with operator	43.3	Building completion and finishing
		43.9	Other specialised construction activities
Non core codes			
14.11	Quarrying of ornamental and building stone	8.11	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate
		9.90	Support activities for other mining and quarrying
17.54	Manufacture of other textiles n.e.c.	13.96	Manufacture of other technical and industrial textiles
20.20	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards	16.21	Manufacture of veneer sheets and wood-based panels
20.3	Manufacture of builders' carpentry and joinery	16.22	Manufacture of assembled parquet floor
		16.23	Manufacture of other builders' carpentry and joinery
		41.20	Construction of residential and non-residential buildings
		43.32	Joinery installation
		43.91	Roofing activities
24.30	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	20.30	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
25.23	Manufacture of builders' ware of plastic	41.20	Construction of residential and non-residential buildings
		43.32	Joinery installation
		22.23	Manufacture of builders' ware of plastic
26.14	Manufacture of glass fibres	23.14	Manufacture of glass fibres
26.26	Manufacture of refractory ceramic prod.	23.20	Manufacture of refractory products
26.30	Manufacture of ceramic tiles and flags	23.31	Manufacture of ceramic tiles and flags
26.4	Manufacture of bricks, tiles and construction products, in baked clay	23.32	Manufacture of bricks, tiles and construction products, in baked clay
26.51	Manufacture of cement	23.51	Manufacture of cement
26.52	Manufacture of lime	23.52	Manufacture of lime and plaster
26.53	Manufacture of plaster		

[13] *Table 1A in Annex lists core and non-core NACE codes in numerical order, without repetitions.*

26.6	Manufacture of articles of concrete, plaster and cement	23.6	Manufacture of articles of concrete, cement and plaster
26.7	Cutting, shaping and finishing of ornamental and building stone	23.7	Cutting, shaping and finishing of stone
28.11	Manufacture of metal structures and parts of structures	25.11	Manufacture of metal structures and parts
	of structures	41.20	Construction of residential and non-residential buildings
28.12	Manufacture of builders' carpentry and joinery of metal	25.12	Manufacture of doors and windows of metal
		43.32	Joinery installation
28.22	Manufacture of central heating radiators and boilers	25.21	Manufacture of central heating radiators and boilers
29.52	Manufacture of machinery for mining, quarrying and construction	28.92	Manufacture of machinery for mining, quarrying and construction
		28.99	Manufacture of other special-purpose machinery n.e.c.
29.72	Manufacture of non-electric domestic appliances	27.52	Manufacture of non-electric domestic appliances
		28.21	Manufacture of ovens, furNACEs and furNACE burners
36.63	Other manufacturing n.e.c.	22.23	Manufacture of builders' ware of plastic
37.20	Recycling of non-metal waste and scrap	38.32	Recovery of sorted materials
45.31	Installation of electrical wiring and fittings	80.20	Security systems service activities
51.53	Wholesale of wood, construction materials and sanitary equipment	46.73	Wholesale of wood, construction materials and sanitary equipment
51.54	Wholesale of hardware, plumbing and heating equipment and supplies	46.74	Wholesale of hardware, plumbing and heating equipment and supplies
70.11	Development and selling of real estate	41.10	Development of building projects
		42	Civil engineering
70.2	Letting of own property	68.2	Renting and operating of own or leased real estate
70.3	Real estate activities on a fee or contract basis	68.31	Real estate agencies
71.32	Renting of construction and civil engineering machinery and equipment	77.32	Renting and leasing of construction and civil engineering machinery and equipment
		77.39	Renting and leasing of other machinery, equipment and tangible goods n.e.c
74.2	Architectural and engineering activities and related technical consultancy	71	Architectural and engineering activities; technical testing and analysis

Source: Authors' own compilation on Eurostat data
Legend: NACE Rev 1.1 codes on the left hand side of the table; NACE Rev. 2 codes on the right. "Section F" contains the codes included in the official definition of construction, whereas the "Non core codes" part lists the additional groups and classes included in the "wide" definition. Divisions and classes are listed following NACE Rev. 1.1 orders, each time indicating the corresponding NACE Rev. 2 group or class. When repeated, due to correspondences, NACE Rev. 1.1 – NACE Rev. 2 codes are shadowed in grey.

The proposed wide definition of construction is in line with the definition contained in the COM(2007)860-final about sustainable construction:"[sustainable construction] embraces a number of aspects such as design and management of buildings and constructed assets, choice of materials, building performance as well as interaction with urban and economic development and management" (COM(2007)860-final, p. 4). In both definitions, emphasis is put on the systemic nature of the industry and the need to take into account all its major stakeholders and actors. The definition we propose clearly unveils the very eclectic nature of construction, an industry whose innovativeness mainly stems from research and innovation activities carried out in other sub-sectors / industries.

4.3 The wide definition and the construction value chain

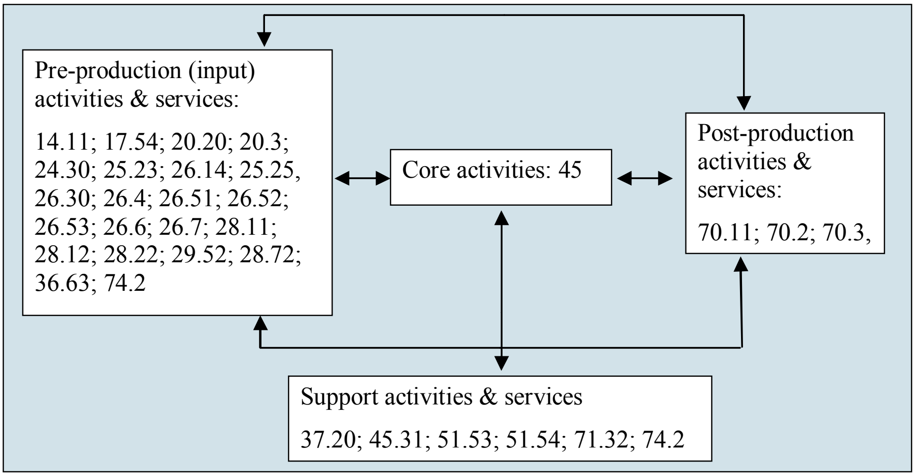
Non-core activities have been chosen after a careful inspection of the complete NACE nomenclature and of its exact content[14], and paying attention to: the type and content of each activity; the extent to which it relates or is functional to core activities; and, more generally, the way in which activities articulate over the construction value-chain.

The activities supplying core construction firms with intermediate inputs - whether manufacture or service activities - were the first to be included in the wide definition. They were followed by the codes of those activities essentially depending on or intrinsically correlated with the construction sector. Examples are NACE Rev. 1.1 classes 51.53-54 (classes 46.73-74 in NACE Rev. 2), i.e. wholesale of construction materials, since the demand for construction materials is affected by, reflects, and contributes to shape the performance of the sector. Finally, support and post-production activities and services were taken into account, being activities whose very existence depends upon and is determined by core construction activities.

Figure 5 relies on the schematisation proposed in Figure 4 to visualise the positioning of non-core activities within the construction value. Three- and four-digit codes are used for non-core activities, whereas core functions are denoted by two-digit codes.

14 *The official names of the NACE sections / groups / classes are unfortunately not fully indicative of the activities comprised thereof.*

Figure 5: Construction value chain, NACE Rev. 1.1 codes



Source: Authors own compilation on Eurostat data

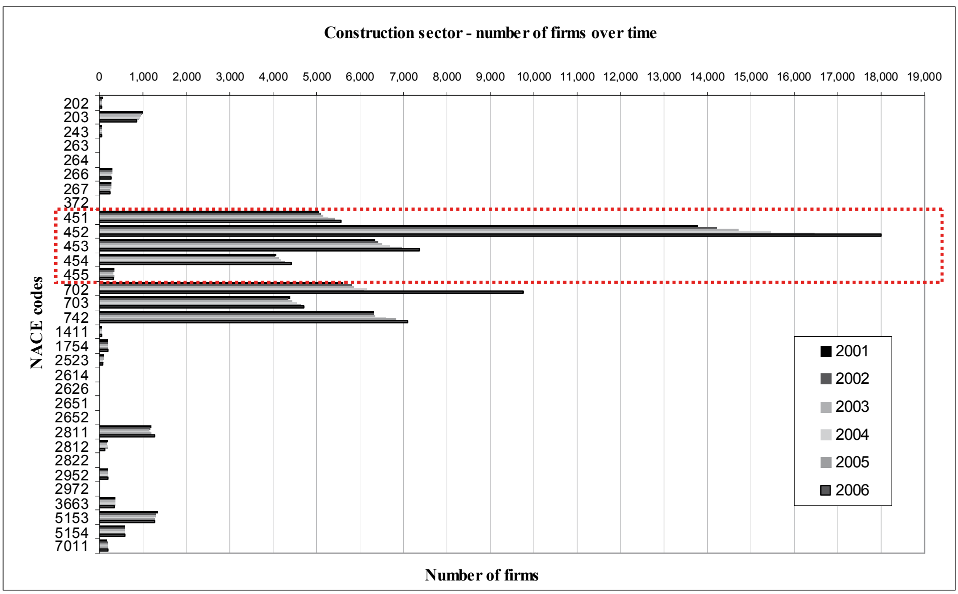
No code explicitly reflects the existing extensive range of public construction activities, related to e.g. the maintenance of public buildings, construction safety inspections, major infrastructures' planning and tendering, urban planning, and so on. Instead of being independently accounted for as (specific types of) construction, these activities are considered part of – and therefore merely functional to the implementation of – other public functions, like education, transport, and public administration. Such a feature of the NACE classification further highlights how underestimated construction activities might be in the statistics.

5. "Core" and "non-core" activities: characterising the "wide" construction sector

The data shown in the present section are aimed at illustrating some key features of the construction sector, and at highlighting how different the industry looks when defined according to our wide definition. To this end, Finnish Business Register data are used to uncover possible differences in the composition of the sector, and in the productivity and growth of core and non-core activities; whereas innovation input and output-related data are taken from the Community Innovation Survey 4.

Figure 6 depicts the number of firms in the construction sector in Finland over the period 2000-2006. The dot area highlights core NACE codes, and points out how much of the sector gets overlooked when only section F of the classification is considered.

Figure 6: Number of firms in the construction sector, over time (2001 – 2006)*



Source: Authors own compilation on StatFi data.
* The dots area points out the NACE Rev 1.1 codes contained in Section F - Construction

Table 4 also use Finnish data and subdivides non-core construction codes into manufacturing and service activities. The top part of the table shows the average value, over the years 2000-2007, of four indicators:

- S/E, i.e. average salary per employee, calculated as: total industry salaries / total number of employees;
- T/F, i.e. average turnover per firm, calculated as: total industry turnover / total number of firms;
- E/F, i.e. average number of employees per firm, calculated as: total number of employees / total number of firms in the industry;
- T/E, i.e. average turnover per employee, calculated as: total industry turnover / total number of employees.

The bottom part of the table shows the average growth of the very same variables, during the period considered.

Table 4: Finnish Construction firms: "core" and "non-core" activities' figures

	S/E	T/F	E/F	T/E
Construction	28.91	572.29	3.95	145.14
Non-core manufacturing	30.40	8407.86	37.31	188.61
Non-core service	33.27	1796.45	14.19	366.99
	Growth S/E	Growth T/F	Growth E/F	Growth T/E
Construction	3.26%	1.72%	-1.86%	3.63%
Non-core manufacturing	3.52%	8.53%	3.57%	6.11%
Non-core service	3.32%	6.37%	18.00%	6.09%

Legend: the figures represent the average for the period 2001-2007. Turnover and salary figures in 1000€.
Source: Authors own compilation on StatFi data.

The values of S/E suggest that non-core construction firms likely employ more skilled workers, since higher average salaries are generally linked to skill premia (see, e.g., Acemoglu, 2003). This is indirectly confirmed by the small difference in the growth of S/E, which might reflect the importance for wage determination of collective bargaining in Finland[15]. T/F, which is the ratio of total turnover divided by the total number of firms, highlights core and service construction firms to be on average smaller than manufacturing ones. This might have been expected given the highly fragmented structure of construction, its project-based nature, and its many trades and specialisms (Dick and Payne, 2005). T/F of non-core manufacturing also proves to have grown comparatively more over the period considered. A similar pattern emerges when looking at E/F values, i.e. the total number of employees divided by the total number of firms. Non-core manufacturing firms on average are the biggest of the sector, but in terms of E/F growth it is non-core services that boost a remarkable 18% during the period considered. Finally, T/E is a rough

[15] *Would differences in S/E be due to changes in the composition and skill of the workforce we would observe a change in growth rates as well.*

measure of productivity obtained by means of dividing total turnover over the total number of employees. Non-core manufacturing construction shows to perform almost a 30% better than core construction activities, whereas non-core services more than double the strict-construction's figure. A similarly stark pattern emerges when looking at growth figures. Taken altogether, the data suggest that non-core construction activities may be the"hidden"engine of growth of the sector, and that they may boost its productivity and employment.

To verify whether this is true also with respect to innovative activities, we use CIS4 data and look at the innovative input and output-related figures shown in Table 5[16].

Table 5: Innovation input and output indicators for core and non core activities

	core			non core		
Variables	N	mean (in %)	sd	N	mean (in %)	sd
Product innovators (inpdgd)	9036	4.79	0.21	11846	17.38	0.38
Process innovators (inpdsv)	9035	5.94	0.24	11828	8.98	0.29
Innov new to market (newmkt)	7563	4.46	0.21	8623	15.97	0.37
Innov new to firm (newffrm)	5317	5.04	0.22	3082	10.97	0.31
New production methods (inpspd)	9022	6.48	0.25	11808	17.06	0.38
New logistics methods (inpslg)	9013	2.69	0.16	11783	9.60	0.29
New support activities (inpssu)	9021	12.43	0.33	11791	18.18	0.39
Intramural R&D (rrdin)	8510	8.52	0.28	10904	20.98	0.41
Extramural R&D (rrdex)	8503	3.50	0.18	10850	11.82	0.32
Acquisition of equipments (rmac)	8499	16.60	0.37	10841	29.30	0.46
Acquis. of external knowledge (roek)	8499	4.04	0.20	10838	8.41	0.28
Technical preparation for inno (rpre)	8472	8.91	0.28	10740	15.28	0.36
Market innovations (rmar)	8467	4.68	0.21	10740	14.89	0.36

Source: Authors' own compilation using Eurostat CIS4 data

Data related to 11 countries, i.e.: BE, CZ, ES, HU, IT, LT, LV, NO, PT, SI, SK. These are the countries included in Eurostat CIS4 that carry out the survey also in the core construction sector.

NACE codes considered: F or equivalently 45 for the core construction sector; 26, 28, 51, 70, DI, and 742 for the non-core part. Not all non-core activities codes could be considered, due to the aggregation level of Eurostat data.

All variables considered correspond to survey questions allowing for a yes or no answer, and are coded as follows: yes = 1 ; no = 0. The names of the variables in parentheses are the same used in the CIS4.

[16] *Due to space constraints, we here show only some of the results obtained.*

Evidence about the higher importance of both innovative input and output indicators for non-core construction firms is absolutely compelling. This strongly supports our claim about the necessity to consider the construction sector in its entirety, i.e. according to the wide definition suggested, rather than confining it to core activities. Doing so it would be possible to more precisely identify the innovation and growth-drivers of the sector, and to design and implement more effective policies.

6. Conclusions

The paper proposes a definition of construction that encompasses the industry's entire value chain. This definition includes the core NACE Section F codes and adds selected four-digit NACE classes that relate to manufacturing and services activities in the pre-production, support and post-production construction segments.

We show simple statistics that help characterising core and non-core activities of the sector and highlight several differences, especially in their productivity performance and innovative behaviour. The results show that non-core activities are more productive and more innovative than core activities.

This evidence clearly argues in favour of the more comprehensive definition proposed in this study. In addition it calls for the need of more broadly defined policies, able to exploit the innovation, growth, and productivity leverage potential of non-core activities.

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ANNEX

Table 1A: "Wide" definition of the construction sector – NACE Rev. 1.1 and NACE Rev. 2 codes in numerical order

NACE Rev. 1.1 (2002)*		NACE Rev. 2 (2008)^	
14.11	Quarrying of ornamental and building stone	8.11	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate
17.54	Manufacture of other textiles n.e.c.	9.9	Support activities for other mining and quarrying
20.2	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards	13.96	Manufacture of other technical and industrial textiles
20.3	Manufacture of builders' carpentry and joinery	16.21	Manufacture of veneer sheets and wood-based panels
24.3	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	16.22	Manufacture of assembled parquet floor
25.23	Manufacture of builders' ware of plastic	16.23	Manufacture of other builders' carpentry and joinery
26.14	Manufacture of glass fibres	20.3	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
26.26	Manufacture of refractory ceramic products	22.23	Manufacture of builders' ware of plastic
26.3	Manufacture of ceramic tiles and flags	23.14	Manufacture of glass fibres
26.4	Manufacture of bricks, tiles and construction products, in baked clay	23.2	Manufacture of refractory products
26.51	Manufacture of cement	23.31	Manufacture of ceramic tiles and flags
26.52	Manufacture of lime	23.32	Manufacture of bricks, tiles and construction products, in baked clay
26.53	Manufacture of plaster	23.51	Manufacture of cement
26.6	Manufacture of articles of concrete, plaster and cement	23.52	Manufacture of lime and plaster
26.7	Cutting, shaping and finishing of ornamental and building stone	23.6	Manufacture of articles of concrete, cement and plaster
28.11	Manufacture of metal structures and parts of structures	23.7	Cutting, shaping and finishing of stone
28.12	Manufacture of builders' carpentry and joinery of metal	25.11	Manufacture of metal structures and parts of structures
28.22	Manufacture of central heating radiators and boilers	25.12	Manufacture of doors and windows of metal
29.52	Manufacture of machinery for mining, quarrying and construction	25.21	Manufacture of central heating radiators and boilers
29.72	Manufacture of non-electric domestic appliances	27.52	Manufacture of non-electric domestic appliances

36.63	Other manufacturing n.e.c.	28.21	Manufacture of ovens, furnaces and furnace burners
37.2	Recycling of non-metal waste and scrap	28.92	Manufacture of machinery for mining, quarrying and construction
45.1	Site preparation	28.99	Manufacture of other special-purpose machinery n.e.c.
45.2	Building of complete construction or parts thereof; civil engineering	38.32	Recovery of sorted materials
45.3	Building installation	41.1	Development of building projects
45.4	Building completion	41.2	Construction of residential and non-residential buildings
45.5	Renting of construction or demolition equipment with operator	42.1	Construction of roads and railways
51.53	Wholesale of wood, construction materials and sanitary equipment	42.2	Construction of utility projects
51.54	Wholesale of hardware, plumbing and heating equipment and supplies	42.9	Construction of other civil engineering projects
70.11	Development and selling of real estate	43.1	Demolition and site preparation
70.2	Letting of own property	43.2	Electrical, plumbing and other construction installation activities
70.3	Real estate activities on a fee or contract basis	43.3	Building completion and finishing
74.2	Architectural and engineering activities and related technical consultancy	43.32	Joinery installation
		43.9	Other specialised construction activities
		46.73	Wholesale of wood, construction materials and sanitary equipment
		46.74	Wholesale of hardware, plumbing and heating equipment and supplies
		68.2	Renting and operating of own or leased real estate
		68.31	Real estate agencies
		71	Architectural and engineering activities; technical testing and analysis
		77.32	Renting and leasing of construction and civil engineering machinery and equipment
		77.39	Renting and leasing of other machinery, equipment and tangible goods n.e.c.
		80.2	Security systems service activities
		81.1	Combined facilities support activities

Source: Authors' own compilation on Eurostat data

Legend: The left hand side of the table shows NACE Rev 1.1 codes, whereas the right hand side contains NACE Rev. 2 codes. Codes are listed in numerical order, independently for NACE Rev. 1.1 – NACE Rev. 2.

Market Incentives to Business Innovation in Sweden*

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Abstract

Does higher competition lead to more innovation? In this paper we empirically study the relationship between innovation and product market competition in Sweden over the period 2001-2007. We test the sensitivity of using different competition measures by calculating two different measures and also test the sensitivity of choosing firm-level or aggregated measurements when estimating the relationship. The results show that the different competition measures give contradicting results and that the firm-level measure is more robust. At the firm-level competition has a direct positive effect on R&D but the marginal effect of competition is offset by the distance to the technology frontier. Competition thus seems to have an overall positive effect on innovation activities in the Swedish business sector but greater competition in combination with being farther from the technological frontier has a negative impact on both R&D expenditure and R&D intensity.

1. Introduction

Investment in R&D in Sweden was 3.6 percent of GDP in 2007 (Statistics Sweden 2009). This puts Sweden in the top of the OECD countries. 16 percent of the companies who carried out innovation activities that year maintained that an obstacle for their innovation activity was the dominance of already-established companies. Can Sweden increase its innovation activity by increasing competition or is market power a prerequisite for innovation activities?

Measuring the relationship between innovation and competition is far from trivial. The casual relationship is unclear and has been of interest for economists for a long time. The traditional view, which goes back to Schumpeter (1943), states that

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the established firm with a leading market position is the driving force behind technological progress. In this case a high degree of market competition is holding the innovation process down; hence monopolistic or oligopolistic firms are more likely to innovate since they already are established, enjoy a leading position on the market and are willing to invest in risky projects. A low degree of market competition is then a prerequisite in order to stimulate innovation activities. Studies such as Acs and Audretsch (1987) confirm empirically these results, i.e. that large firms and market power increases innovation activity. Society should then accept a certain degree of market power in order to sustain a high degree of innovation activity. This view also has theoretical support in models such as Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992) in which higher levels of competition are predicted to decrease innovation. On the other hand empirical studies such as Nickel (1996) found that innovation increases with competition, i.e. the opposite effect.

Aghion et al. (2005) found a strong inverted–U relationship between market competition and innovation for the U.K. Their explanation behind the inverted-U relationship between competition and innovation is that increasing competition in markets where the innovation intensity is level leads to incentives to go ahead of competitors. As a result, these firms "escape competition" but this could also lead to lowering the incentives to catch up with the leading firms since catching up would imply less profit (with equal innovation levels):

> *The essence of the inverted-U relationship between competition and innovation is that the fraction of sectors with neck-and-neck competitors is itself endogenous, and depends upon equilibrium innovation intensities in the different types of sectors. More specifically, when competition is low, a larger equilibrium fraction of sectors involve neck-and-neck competing incumbents, so that overall the escape-competition effect is more likely to dominate the Schumpeterian effect. On the other hand, when competition is high, the Schumpeterian effect is more likely to dominate, because a larger fraction of sectors in equilibrium have innovation being performed by laggard firms with low initial profits.*

A recent study by Hashimi (2008) confirms the overall result for the US.

In the empirical literature, classical measures of innovation and competition are mainly used, i.e. concentration measures and the Lerner index. Recent research has shown that these measures suffer from severe drawbacks both theoretically and empirically, and literature on revenue-based measures has gained increasing interest. Most empirical studies are based on industry-level data and recent studies have shown that using firm-level data can give different results.

This study aims at empirically estimating the relationship between innovation and competition in the Swedish manufacturing industries for the period 2001-2007. In order to study the relevance of the competition measure used, two different measures are used: a Lerner index and a newly purposed profit elasticity measure by Boone (2007). The Lerner index is calculated both on the firm-level and aggregated at the industry-level to test if the results differ. There is no study, as to our knowledge, that has tested this setting for Sweden. Hence this study aims to answer the questions:

- Does greater competition lead to lower or higher innovation levels?
- Do the Lerner index and the profit elasticity measure give the same result?
- How important is the aggregation-level?

This paper is organised as follows. Following this first introduction, the second section gives a brief description of the different measures of competition and innovation and presents the model used. Section 3 presents the data used. The fourth section gives the results from the model and the final section presents the conclusions for the study.

2. Competition and innovation

Measuring innovation and competition is almost as complicated as trying to solve the casual relationship. Therefore a brief presentation of the most common measures is needed before we present our model.

2.1 Measuring competition and innovation

Common measures for innovation are patents and R&D data. These two measures cannot theoretically be regarded as synonyms since the latter is a form of *innovation effort* whereas the former is a form of *innovation success*. In empirical studies however, R&D expenditure is commonly used as a proxy for innovation and has shown to have a positive and strong relationship with productivity growth.

There are many different measures of competition. Classical measures such as the Herfindahl-Hirschman index (HHI) and the concentration ratio are commonly used in legal practice. These measures have been heavily criticized since they depend on the definitions of the geographical market and product markets, a drawback since many firms are active in international markets. Another problem associated with the concentration measures is that of differing efficiency levels among firms. If the efficiency level differs, the concentration measures can be misleading (Boone, 2001).

Another measure which is commonly used is the Lerner index, defined as the difference between price and marginal cost divided by the price. A higher index implies greater market power in terms of keeping price over the marginal cost; the predictions of the measure is that in a perfect competitive market the value is zero and values greater than zero imply lower degrees of competition. However, the Lerner index is problematic from a theoretical perspective, since it indicates higher values with more intense competition instead of showing lower margins. This is of course problematic for empirical studies, but it has not yet been shown that these theoretical findings are causing difficulties.

In line with the criticism against the classical measures and the Lerner index, new revenue-based measures have gained increasing interest in the literature. Boone (2000) argues that an increase in marginal cost leads to greater drops in profit levels for firms in a more competitive market. Thus, in more competitive markets firms are punished more harshly for being inefficient. This measure is further developed in Boone et al. (2007) in a measure they call profit elasticity (PE):

> *PE is measured for a market and is defined as the percentage fall in profits due to a percentage increase in (marginal) costs. In all markets, an increase in costs reduces a firm's profits. However, in a more competitive market, the same percentage increase in costs will lead to a bigger fall in profits. The underlying intuition is that in a more competitive market, firms are punished more harshly (in terms of profits) for being inefficient.*

The PE therefore measures the efficiency level of the firm under the assumption that higher efficiency level firms produce the same quantity with lower marginal cost and lower production cost. They specify this relationship as

$$ln(\pi_i) = \alpha - \beta ln(c_i) \qquad 1$$

where π is profit of firm i and c is cost of firm i. The competition measure is β, where a high/low β indicates a high/low level of competition, i.e. a steeper/level slope implies higher/lower competition.

Boone (2004) argues that in order for the measurement to work properly, data at the four or five digit levels is needed. More aggregated data is not recommended. Several studies have used the PE in various forms. Boone et al. (2005) use operating profits regressed on a constant term and average variable cost by OLS for each industry in UK data. Creusen et al. (2006) use operating profits regressed on a constant term, average variable cost and time dummies by fixed effects for each industry for the Netherlands. Maliranta et al. (2007) test several alternative specifications of PE on the Finnish business sector and suggest that operating profits should be regressed on a constant term, average variable cost and its interaction with a linear time trend, estimated with OLS for each industry.

Creusen et al. (2006) test if HHI, the Lerner index and PE tell the same story when using firm-level data and industry-level data. They found that the data source indeed matters. For the Lerner index, competition declined using firm-level data but intensified using industry-level data. At the industry-level they also found that the three indicators frequently contradicted each other.

2.2 Empirical strategy

This paper is part of a larger project run by the OECD called *Market incentives to innovate*. The model used is therefore constrained by the decisions by the OECD in order to estimate the same model in different countries.

The model used to estimate innovation is largely influenced by Griffith et al. (2006). The original model is used for the industry-level but we use it at the firm-level.

The model also includes the same features as the empirical model used in Aghion et al (2005) in that the distance to the firm's technological frontier is accounted for. Variables which have shown to determine innovation in previous studies are included in the model. The model used is the following:

$$Innovation_{it} = \alpha + \beta_1 C_{it} + \beta_2 DTF_{it-1} + \beta_3 C_{it}(DTF_{it-1}) +$$

$$+ \beta_5 lnL_{it-1} + \beta_6 ln\left(\frac{K}{L}\right)_{it-1} + \sum_{k=1}^{4} \gamma_k sector_k + \epsilon_{it} \qquad 2$$

where *i* is company and *t* is year. Two measures of innovation are used: the logarithm of R&D expenditure and R&D expenditure over gross production.

C is the competition measure and we will run the same innovation equation for all the three competition measures. To test the sensitivity of using measures at the firm-level vs. measures aggregated at the industry level, one of the competition measures is calculated on both levels. In line with previous studies the Lerner index is used, but this study also uses the PE measure. However, the PE measure is calculated only on the industry level. The Lerner index at the firm-level is calculated according to the equation below,

$$Lerner\ index_{it} = \frac{y_{it} - vc_{it}}{y_{it}} \qquad 3$$

where y is gross production, j is industry, vc is variable cost. In the regressions one minus the Lerner index is used. Following Aghion et al. (2005), one minus the average of each industry's Lerner index is used as the aggregated measure[1], thus:

$$Lerner\ index_{jt} = 1 - \frac{\sum_{i=1}^{n_j} Lerner\ index_{ijt}}{n_j} \qquad 4$$

The PE measure is calculated as a modified Griffith et al. (2005) model. We use a log-log model and also control for the size of the firm:

$$ln(y - vc)_{ijt} = \alpha + \beta ln\left(\frac{vc}{y}\right)_{ijt} + \varphi lnL_{ijt} + \mu \qquad 5$$

where *y-vc* is used as profit and average variable cost is used instead of marginal cost. Average variable cost for each firm is obtained by dividing variable cost by gross production of the firm, where the number of employees *L* controls for the size

[1] *We also tried to calculate a weighted aggregated Lerner index by multiplying each firm's Lerner index by the market share for each firm and then proceed as in equation 4, see Boone (2005). However, the results turned out rather unreasonable and we believe this to be the result of using the three digit NACE rather than showing the actual market share of each company. Hence, we dropped the market share in our aggregated Lerner index.*

of the firm. Estimating the equation above for each *j*, we thus obtain a β_{jt} for each industry at the NACE three digit level. One of the practical drawbacks of estimating the PE is that companies with a negative profit do not enter the equation.

We thus obtain three different competition measures, two measures aggregated on the industry-level and one on the firm-level. This enables us to test if using different levels of aggregated data provides different results. In this paper the Lerner index at the firm-level is denoted LIF and the Lerner index aggregated at the 3-digit NACE level is denoted LIA.

DTF stands for the distance to the technology frontier and measures the size of the technology gap between firms in an industry. This is calculated as:

$$DTF_{it} = \frac{TFP_{Fjt} - TFP_{ijt}}{TFP_{Fjt}} \qquad 6$$

where *TFP* denotes total factor productivity and *F* denotes the frontier firm which is defined as the firm with the highest *TFP* in industry *j*. The idea behind this technological spread measure is that the size of the technology gap between firms should be steeper when firms compete neck-and-neck and that the technology gap should be an increasing function of the overall competition in the industry. A low value of *DTF* implies that the firm is close to the technology frontier (neck-and-neck) whereas a high value of *DTF* implies that the technology gap is large to the frontier (in this case a laggard firm in a unleveled industry).

The interaction between competition and distance to technology is captured by the term *C*(1-DTF)*. This cross-term implies that the marginal effect of competition on innovation is dependent upon the distance to the technology frontier. By using lagged values of *DTF* it is assumed that the marginal effect of competition on innovation depends on how close or far away the firm was in the previous year to the frontier.

To study the impact of the size of the firm, the number of full-time employees for each firm, *L*, is included and to control for the capital intensity the *(K/L)* ratio is included. Both of these terms are used as lagged variables so it is expected that the size of the firm and the capital-labour ratio from previous years will influence the innovation rate of the current year.

Instead of controlling for each industry, we use an OECD modified definition of the classifications of sectoral patterns of innovation, originally purposed by Pavitt (1984). This classification divides industries into resource-, labour-, scale-, specialized-, and science intensive sectors. The technology level is assumed to be highest for the science sector. Dummy variables are used to control for these different sectors.

3. Data

The period we study is 2001-2007. The data used in this paper is taken from the R&D expenditure survey and the longitudinal integration database for health insurance and labour market studies (in Swedish called LISA). The R&D survey is conducted by Statistics Sweden and covers activities within enterprises with at least 10 employees[2]. It is carried out every other year and covers around 7 000 enterprises. The definition of research used in the survey is "...systematic work to acquire new knowledge or new ideas with or without a specific application in view..." and development activities are defined as "...systematic work that uses research results, scientific knowledge or new ideas to produce new materials, goods, services, processes, systems and methods or substantially improve those already existing." In order to calculate the necessary measurements we use a unbalanced panel at the three digit NACE level for the period 2000-2007. The data for R&D varies between 300-500 observations dependent on year and about 30 000 observations for each year from the LISA database. All variables except the R&D variables are calculated using the LISA database.

4. Results

The innovation equation, equation 2, is estimated using a balanced panel with OLS[3]. In presenting the results focus is on the competition measures and the statistically significant variables. Significance-levels are reported according to table 1.

Table 1 Reported significance levels

Notation for significance levels
* Significant at 10%
** Significant at 5%
*** Significant at 1%

The dependent variable is the natural logarithm of *R&D expenditure over gross production* which is called R&D intensity and *ln (R&D expenditure)*.

Table 2 shows the OLS results for estimating the innovation equation with R&D over gross production, hence forth R&D intensity, whereas table 3 shows the results by using ln(R&D expenditure) as dependent variable. For the OLS regressions Newey-West standard errors, i.e. heteroscedasticity and autocorrelation consistent standard errors are used. In the tables, the first row for each variable reports the parameter estimate and the second row reports the standard error.

[2] For 2001 and 2003, firms with less than 50 employees were not included in the survey.

[3] We also estimated fixed effects models both the results were very poor especially for R&D intensity. For ln(R&D expenditure) the LIF performed better with significant values for competition (positive), DTF (negative) and the cross term (positive). The results are available on request.

Table 2 R&D intensity

Dependent variable	R&D expenditure over gross production		
	Profit Elasticity	Lerner Aggregated	Lerner Firm-level
Intercept	0,016116	0,017082	-0,137491*
	0,038069	0,037674	0,079837
Competition	-0,001016*	0,002835	0,165152**
	0,000576	0,007289	0,069211
DTF	0,000185	0,006775***	0,005317*
	0,000356	0,000686	0,00288
DTF*Competition	0,0000195**	-0,006393***	-0,005001*
	0,00001	0,000693	0,002899
ln(L)	-0,000617	0,00048	-0,001299
	0,001889	0,001727	0,002108
ln(K/L)	0,003005	0,001246	0,002797
	0,004301	0,004111	0,003988
Resource	-0,020276***	-0,023651***	-0,032997***
	0,004791	0,005298	0,007722
Scale	0,007624	0,003211	-0,006958
	0,004735	0,004513	0,006845
Specialized	0,037602***	0,036082***	0,02993***
	0,007449	0,007383	0,007147
Science	0,102217***	0,102465***	0,092635***
	0,017961	0,018159	0,013236
time_2003	-0,002222	-0,002142	-0,0024
	0,009179	0,009714	0,00739
time_2005	-0,007471	-0,004989	-0,001361
	0,008387	0,009117	0,006435
time_2007	-0,005045	-0,0034	0,00000954
	0,009521	0,010103	0,007555
Number of observations	663	663	663
Adjusted R-squared	0,17	0,18	0,27

Newey-West HAC Standard Errors & Covariance

We can conclude from table 2 that both PE and LIF are significant but not LIA. However while PE has a negative sign, LIF has a positive sign. The positive sign implies that higher levels of competition give higher levels of R&D intensity while a negative sign implies the opposite. Thus, PE and LIF do not tell the same story for R&D intensity. The distance to the technology frontier is significant and positive for LIF and LIA, so firms further away from the frontier invest relatively more in R&D. DTF is not significant for PE. The cross-term is significant for all the competition measures, positive for PE and negative for LIA and LIF. The negative value can be interpreted as the interaction of being farther from the frontier in combination with a high level of competition has a negative effect on R&D intensity. The above results imply that using the Lerner index the direct effect of competition on R&D intensity is positive but this effect is offset by the distance to the technology frontier i.e. the marginal effect of competition when taking into account the distance to the technology frontier is negative. The result for these variables using the PE is the total opposite. Hence PE and the Lerner indices give very different pictures of the relationship between R&D intensity and competition.

The size of the firm and capital intensity is insignificant for all competition measures. The sector dummies are significant and positive for Science and Specialized, but negative and significant for Resource. Moreover, the parameter estimates are in general small and the adjusted R-squared is highest for the innovation equation with LIF.

Table 3 gives the results from estimating the innovation equation with the ln (R&D expenditure) as dependent variable.

Table 3 R&D expenditure

Dependent variable ln(R&D expenditure)	Profit Elasticity	Lerner Aggregated	Lerner Firm-level
Intercept	3,694872***	3,548075***	3,058572***
	0,628483	0,647035	0,720525
Competition	-0,00631	0,277203***	0,719544**
	0,015258	0,105512	0,328955
DTF	0,015105	0,169657***	0,266203***
	0,014155	0,018833	0,065847
DTF*Competition	0,0000873	-0,15487***	-0,262512***
	0,000282	0,019102	0,066342
ln(L)	0,22667***	0,254304***	0,258665***
	0,067666	0,066481	0,06999
ln(K/L)	0,439594***	0,398179***	0,416116***
	0,068307	0,062551	0,066613
Resource	-0,879472***	-0,853821***	-0,914938***
	0,193199	0,175118	0,177646
Scale	0,578738***	0,554871***	0,472091***
	0,18655	0,181832	0,183463
Specialized	0,994763***	0,99001***	0,957541***
	0,171379	0,170579	0,173805
Science	1,630974***	1,605949***	1,60188***
	0,185234	0,184765	0,188594
time_2003	-0,041688	0,051003	-0,052614
	0,157301	0,148216	0,15869
time_2005	0,063335	0,171367	0,061472
	0,167492	0,155931	0,166733
time_2007	0,078988	0,179953	0,074481
	0,170196	0,159809	0,168184
Number of observations	657	657	657
Adjusted R-squared	0,21	0,24	0,24

Newey-West HAC Standard Errors & Covariance

In table 3 both Lerner indices are positive and significant. Thus, higher competition gives more R&D expenditure. The profit elasticity measure is still negative and insignificant. DTF is significant and positive for the Lerner indices but not for the Profit elasticity measure. The cross-term is negative and significant for the Lerner indices but positive and insignificant for the Profit elasticity measure. The results are thus very similar compared with table 2. As for R&D intensity the sector dummies are significant and positive for Science and Specialized, but negative and significant for Resource. The sector Scale is also positive and significant over the period. The size of the firm and the capital intensity both have a positive and significant effect on R&D expenditure and this result remains for all competition measures.

Comparing the results for table 2 and table 3 we see that studying ln (R&D expenditure) in equation 2 gave stronger results than using R&D intensity. One explanation could be that no small firms are included in the panel. The third column in table 3 provided the strongest result, i.e. using LIF as competition measure. Further, PE and the Lerner indices do not show the same signs. PE has a negative sign and is only significant for R&D intensity whereas LIF is positive and significant for both R&D intensity and R&D expenditure. Thus, the Lerner index says that competition increases both the intensity and level of R&D whereas PE gives the opposite result, DTF was significant for the Lerner indices but not for PE. The positive sign of the DTF implies that firms farther away from the frontier have a higher R&D expenditure. The magnitude of the parameter estimates differ as well. For ln(R&D expenditure) the parameter estimates are greater for all variables compared with R&D intensity.

5. Concluding remarks

We asked in the introduction of this paper if higher competition lead to more innovation? As shown in this paper using classical competition measures at the firm-level gave stronger results whereas a newly proposed competition measure at the aggregate-level gave weaker and non-robust results. Using the Lerner index at the firm-level provided the strongest results regardless of using R&D intensity or the level of R&D expenditure as dependent variable. The results indicate that competition has a direct positive effect on R&D but the marginal effect of competition is offset by the distance to the technology frontier.

Competition thus seems to have an overall positive effect on innovation activities on the Swedish business sector but greater competition in combination with being farther from the technological frontier has a negative impact on both R&D expenditure and R&D intensity. This result is to some extent in line with the model purposed by Aghion et al (2005).

Our results allow us to compare how sensitive the results are in using firm-level or aggregated-levels of the Lerner index. The results were similar but the firm-level measure gave better results since the aggregated measure was not significant when using R&D intensity as dependent variable.

The newly purposed competition measure by Boone (2007) gave poor results in comparison with the Lerner indices and had a negative but not robust parameter estimate.

It should be noted that the results in this paper needs to be confirmed by using a longer time period.

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What is the composition of human capital in the most successful firms?

– A Swedish microdata perspective

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Abstract

The importance of human capital for growth was confirmed by using Swedish micro data. Firms with the highest growth rates had a different human capital composition than firms with lower of negative growth. In the growth periods of 1997 to 2000 and 2003 to 2006, the mean number of employees with ICT skills and highly educated engineers were overrepresented in high growth firms. The time period between 2000 and 2003 was affected by the ICT bubble and the pattern was radically different. Due to the crisis for the ICT and high-tech industry, firms with less qualified employees as administrators and, managers were doing relatively well.

The views represented here are those of the author and does not necessarily present those of Statistics Sweden. The author is thankful to Hans-Olof Hagén for invaluable help with this paper.

1. Introduction

In today's economy, knowledge has become an increasingly more important input in the production process. The knowledge that individuals have accumulated from life experience, education and on the job training is essential for the firm's technological progress. Apart from knowledge it is also important how the individuals can interact with one another. In analyses of productivity and growth in the modern economy it is therefore important to capture the input of human capital. The access to human capital is vital for new firms to survive and grow, and for established firms to develop.

There are two approaches of the role of education policy and how it supports the development of the business sector. One approach says that education should be adaptive and oriented to the needs of the business of today in the country or in the region. The other approach is that the education process is an investment in the knowledge base of the business sector and can change the structure and the development of the business sector in the future. The latter is a more fruitful approach, but the education level and orientation of a nation's work force is not the only determining factor of growth in a nation's business sector. A new industry structure does not evolve overnight and the specialisation is also a reflection of the comparative advantage that has developed in each country over a long time.

According to Krueger and Lindahl (2001) two different approaches to return to investments in education were analysed in the 1990s, the micro and the macro approach. In the macro growth literature, the primary question raised was if the level of schooling in cross-country comparisons was associated with GDP growth. When including occupation as a proxy for human capital in a panel data set of OECD countries, E. Köksal (OECD 2008) included occupation as a proxy for human capital in a panel data set of OECD countries. She found a positive relationship to productivity from both education and occupation. However, all these cross-country studies are associated with some drawbacks. Differences among countries according to classification, measurements and policies as well as time series breaks are some examples.

The micro oriented labour literature focus was rather on estimating the monetary return to schooling like the Mincer's wage equation. But there are micro data studies with different focal points. For example, the US Census Bureau analysed the relationship of human capital, productivity and market value. But due to the lack of adequate data, this type of analysis has been rare. In this analysis we will use a complete merged data set on all individuals and firms in the Swedish labour market within the private sector. The data used is register data from the Swedish tax authorities. The time series are capturing 1997 to 2007. Sweden is one of few countries with access to information on all individuals and firms during that period of time and also being allowed to merge that information. Firm output is generally easier to measure in private sector. That is why the public sector was excluded in this analysis.

The approach in this paper is closer to the traditional macro studies, but with a micro perspective. Rather than a cross-country human capital relation to GDP growth, this paper describes what kinds of education and occupations that are more common in firms with higher growth within one country, in this case Sweden. Not only will we compare well educated people with less educated, but analyse what combination of level and orientation as well as different occupations are more frequently represented in growing firms. This should be of relevance for a growth oriented education policy.

The primary questions which will be answered in this paper:

1. Do successful firms have a different staff composition than less successful firms?

where successive firms are defined either as firms with higher growth rate or surviving firms. Growth is measured both in value added terms and in terms of productivity. Another question asked is:

2. Do new firms have a different staff composition than older firms?

In order to see the demand of human capital in new firms this second question is asked.

Firstly we describe data and methods used. Secondly a short background on human capital and firm growth in Sweden is presented. Last results and conclusions are presented.

2. Data

Data used in this paper is from the integrated database for labour market research, LISA. LISA contains more or less all individuals above the age of 15 and all registered firms. A link between individuals and their workplace makes it possible to merge data. Due to restrictions in firm data time period used was 1997 to 2006.

Growth in value added terms and growth in productivity was used to measure firm success. According to a short time period and in an attempt to follow the business cycle, firm's growth periods were set to 1997-2000, 2000-2003 and 2003-2006. Three years were considered reasonable as it takes time to create growth (R&D to output, organisational changes, to build a business from a good idea to profit and so on). A longer time period would reduce number of observations as firms.

Mean values per firm for the human capital proxies' education and occupation were calculated for 1997, 2000 and 2003. Education orientation was defined according to the International Standard Classification of Education, ISCED 1997. The classification of the Swedish educational terminology (SUN) was revised in 1998-1999. Educational level was classified according to the old system which is based on ISCED 1997. Both are consistent within the whole time period.

The other proxy for human capital is occupation. Occupation is defined according to International Standard Classification of Occupation, ISCO, where the tasks of the employees are in focus. Occupation is based on both the level of specialisation and qualification demanded. Armed force is excluded due to the irrelevance for the private sector. In an attempt to diversify occupation further, a transformation into 20 groups according to a classification used in the Swedish Public Employment Service (Arbetsförmedligen, Appendix), SPES, has been done. A correlation table between ISCO and SPES is included in Appendix.

Moreover, two measurements according to the OECD definition for broad and narrow ICT users are included later on in the analysis, to highlight the ICT sector further. In 2000 no ISCO codes were available, so the individuals' codes for the following year, 2001, were used as a proxy for the employees in private sector in 2000. Only occupations that in 2000 comprised more than one percent of the private sector were included in the models.

3. Empirical estimates

The traditional Cobb-Douglas production function is defined as:

$$Y(t) = A(t)K(t)^{\alpha}L(t)^{1-\alpha} \qquad 0 < \alpha < 1$$

where Y is aggregate output, A is the technology, K is the physical capital and L is labour. L is measured as hours worked multiplied by the quality (human capital) of the employees. Our focus will be on the L variable.

However, this paper is not aiming at measuring the total human capital stock, but differences in human capital composition between firms.

In model 1, the ordinary least squares, OLS method was used with one exogenous variable, human capital:

$$\text{LOG}\Delta\ Y_{i,\ t,\ t+3} = \alpha + \beta * \mathbf{HC}_{i,t} + \varepsilon_t$$

The exogenous variable in the time period t will explain firm growth in the following three year period Growth, $\text{LOG}\Delta Y_{i,\ t,\ t+3}$, is measured both as LOG difference in value added, $VA_{t,\ t+3}$ and as LOG difference in value added multifactor productivity; $VAMP_{t,\ t+3}$. The exogenous variable $HC_{i,t}$ is either measured as the individuals education or occupation level at time *t*, where *i* is firm level. Education is measured as the firms mean value for each education combination of level and orientation. Occupation is measured in the same way, that is, as the mean value of every occupation by firm *i* according to the SPES classification.

Value added multifactor productivity is calculated in this way:

$$VAMP_{t,\,t+3} = LOG\Delta\, V.A._{\,i,\,t,\,t+3} - \lambda_1 *LOG\Delta\, L_{\,i,\,t,\,t+3} - \lambda_2 * LOG\Delta\, C_{\,i,\,t,\,t+3}$$

Where $LOG\Delta V.A._{i,\,t,\,t+3}$ is log value added in constant prices for firm *i* between *t* and *t+3*. λ_1 is median value of employment cost divided by gross production in constant prices per industry. $LOG\Delta\, L_{i,\,t,\,t+3}$ is the log difference in labour cost for firm *i* in period *t* to *t+3*. λ_2 is the median value of capital cost divided by gross production in constant prices per industry and last $LOG\Delta\, C_{i,\,t,\,t+3}$ is the log difference in capital cost for firm *i* in period *t* to *t+3*.

Not all education combinations are included in the model, only the most important ones. A restriction was set to include only education combinations of two percent or more of the individuals working within the private sector in 1997 (see Appendix). Individuals are not choosing their education without planning. This implicates that education is capturing more than school training. Ambitious and smart individuals are drawn to/overrepresented in certain education levels and fields, which causes measurement problems. Education can therefore be seen as a proxy for human capital, but it is not complete since it lacks information on social skills and other personal characteristics. Normally bad quality underestimates the educational level and this measurement error can compensate for this upward bias, but in Sweden's case the data is quite reliable. Only one or two percent of the private sector's workforce has an education level that is unknown. In 2007 approximately 85 percent of the education, level and subject, of the population were correct and the rate is probably higher within the private sector. About 5 percent of the working force has a missing ISCO code for occupation.

In order to separate the effects of human capital from age structure and differences in scale, dummy variables were included in model 2. Further 50 dummies for industries were also included. When including industry dummies one can separate the effect between a growing firm and a growing industry by holding the growth of the industry constant.

Model 2, an extended model 1:

$$LOG\Delta Y_{i,\,t,\,t+3} = \alpha + \beta * \mathbf{HC}_{i,t} + \beta * YOUNG_{i,t} + \beta * OLD_{i,t} + \beta * SMALL_{i,t} + \beta * LARGE_{i,t} + \beta * \mathbf{IND}_{i,t} + \varepsilon_t$$

where, $LOG\Delta Y_{i,\,t,\,t+3}$ and $HC_{i,t}$ is measured as in Model 1. The variables YOUNG and OLD are proxies for mean number of employees per firm for two different age groups. The groups are divided into less or equal to 35 years, YOUNG, and equal or above 55 years of age, OLD. They are included as proxies for labour market experience which use to be positively correlated to age. Young people on the other hand have a more up to date and a higher level of education and has grown up with new technology. They are quicker and healthier, but except for less experience they have a disadvantage to older persons in the workforce since they have a much higher tendency to become parents, thus using parental leave to higher extents.

Sweden is a relatively small country with a considerable number of large worldwide companies. In order to control for different growth and productivity in different markets, two dummy variables were included for firm size. SMALL with at most 10 employees is assumed to be operating mainly on the local market. LARGE firms with at least 250 employees might be operating on a wider market like the European or the international market.

Another measurement of human capital, mean value of each occupation per firm, is replacing education in both Model 1 and Model 2. Also the two OECD definitions, narrow and broad users of ICT, are presented in the results.

Further to be able to decide whether or not there are any differences in human capital between successive firms, odds ratios were calculated from the Logit model for both education and occupation. Success firms were defined as those growing with at least 100 percent in three years time. The Logit model setup, that is model 3:

$$logit(p_i) = \ln\left(\frac{p_i}{1-p_i}\right) = \alpha + \beta * \mathbf{HC}_{i,t} + \varepsilon_t$$

here the probability p_i is defined as the probability for a firm to grow by at least 50 or 100 percent between *t* and *t*+3. This logistic model is also used to see if there are any differences in human capital between surviving and non surviving firms as well as between new and old firms. Results from the Logit model are transformed into an odds ratio to make the interpretation easier.

The hypothesis of education is that firms with higher mean values of highly educated individuals in the subjects of natural and technical science and working as professionals or ICT skilled is more common in high growing firms, in surviving firms and in new firms.

4. Human Capital and growth

The purpose of this chapter is to describe the major changes that took place on the labour market in the Swedish business sector during the time period from1997 to 2007 with focus on human capital.

Human capital is regarded as being "the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (OECD, 2001 p.18) and thereby impossible to measure correctly. Instead proxies are created aiming to measure something close to human capital. A commonly used proxy for human capital is educational level. In this paper, not only will the level of education, but also the educational subject and occupation be included to deepen the micro level knowledge about human capital.

4.1 Firm growth

Lucas R.E. (1993: 270) wrote "The main engine of growth is the accumulation of human capital – of knowledge – and the main source of differences in living standards among nations is differences in human capital. Physical capital accumulation plays an essential but decidedly subsidiary role". Abramovitz (1993) wrote that "total factor productivity is the unmeasured source of growth". To be able to further raise standards of living, a rise in productivity is crucial. So far human capital has been one of the dividing forces for higher growth and productivity.

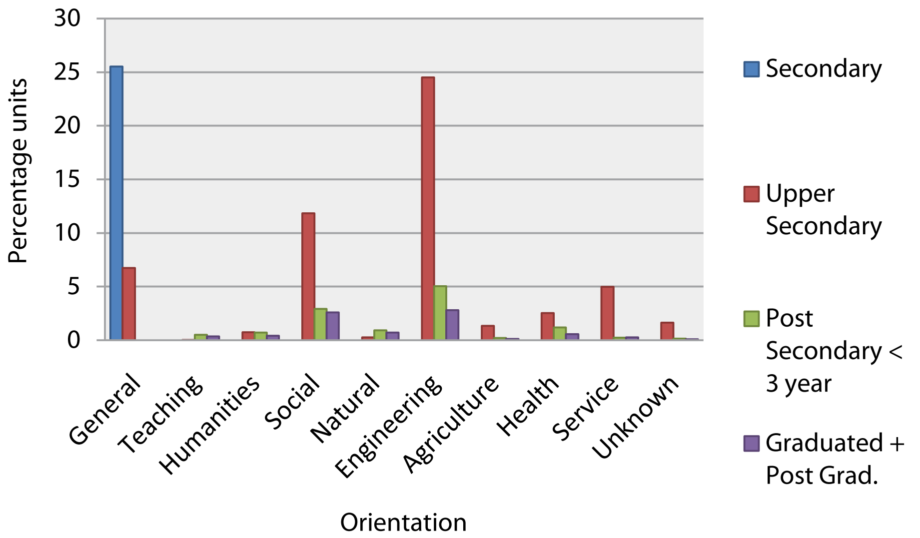
Sweden is a relatively high-tech country and was therefore one of the countries which were the most affected by the ICT sector's bubble burst in 2001. ICT related firms went from rapid growth and high value on the stock market to a collapse that affected more or less the whole labour market of ICT-intense and high tech firms which experienced a crisis. In comparison to those firms that used to be high growth firms, low-tech and low ICT-intensity firms with less educated employees were less affected by the ICT crisis.

4.2 Education

The Swedish school system allows anyone smart enough to study and achieve higher education degrees, as all levels within the school system are free of charge. Students are also not dependent on their parent's wealth as everyone has the opportunity to get a government loan for higher education.

A frequent used proxy for human capital is education. A common measure to use in this context is the share of high educated. In this paper the measure will be a bit broader. Not only has the level been split into four different categories, but the orientation is also included to widen the picture.

Figure 1, Private sector, individual's education in 1997, percent



N= 1511796 individuals

The most common education level in 1997 was upper secondary. About 55 percent had achieved that level, but among individuals 35 years and younger the rate was higher, 65 percent. In 1997 one quarter of the working force in the private sector had only a secondary degree. This, the lowest level, is overrepresented among the elderly. Almost half, 48 percent, of those above 54 years of age had the lowest eduation level. Among those age 35 and younger only 14 percent had a secondary degree as the highest level achieved. The most common orientations are general orientations and engineering. Among the secondary educated general is the only orientation. All individuals with a secondary level are by default coded as general. For the highest education levels, post secondary and graduated, general is not an option. Instead, social science and engineering are the most common. Social science also includes fields like psychology, business, administration, journalism and law. Number of unknown is relatively small, only about 2 percent.

As can be seen from table 1, the number of individuals with the lowest education level has fallen by 9 percentage points, that is, from 26 percent to 17 percent in ten years time.

Table 1, Change in individual's education in private sector between 1997 and 2007, Percentage points

Subject	Secondary	Upper Secondary	Post Secondary < 3 years	Graduated + Post Grad.	
General	-9	3	0	0	-6
Teaching	0	0	0	1	1
Humanities	0	1	0	0	2
Social	0	-3	0	2	-1
Natural	0	0	0	1	1
Engineering	0	-2	0	2	1
Agriculture	0	0	0	0	0
Health	0	1	0	1	2
Service	0	0	0	0	0
Unknown	0	0	0	0	0
	-9	1	1	7	0

Year 1997, N = 1511796 individuals
Year 2007, N = 2270825 individuals

The labour market in 2007 was represented by a higher degree of well educated, that is, with at least 3 years of post secondary education, named Graduated + Post graduated. Among those with an upper secondary education level, there was a change from the two major groups of social and engineering to general, but also humanities were included. The increase in health education is to a great extent explained by the structural effect resulting from a shift in production from public to private sector.

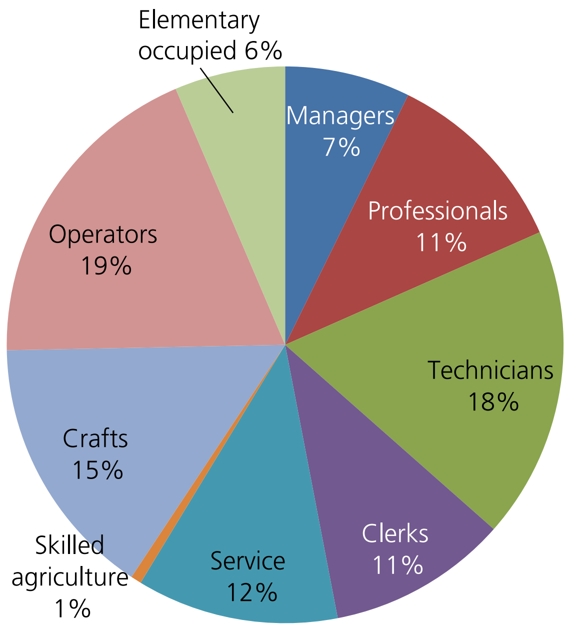
Small firms, that is, those with 10 or fewer employees, have in general less educated employees compared to larger firms. In addition, large firms with at least 250 employees, have in general a higher educated staff than medium sized firms. They also have fewer employees with a general education and more often employees who have studied engineering and healthcare than medium and small firms.

4.3 Occupation

The other proxy used for human capital, besides education, was occupation. Compared to education, occupation is expected to include differences in personal characteristics. It is also more closely linked to what people actually work with, as many people are not working within the same area as they were trained.

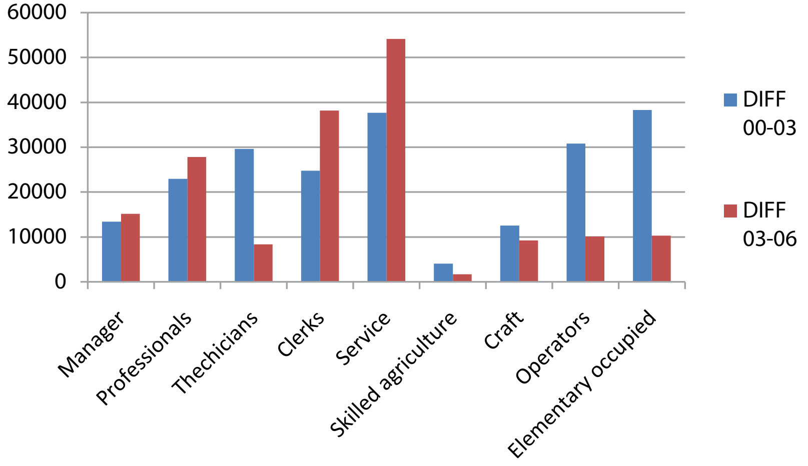
In figure 1 occupation by 1-digit level ISCO are presented for the private sector in Sweden in 2000. This division is not presented in the results, the purpose for it is rather to show the Swedish distribution of occupations within the private sector according to the more common 1-digit level ISCO.

Figure 2 Occupation in private sector by ISCO, 2000



From Figure 2 we see that the Swedish labour force in the private sector was diversified to many occupations. The most frequent occupation according to ISCO was plant and machine operators, followed by technicians and associate professionals, each close to 20 percentage points of the private sector's work force. Seven percent of employees in the private sector were classified as managers. One particularly small group was skilled agriculture.

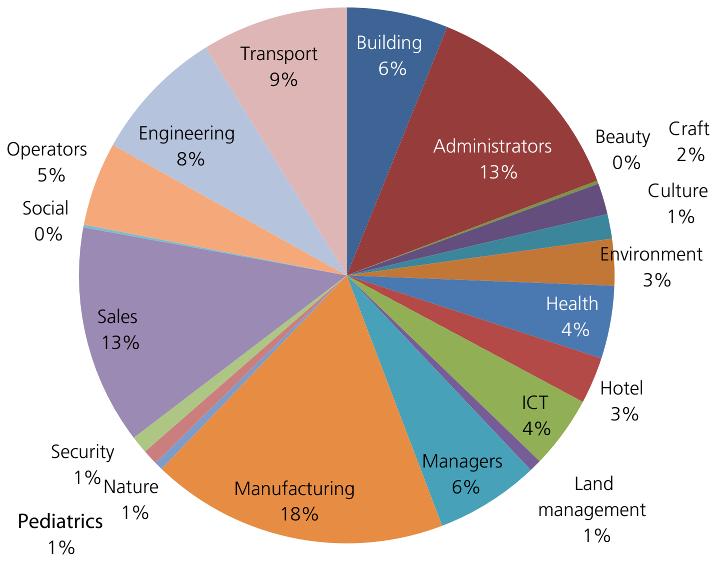
Figure 3 Change in number of employees per ISCO between 2000 and 2003, 2003 and 2006



In the three years following 2000, which were heavily affected by the ICT-bubble burst, low-skilled occupations like elementary occupations and service expanded the most, both by 38 000 individuals. Meanwhile the smallest group, skilled agriculture, had the highest percentage growth rate, 38 percent. In the following 3 year period, 2003-2006, service workers grew even more. Occupied as clerks grew also substantially.

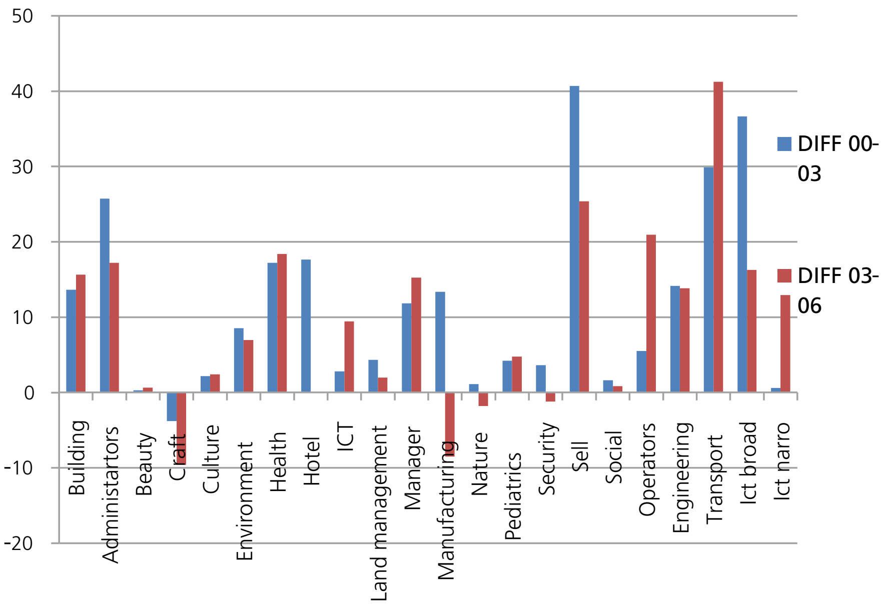
Instead of using the 1-digit level ISCO classification in the models, the classification used in the Swedish Public Employment Service, SPES, was used. This was done to widen the picture and raised number of occupations.

Figure 4, Private sector by occupation according to SPES in 2000



According to the wider SPEC classification, the occupation that contains the largest share of people, 18 percent, in the private sector is manufacturing. Also, sales personnel and administrators are common occupations, 13 percent each. The occupations according to the SPEC classification is correlated to industry, but not strictly bounded to it. For example, employees classified as administrators or sales are represented in many industries, whereas workers within building are often working within the construction industry.

Figure 5 Change in number of employees per occupation by SPEC between 2000 and 2003 and between 2003 and 2006



This broader presentation of occupations, including the OECD definition of broad and narrow ICT occupied to the right, reveals that a few occupations have decreased from 2003 to 2006. There were nearly 10 000 people leaving both craft and manufacturing occupations. More individuals with high education entered the private labour market in the beginning of the 21th century, explaining some of the expansion of the ICT industry with the broad definition. Twenty three percent were coded according to the broad OECD measure and about six percent according to the narrow one. The telemarketing industry expansion explains some of the increase in the number of employees working with sales. Outsourcing production is another explanation when focus is moving from production to advertising and sales. The number of people working with transport increased within the private sector due to the deregulation of the Swedish taxi industry.

5. Results

Results from Model 1 with no exogenous variables other than education are shown in Table 1 and Table 2. In Table 1, log differences in value added between t and t+3 are explained by firm level mean of the major education combinations.

The model explanation was not expected to be high from just the mean number of the education combination on growth, but Table 1 reveals a far lower explanation of the model than expected. The highest value of adjusted-R^2 is only 0.013, found in 2003. Still, significant coefficients can be seen. This means that there are distinct differences in staff structure between firms with different growth patterns.

The major education combinations of level and subject are included in the model and presented in the tables below. The intercept captures all the other education combinations. The major combination's coefficients are related to the intercept. If the education combinations captured in the intercept were performing better than the rest, all the other coefficients will be negative. In the following year the intercept is doing worse and the major education combinations are doing better as they all get positive correlations. But this is not due to the fact that the presented education combinations are all contributing so much more to growth, but rather that they are doing better than the intercept. This means that it should not be interpreted as if an education combination is doing better when the coefficient is rising from 0.15 one year to 0.25 the following period.

Table 1, OLS, Firm growht in value added

Level	Subject	1997-2000	2000-2003	2003-2006
Secondary	General	-0.002	0.06***	-0.16***
Upper sec	General	0.13***	0.05***	0.05***
	Social	0.09***	0.06**	-0.16***
	Engineering	0.15***	0.03***	-0.02
	Agriculture	-0.02	0.06*	0.32***
	Health	0.06*	0.01	-0.05*
	Service	0.09***	0.06**	-0.16***
Post Sec	Social	0.12***	-0.05	0.02
	Engineering	0.28***	0.04	0.08***
Grad	Social	-0.01	0.05*	-0.01
	Engineering	0.10***	-0.02	0.24***
Adj-R^2		0.005	0.001	0.013
N		50859	58081	68885

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

The time period 1997-2000 was a period with a general economic expansion with a special emphasis on the ICT-related activities. This emphasis also created a bubble on the stock market with over-investment in almost everything relating to the

Internet. The highest coefficients in the 1997 regression are found in upper and post secondary education with engineering orientation, with estimates of 0.15 respectively 0.28.

The ICT bubble burst in 2001 affected the whole economy, but mostly the ICT sector and high-tech industries. In comparison to the ICT and the high-tech sector, more traditional firms with less advanced educated staff seemed to be growing. The results in table 1 confirm this economic downturn between 2000 and 2003. A disadvantage for these models with computed log values, concerning both growth and productivity, is the exclusion of firms with negative growth. The Logistic model presented in table 5, 6 and 11 therefore includes more observations as firms with negative growth are included.

The last time period for which results are presented in this paper, 2003-2006, is telling another story. Firms with a higher degree of well educated engineers had grown faster, whereas firms with low educated had done worse. Firms with a high proportion of upper secondary educated persons with social and service focus had grown in late 20th century, whereas the pattern was the opposite in 2003-2006. Upper secondary educated persons within the agriculture field are having a strong positive effect as the agriculture sector experienced a period of quite high growth during these years.

Moving from value added growth to productivity growth in table 2, the education pattern is rather similar. Even more significant values appear, especially in 2000, indicating a stronger link between productivity and employees' education than between growth in value added and education.

Table 2, OLS, Value added multifactor productivity

Level	Subject	1997-2000	2000-2003	2003-2006
Secondary	General	0.09***	0.11***	-0,07***
Upper sec	General	0.19***	0.11***	0,04*
	Social	0.21***	0.15***	-0,06***
	Engineering	0.19***	0.08***	0,01
	Agriculture	0.08**	0.09**	0,32***
	Health	0.09***	0.03	-0,05*
	Service	0.14***	0.12***	-0,14***
Post Sec	Social	0.12***	0.01	-0,02
	Engineering	0.25***	0.08***	0,11***
Grad	Social	-0.03	0.09***	-0,02
	Engineering	-0.03	-0.02	0,16***
Adj-R2		0,006	0.001	0.007
N		50051	57235	67539

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

In 1997 firms with a higher degree of employees with education levels below 3 years of university studies had improved their productivity more than firms with higher degrees of graduated persons. The results from table 2 are rather similar to those in the value added model in table 1. In general the productivity coefficients are a bit higher, indicating that those with less common education combinations captured by the intercept are less productive.

The adjusted R^2 is telling in small gestures that education was a less important explanatory variable in 2000 for firm level growth and productivity gains between 2000 and 2003 than the other two periods. In 2003 education combinations are more diversified and better explained by the model. A high degree of employees of general, social and service educated are seen in less productive firms in 2003. In contrast, the employees with agriculture and engineering fields are overrepresented in firms with the largest productivity increases in the latest time period.

In Table 3 an expanded Model 1 is presented, including firm size and two dummy variables for firm's mean age of employees as well as 50 industry dummies (approximately 2-digit level NACE-code).

Table 3, OLS, Firm growht in value added

Level	Subject	1997-2000	2000-2003	2003-2006
Secondary	General	-0.05***	-0.01	0,01
Upper sec	General	-0.02	0.04***	0,03
	Social	-0.02	0.01	-0,07***
	Engineering	0.01	0.01	0,04***
	Agriculture	-0.12***	0.04	0,03
	Health	-0.11***	0.01	-0,02
	Service	0.01	-0.01	0,03
Post Sec	Social	0.07**	-0.07**	0,07***
	Engineering	0.12***	0.05**	0,01
Grad	Social	0.04	0.06**	0,03
	Engineering	0.16***	0.01	0,14***
Firm <= 10 employees		0,09***	0.08***	0.06***
Firm > 250 employees		-0,09***	-0.12***	0.01
Employees age <= 35		0,17***	-0.09***	0.31***
Employees age >= 55	-	0,14***	0.09***	-0.15***
50 Industry dummies		included	included	included
Adj-R2		0,07	0.08	0.12
N		50859	58081	68885

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

The new variables improved the overall significance, but the highest Adj-R^2 level is still only 0.12 (in 2003). When firm composition is taken into account, a somewhat different pattern appears compared to model 1. Some coefficients that were significant now became insignificant, indicating that the education combination was connected to a certain firm or industry component. For example, individuals within the fields general, social or engineers with a upper secondary level were overrepresented in growing industries rather than in growing firms within industries in 1997-2000. This is because the coefficients are dropping when industry, firm size and firm age composition were taken into account.

Most important for value added growth according to table 3 is the age composition. Growing firms have a high share of young employees . It does not have as much to do with young people's creativeness, but rather the growing firms' needs to recruit and the supply of young individuals entering the labour market are leading to higher degree of young people in growing firms. In economic downturns firms do not need to recruit to the same extent as before. This affects young people who are about to enter the labour market by delaying or preventing the entrance. The young people entering the labour market are also affected because firms by law are forced, with some exceptions, to dismiss the latest recruited employee when people are withdrawn from the labour market, which more often is younger people. This can be seen from the 2000 column with a much lower coefficient for the mean value variable of employees 35 years of age and younger. The high coefficient for upper secondary agriculture in 2003 in table 1 is to a high extent explained by the growth in the agriculture industry, since the strong positive effect from table 1 is gone in table 3.

The strong effect still remains, after controlling for firm characteristics, for highly educated engineers with post secondary or graduated in 1997 and graduated in 2003. Besides having many qualified engineers it is also important for a firm to compete successfully in this industry. The agriculture and health orientations for upper secondary educated persons were kept up by other factors than their human capital in 1997. When controlling for industry, firm size and age they were significantly overrepresented in less growing firms.

Table 4 is with value added multifactor productivity as endogenous variable and including more exogenous variables than table 2.

Table 4, OLS, Value added multifactor productivity

Level	Subject	1997-2000	2000-2003	2003-2006
Secondary	General	-0.04**	0	0
Upper sec	General	-0.02	0.03*	0
	Social	-0.002	0.03	-0,06***
	Engineering	0.01	0.01	0,04**
	Agriculture	-0.07**	0.02	0
	Health	-0.11***	0.04	-0,04
	Service	0.03	0.01	0,03
Post Sec	Social	0.03	-0.04	0,01
	Engineering	0.08***	0.05	0,01
Grad	Social	0.01	0.09***	0,03
	Engineering	0.05	0.01	0,09***
Firm <= 10 employees		0,05***	0.04***	0.01
Firm > 250 employees		-0,02	-0.04	0
Employees age <= 35		0,09***	-0.05***	0.13***
Employees age >= 55		-0,09***	0.04***	-0.07***
50 Industry dummies		included	included	included
Adj-R2		0,09	0.07	0.10
N		50051	57235	67539

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

The overall significance of the model is improved by the additional firm characteristic variables included in the model, as was the case with value added growth. Some of the education information is now transferred to the additional variables as the significance for most of the education variables drops compared to the smaller model in table 2.

Post secondary educated engineers in 1997, social science educated with post secondary degrees in 2000 and graduated engineers in 2003 have the highest coefficient in the productivity model. As in the growth model, those with orientations of agriculture and healthcare are working within less productive firms in 1997. The upper secondary on the subject social continue to contribute the least to firm growth in 2003. This education is decreasing among the youngest and growing within the oldest age group.

In table 5 the same model is used as in table 1, but instead of using an OLS-regression, a Logit model is used to predict the probability for an event to happen as a robustness check. However, this will also lead to results that are easier to interpret. Still, the question is the same: are there any differences between high growth firms and others?

The odds ratio shall be interpreted as: what is the probability of a firm with at least 100 percent growth from t to t+3 to have a certain education composition of their staff compared to a firm with less than 100 percent growth? When the odds are 1, no effect from education is found. Two is twice as high a chance for the firm to have high growth, given that all staff has that particular education background. The number of observations is higher in this model, as the firms with negative growth are included. This was not the case in the previous tables where the OLS method was used.

Table 5, Odds Ratio, Value added growth > 100 percent

Level	Subject	1997-2000	2000-2003	2003-2006
Secondary	General	0.3***	1.2	0,3***
Upper sec	General	1.2	1.9***	1,7***
	Social	1.0	1.9***	0,5***
	Engineering	1.0	1.2	0,8*
	Agriculture	0.3***	0.6**	1,6***
	Health	0.2***	0.7	0,2***
	Service	0.9	1.1	0,5***
Post Sec	Social	1.9***	1.8***	1,2
	Engineering	3.0***	3.0***	1,2
Grad	Social	1.3	1.9***	1,4**
	Engineering	1.5*	1.8***	2,1***
Likelihood Ratio		377	120	414
n(p=1)		2777	3123	3288
N		59864	78669	90380

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

The models are all significant with a high likelihood ratio, partly due to large numbers of observations, lowest during the crisis in the beginning of 21st century (education less important to explain growth/lack of growth in firms) and highest thereafter. It is also because there actually were differences in education composition among firms with extremely high growth and others.

For example, in a firm where all staff members were graduated engineers, the chance was about twice (2003 graduate) or three times (post sec. 1997, 2000) as high of having a growth of at least 100 percent in three years time, compared to firms with only more rare educations, as in the intercept. In general, highly educated persons were significantly overrepresented in extremely high growing firms. Those who were less educated with only secondary education were not that frequent in these exceptionally well performing firms.

Table 6 is the same as table 5, but the definition of a extremely high growing firm is less narrow. The odds ratio in table 6 is reflecting the probability for a firm to grow with at least 50 percent in three years time with all of the employees within a certain education combination. This definition of less extreme growth will lead to more observations for the firms defined as highly growing, or about 10 000 in table 6 rather than about 3 000 in the narrow definition in table 5.

Table 6, Odds Ratio, Value added growth 50 percent

Level	Subject	1997-2000	2000-2003	2003-2006
Secondary	General	0.6 ***	1.3***	0.5***
Upper sec	General	1.3***	1.1	1.2***
	Social	1.2*	1.1	0.6***
	Engineering	1.4***	1.3***	1.0
	Agriculture	0.6***	1.2	3.4***
	Health	0.8	0.7**	0.4***
	Service	0.9	1.1	0.6***
Post Sec	Social	1.8***	1.0	1.1
	Engineering	2.6***	1.9***	1.3***
Grad	Social	0.9	1.1	1.0
	Engineering	1.8***	1.4***	2.1***
Likelihood Ratio		499	94	1013
n(p=1)		9957	9642	12009
N		59864	78669	90380

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

The model significance is higher with this lower definition of growth except in 2000. The overall patterns compared to the more extreme growth are more or less the same, although the coefficients are generally lower in table 6, meaning that education is more important for more extremely growing firms. The importance for the firms to have a high degree of well educated engineers remains, but is lower after reducing the limits for high growth.

In 1997 a firm with all employees within post secondary education in engineering had 2.6 times higher a chance of growing by 50 percent compared to a firm with all staff having more rare educations. The opposite was true for a general secondary education, where the chance was nearly half compared to the intercept. In 2003 the growth of the industry is appearing, which gives upper secondary agriculture a high value.

Moving from education to occupation as a proxy for human capital, we will lose one time period as no data were available for occupation before 2001. For 2000 individuals' occupations in 2001 were used as a proxy. Table 7 shows the twelve occupations out of twenty defined according to the Swedish Public Employment Service, SPES. A limitation was set to include only occupations represented by at least two percent of the labour force in private sector.

Table 7, OLS, Firm growht in value added

	2000-2003	2003-2006
Administration	0.21***	-0.33***
Building	0.12***	-0.29***
ICT	-0.07***	0.14***
Sales	0.10***	-0.16***
Hotel	-0.03*	-0.22***
Health	0.12***	-0.20***
Manufacturing	-0.01	-0.10***
Operators	0.10***	-0.10***
Environment	0.02	-0.15***
Engineer	0.05**	-0.03*
Transport	0.22***	-0.29***
Manager	0.20***	-0.24***
Adj-R2	0.01	0.02
N	58655	68885

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

From table 7 it seems as the smallest occupations in 2003 are doing better than all those included in the model, with one exception, as all coefficients are negative. The position of the intercept is relatively lower in 2000 than 2003. During the crisis a high proportion of administrators and managers seemed important to keep up the firm value added growth, but it also seems important not to keep all of them in the following period, as they seemed to contribute less to growth during the next growth phase in the business cycle. The occupation contributing the most to value added growth in 2003 is the ICT industry. The ICT crisis is shown in the coefficient in 2000, with the lowest value of all occupations. That those working with transportation are doing relatively better in 2000-2003 than in the more expansive period is not as expected. A more common hypothesis is instead that it would be closer linked to the business cycle. The deregulation of the government railway monopoly was abolished in 1988 and two years later the monopoly of the taxi industry was abolished.

Table 8, OLS, Value added multifactor productivity

	2000-2006	2003-2006
Administration	0.24***	-0.34***
Building	0.12***	-0.31***
ICT	-0.09***	0.03
Sales	0.16***	-0.13***
Hotel	0.02	-0.20***
Health	0	-0.28***
Manufacturing	0.05***	-0.06***
Operators	0.13***	-0.09***
Environment	0.01	-0.16***
Technical	0.07***	-0.05*
Transport	0.20***	-0.32***
Managers	0.18***	-0.18***
Adj-R2	0.01	0.02
N	57235	67539

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

There are no great differences between occupation coefficients in the growth model in value added terms in table 7 and the productivity growth model in table 8. Compared with the value added model, ICT workers were not contributing as much to the rise in productivity as to growth in value added in 2003.

Table 9, OLS, Firm growht in value added

	2000-2003	2003-2006
Administration	0.07***	-0.06***
Building	0.08***	-0.05***
ICT	-0.08**	-0.02
Sales	0.06***	-0.05***
Hotel	0	-0.01
Health	0.10***	0.01
Manufacturing	0	
Operators	0.01	0.03
Environment	0.01	0.01
Technical	0.02	0.07***
Transport	-0.07***	0.13***
Managers	0.11***	-0.02
Firm <= 10 employees	0.07***	0.07***
Firm > 250 employees	-0.11***	0.01
Employees age <= 35	-0.07***	0.31***
Employees age >= 55	0.08***	-0.16***
50 Industry dummies	included	included
Adj-R2	0.09	0.13
N	58081	68885

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

Those extra variables included in model 9 are absorbing some of the common information with occupations, leading to less diversity between occupations. The picture is still much the same. Administrators and managers had high values in 2000 and low ones in 2003. The strange results for those working in transport in model 7 are not repeated in table 9. This is because the results are more in line with what was expected, that is, closely affected by the business cycle. Engineers are doing better than the reference occupations in 2003 when control variables are included in the model. It is surprising that the coefficient for builders is so high for the value added growth in 2000-2003, because the construction industry was having difficulties in late 1990s, in other words, right before the ICT crisis.

Educated within the healthcare area did not mean as much for value added growth as those working in the healthcare area. This might be explained by the growing amount of care for the elderly within the private sector, where most are assumed to be coded as working within health; however, not all employees have a relevant education. When the health sector was compared to others, it was relatively more robust through the business cycle and was therefore performing relatively better in the economic downturn period 2000-2003.

Table 10, OLS, Value added multifactor productivity

	2000-2003	2003-2006
Administration	0.11***	-0.06***
Building	0.05**	-0.04**
ICT	-0.07*	-0.03
Sales	0.06***	-0.08***
Hotel	0.04	-0.02
Health	0.06*	-0.01
Manufacturing	0.01	0
Operators	-0.01	-0.01
Environment	0	0.03
Technical	0.06**	0.08***
Transport	-0.08***	0.10***
Managers	0.08***	-0.03*
Firm <= 10 employees	0.04***	0.01*
Firm > 250 employees	-0.04	0
Employees age <= 35	-0.04***	0.13***
Employees age >= 55	0.03**	-0.07***
50 Industry dummies	included	included
Adj-R2	0.07	0.10
N	57235	67539

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

Firms with higher productivity growth in 2000-2003 had relatively more workers with tasks as administration, managers and sales. During the period 2003-2006 the picture was different. Engineers were over-represented in productive firms. As seen before, the demand for workers within transport was highly correlated to the business cycle. Effective logistics of goods and humans is important for productivity during a growth period.

To be able to diversify high growing firms from others, a Logit model was used in the same way as with education in table 5. Table 11 is presenting the probability for a firm to be a high growth firm, where high growth is defined as having at least 100 percent growth in 3 years time.

Table 11, Odds Ratio, Value added growth > 100 percent

	2000-2003	2003-2006
Administration	7.0***	1.0
Building	2.8***	0.8*
ICT	2.2***	2.5***
Sales	1.7***	0.7***
Hotel	0.7	0.5***
Health	1.6**	0.4***
Manufacturing	1.7***	0.7***
Operators	1.8***	0.5***
Environment	1.0	0.5***
Technical	3.3***	1.2*
Transport	3.3***	0.6***
Managers	5.3***	0.8*
Likelihood Ratio	627	286
n(p=1)	3123	3288
N	78669	90380

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

An interesting observation to notice is the high Likelihood Ratio in 2000. In previous tables the explanation was lower for that time period. When separating the extremely high growth firms from the others, occupation made a difference. As with the continuous growth in the previous tables, administrators and managers are well represented in these high growth firms in 2000. In 2003 the ICT skilled are the ones overrepresented in the growing firms. The smallest occupations are also more common in high growth firms compared to other occupations, as the coefficients presented in the model generally are lower in 2003. However, why is the demand so high for administrators in extremely high growing firms?

OECD definition ICT workers

In table 12 both the OECD broad and narrow definitions of ICT users were tested, but in different setups. This was done as the broad definition includes all the narrowly defined, which makes them positively correlated. As a result, it was not a good idea to put in the same model. The other variable included was firm size, one dummy variable for small and one for large.

Table 12, OLS, Firm growht in value added

	00-03	00-03	03-06	03-06
ICT, narrow definition	-0.09***		0.25***	
ICT, broad definition		-0.01		0.10***
Firm <=10 employees	0.08***	0.08***	0.04***	0.04***
Firm > 250 employees	-0.06***	-0.07***	0.02	0.02
Adj-R2	0.005	0.004	0.005	0.003
N	58081	58081	68885	68885

*** indicate significance at the 1% level, ** significance at the 5 %-level and * significance at the 10 %-level.

There is a significant difference between ICT skilled and non ICT skilled employees in growing firms according to the OLS results in table 12. The narrow defined are more negative in 2000 than the broad defined. No differences between broad ICT users and others were found in 2000 concerning contribution to value added growth. The coefficient for the narrow ICT definition for 2003 can be interpreted as if all employees were ICT experts the firms growth would in general be 25 percent higher than an average firm with no ICT experts. Even though the coefficients are quite high and significant, they do not explain all of the difference in growth between firms, but they say something. The Adj-R^2 is, as in the first two tables, extremely low.

Table 13, OLS, Value added multifactor productivity

	00-03	00-03	03-06	03-06
ICT, narrow definition	-0.12***		0.17***	
ICT, broad definition		-0.02*		0.06***
Firm <=10 employees	0.05***	0.05***	0	0
Firm > 250 employees	0	0	0.02	0.02
Adj-R2	0.002	0.001	0.002	0.001
N	57235	57235	67539	67539

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10 % level.

The occupation coefficients are a bit lower when it comes to the productivity model. The patterns are thou still the same. Firms with a high degree of ICT skilled are decreasing and have lower productivity growth as a result of the ICT bubble burst. Thus these firms contribute to faster value added and productivity growth between 2003 and 2006.

Table 14, Odds Ratio, Value added growth > 100 percent

	00-03	00-03	03-06	03-06
ICT, narrow definition	1.1		2.7***	
ICT, broad definition		1.7***		2.0***
Likelihood Ratio	0,84	93	117	192
n(p=1)	3121		3288	
N	78669		90380	

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

An interesting observation in 2000 is that ICT experts, narrow definition, on average are equally important for highly growing firms as any other occupation, not less, not more. However, those defined as broad ICT users seem to be significantly more important. In 2003, not only are the narrowly defined ICT users common in highly growing firms, but the broadly define ICT users are also common.

Until now focus has been on one particularly measure of firm success, that is growth. Next another measure of success is used, survival. Table 15 presents the odds of a firm's survival from 1997 to 2000 and from 1997 to 2006. The measure for human capital is mean number of each education combination per firm. Two different model setups are used, without and with control variables. In Table 16 results from 2000 and 2003 are presented.

Table 15, Odds Ratio, Survived firms

Level	Subject	97-00	97-00	97-06	97-06
Secondary	General	1,5***	1,3***	1,5***	1,1**
Upper sec	General	1,4***	1,1	1,1	0,9
	Social	1,7***	1,7***	1,3***	1,2***
	Engineering	2,3***	1,4***	1,9***	1,2**
	Agriculture	2,0***	1,2	1,3**	0,9
	Health	2,3***	1,7**	2,2***	1,3**
	Service	1,7***	1,2	1,2	1,0
Post Sec	Social	0,7**	1,0	0,7***	0,8**
	Engineering	3,2***	2,3***	2,1***	1,8***
Grad	Social	0,5***	0,9	0,6***	0,8**
	Engineering	0,8	1,4*	0,9	1,3**
Firm <= 10 employees			0,4***		0,6***
Firm > 250 employees			0,8		1,2**
Employees age <= 35			1,6***		1,1***
Employees age >= 55			0,5***		0,5***
50 Industry dummies			included		included
Likelihood Ratio		350	2409	554	2589
n(p=1)		54561	54561	37674	37674
N		59864	59864	59864	59864

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

Results are quite robust trough both time periods and model setups, even though the effects are to some extent captured by the included control variables, lowering the education importance. In the shorter time period the results are more diversified and more often significant, that is, greater differences between education combinations between 1997 and 2000 rather than 1997 and 2006. Can it be due to a more homogenous time period?

Higher odds for surviving have firms with higher proportions of employees with a secondary and upper secondary education as well as post secondary engineers. Individuals with an orientation in engineering and health are more frequently represented in surviving firms than staff with an orientation in social. Of importance is also young rather than high mean age of employees and not being a small firm. The latter is probably a result of new firms die early.

Table 16, Odds Ratio, Surving firms

Level	Subject	00-03	00-03	03-06	03-06
Secondary	General	2,2***	1,4***	1,0	1,1**
Upper sec	General	1,0	1,1	1,4***	1,2***
	Social	1,4***	1,3***	1,0	1,1**
	Engineering	1,9***	1,4***	1,6***	1,2***
	Agriculture	2,2***	1,5***	1,6***	1,4***
	Health	1,6***	1,1	1,2**	1,1
	Service	1,0	1,0	1,2**	1,2**
Post Sec	Social	0,9	1,0	0,8**	1,0
	Engineering	1,4***	1,6***	1,3***	1,3***
Grad	Social	0,7***	0,9	0,7***	1,0
	Engineering	0,8**	1,1	1,0	1,3***
Firm <= 10 employees			0,7***		0,6***
Firm > 250 employees			1,3***		1,2*
Employees age <= 35			0,5***		2,0***
Employees age >= 55			1,3***		0,6***
50 Industry dummies			included		included
Likelihood Ratio		863	2687	355	3093
n(p=1)		61530		70026	
N		78669		90380	

In the two later time periods, that is from 2000 and 2003 the most remarkable findings are the age differences. This can be found in the control variables for mean age and in the lowest education level, secondary. The ICT crisis left out young people from the labour market in the first time period. From the right column one can found that a firm hire only young people, that are no older than 35, will have twice the odds of surviving until 2006 than a firm only hiring people between 36 and 54 years of age.

In table 17 educations is replaced by occupations.

Table 17, Odds Ratio, Surving firms

	00-03	03-06
Administration	0,8***	0,9***
Building	1,3***	1,3**
ICT	0,3***	0,8***
Sales	1,0	1,0
Hotel	0,7***	0,7***
Health	0,9*	1,1*
Manufacturing	1,4***	1,7***
Operators	1,7***	1,9***
Environment	1,3***	1,1*
Technical	1,0	1,1*
Transport	1,4***	1,3***
Managers	1,4***	0,7***
Likelihood Ratio	936	689
n(p=1)	61530	70026
N	78669	90380

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

The ICT crisis is shown in the results in 2000-2003. As no surprise ICT experts were overrepresented in firms not surviving, but this is true even for the time period 2003-2006. The odds of a firm to survive are quite similar between the two time periods, which were not the case with growth. One exception is managers, which like in the growth tables shows the importance for managers during the ICT crisis, but not in the following period. If the managers are overrepresented in the first time period is explained by the use of them during the crisis or that they just are overrepresented in older firms doesn’t the story tell.

In table 18 another approach are presented. Previous tables presented firms who did not die during the time period. Next table, table 19, present what the demand for human capital, measured by education, was in new firms starting after 1997 respectively 2003.

Table 18, Odds Ratio, New firms

Level	Subject	97-06	97-06	03-06	03-06
Secondary	General	0,4***	0,7***	0,5***	0,8***
Upper sec	General	0,7***	0,8***	0,9**	0,8***
	Social	0,3***	0,5***	0,4***	0,5***
	Engineering	0,5***	0,8***	0,6***	0,8***
	Agriculture	1,4***	1,0	0,6***	0,6***
	Health	0,7***	0,8***	0,6***	0,7***
	Service	1,0	0,9*	1,0	0,8***
Post Sec	Social	0,8***	0,9	1,0	1,0
	Engineering	0,4***	0,7***	0,6***	0,7***
Grad	Social	1,0	1,0	1,4***	1,1**
	Engineering	0,9**	1,0	1,0	1,0
Firm <= 10 employees		3,4***		3,6***	
Firm > 250 employees		0,5***		0,5***	
Employees age <= 35		2,0***		1,7***	
Employees age >= 55		0,4***		0,5***	
50 Industry dummies		included		included	
Likelihood Ratio		1962	13292	990	9648
n(p=1)		48810		32575	
N		103703			

*** indicate significance at the 1% level, ** significance at the 5% level and * significance at the 10% level.

New firms, defined as firms who started their business after or in 1997, hired to a higher degree individuals with narrow education. That is small education combinations excluded in the model are more frequent in new firms as almost all education combinations presented are equal to or less than one. Less frequent in new firms are individuals with upper secondary education in social and secondary educated, all thou secondary to some extent is correlated with the age variables.

As was the case when using growth as an endogenous variable, growth in the agriculture industry between 1997 and 2006 was probably explaining why individuals with an education orientation in agriculture were overrepresented in successful firms. For individuals with a graduation in the field social, the higher odds for 2003-2006 remains after including control variables.

6. Conclusions

In 1997, the main levels of education among those in the labour force in the private sector in Sweden were general secondary education and engineering with upper secondary education. About half of the individuals in the private sector had either of those educations. Among those with a secondary degree, older people were overrepresented, whereas younger people in general had a higher education.

The human capital composition in firms with higher growth differed to firms with low or negative growth. Firms defined as high growing are different between the time periods of our study. It depended on the business cycle and was especially affected by the ICT-bubble burst in 2001. The switch of firms was visible in the high growth firms' staff structure. Another factor was that young people had problems entering the labour market during the years that followed the ICT crisis. When ICT and high-tech firms not were able to grow as before, low-tech firms with low human capital composition were equally well off. Firms with relatively high growth in 2000-2003 had a high proportion of administrators and managers.

Growing firms between 2003 and 2006 had, as expected, a high proportion of engineers and ICT skilled employees. Furthermore, individuals within the smaller education combinations and occupations excluded from the models were overrepresented in high growth firms in 2003-2006.

Before the ICT crisis, in the time period 1997-2000, highly educated engineers were overrepresented whereas upper secondary educated persons within agriculture and healthcare were less represented in high growth firms. The overrepresentation of well educated engineers was quite significant, especially for the firms with exceptional growth of at least 100 percent in a period of three years.

Sometimes the difference in education and occupation were due to industry, firm size and/or mean age of employees. For example, individuals with an upper secondary education in agriculture (in 1997 and 2003) or healthcare (in 1997) were rather overrepresented in growing industries than in growing firms.

Even though the number of observations was high, the models were quite sparsely explained. However, the coefficients from the human capital were quite often significant, indicating relevance for firm growth. Still, there are other factors that can explain growth. For instance, the organisation structure, the business concept, ICT uses, distribution and the market competition. This analysis is more of a mapping than in-depth explanation. However, it is an important step before we move on to more advanced analysis, since these results give us an insight in the types of education and occupations that are the most important for growing firms. These insights will be used in further steps in this project when human capital variables will be used in analysis of productivity, innovation and ICT use. In this coming analysis it will also be possible to combine the human capital with some cross-section data on work practices, organisations and organisational innovations for analysis of these relationships.

New firms had another staff composition than older firms. The mean age in new firms was younger.

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APPENDIX

Education definition, ISCED-97

Level	Label	Contains
1+2 (10) year	Secondary	Primary + lower secondary education, 9
3	Upper Secondary	Upper secondary, 2-3 years
41+52	Post Secondary < 3 years	Post secondary < 3 years
53+54+55+6	Graduated + Post Grad.	Graduated + Post Graduated, >= 3 years

Subject	Label	Contains
0	General	Broad general education
1	Teaching	Teaching methods and teacher education
2	Humanities	Humanities and arts
3	Social	Social sciences, law, commerce, administration
4	Natural	Natural sciences, mathematics and computing
5	Engineering	Engineering and manufacturing
6	Agriculture	Agriculture and forestry, veterinary medicine
7	Health	Health care and nursing, social care
8	Service	Services
9	Unknown	Unknown

Mean number of individuals

Level	Subject	1997	2000	2003
Secondary	General	27	25	22
Upper Secondary	General	6	8	9
	Teaching	0	0	0
	Humanities	1	1	2
	Social	14	12	11
	Natural	0	0	0
	Engineering	24	24	23
	Agriculture	2	2	3
	Health	2	3	3
	Service	3	5	5
Post Secondary	Teaching	1	1	1
	Humanities	1	1	1
	Social	4	3	3
	Natural	1	1	1
	Engineering	4	4	4
	Agriculture	0	0	0
	Health	1	1	1
	Service	0	0	0
Graduated + Post Graduated	Teaching	0	1	1
	Humanities	0	1	1
	Social	3	3	3
	Natural	0	1	1
	Engineering	2	2	2
	Agriculture	0	0	0
	Health	0	1	1
	Service	0	0	0
Total		96	98	98

The column does not equal 100 due to missing values.

International Standard Classification of Occupation, ISCO-88

Subject	Label	Contains
1	Managers	Legislators, senior officials and managers
2	Professionals	Professionals, physical, math and engineering
3	Technicians	Technicians and associate professionals
4	Clerks	Clerks
5	Service	Service, shop and market sale workers
6	Skilled agriculture	Skilled agricultural and fishery workers
7	Craft	Craft and related trades workers
8	Machine operators	Plant and machine operators and assemblers
9	Elementary occup	Elementary occupations, sale, agriculture, mining
0		Armed forces (excluded)

OECD definition of ICT occupied, using ISCO-88

Subject	Contains
ICT narrow	ISCO-code: 213, 312, 313, 724
ICT broad	ISCO-code: 121, 122, 123, 211, 212, 213, 214, 241, 242, 243, 312, 313, 341, 342, 343, 411, 421, 724

Occupation defined according to: Swedish Public Employment Service, SPES

Subject	Label	Contains
1	Adm	Administration, business economics, law
2	Build	Construction
3	ICT*	Information and Communication Technology
4	health	Keep-fit-activities, health
5	Sales	Selling, purchase, marketing
6	Craft	Craftsmen
7	Hotel	Hotel, restaurant, large-scale household
8	Health	Health and nursing
9	Manuf	Manufacturing construction
10	Operators	Installation, operate the machinery, maintenance
11	Culture	Culture, media, design
12	Environ	Environmental control, health safeguard, cleaning
13	Landman	Natural resource
14	Nature	Natural sciences
15	Teach	Teaching methods
16	Social	Social
17	Secure	Security
18	Engine	Engineering /technical
19	Transp	Transport
20	Manage	Manager

*ISCO-code: 213, 312

ISCO vs. SPEC, Number of individuals in 2006 per occupation

		ISCO									
		Manag	Professi	Technic	Clerks	Service	S. agric	Craft	Machin	Elemen	
SPEC	build							130424		2895	133319
	adm	19148	62554	44478	140029						266209
	beauty					4273					4273
	craft							18551			18551
	culture		23044	6417	378	55					29894
	envir							16823		46446	63269
	health		16182	21612		72526					110320
	hotel					30201		6893		28528	65622
	ict		57748	28867							86615
	landma			1133			16216			1683	19032
	manuf							35825	245238	29026	310089
	nature		6287	1708							7995
	ped		17165	7404							24569
	security			4480		16005					20485
	sales			110789	17044	163123				88	291044
	social		39	5168							5207
	support							72532	3255	36719	112506
	tech		56479	108809							165288
	transp			6021	83563	5101			113891	12732	221308
	manage	133496									133496
		152644	239498	346886	241014	291284	16216	281048	362384	158117	2089091

Technical production frontiers in the Swedish business sector

Multifactor productivity, technical efficiency, technical change and innovation in Swedish industries 1997-2006

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The main findings

The best practice technology has developed positively for most industries in the Swedish business sector during the time period 1997-2006. This development, the technical change, is the basic driving force behind the productivity development. However, there are considerable differences among the 32 industries for which we have estimated the best practice, or production frontiers. The other component in the multifactor productivity growth, technical efficiency, is a measurement of the slack or the distance to the production frontiers for the other firms in an industry.

There is no general trend in the changes in technical efficiency over the same time period. The change in technical efficiency is negatively correlated with technical change, meaning that when the production frontier expands faster, the average firms' distances to the frontier increase. Therefore it is natural to see technical change as the dominant contributor to the growth in multifactor productivity. And it is of course a necessary force behind productivity development in an industry. However, the industry average also depends on what happens in the firms which are beneath the production frontier. And it seems that the rest of the firms on average managed to almost develop at the same pace as the frontier. We also found that technical efficiency was higher among the larger and more specialised firms and lower among these firms that were more capital-intensive, depending of course on the industry.

We also found a significant positive relationship between the industry's innovation output and technical change. There is also a positive correlation between the share of firms in industry that has patents and the change in multifactor productivity.

[1] *This paper is based on a master thesis made by Sara Johansson at Statistic Sweden*

Technical change and growth with a combined firm-industry perspective

Is it still meaningful to study economic growth?

There is always a discussion on the relevance of economic growth, and the meaningfulness of an increased consumption of goods and service. Does this really make people happier and more satisfied with their lives?

The OECD in cooperation with many other organisations is thus pursuing the path to broaden the concept of well-being beyond material consumption. This will be discussed in the large 3rd World Forum in Korea this October. The Stieglitz commission, to which the OECD also has made a contribution, is another expression of this thinking.

Still, during the financial and economic crisis we endure just now it has become obvious that production and consumption of goods and services is, even if not everything, a very important part of a good life. And a drop in production and consumption affect people's lives very much. So it is indeed still quite meaningful to study economic growth and the forces behind it.

The role of the forerunners

In this paper we will concentrate on the economic growth which is created by the firms that are forerunners. The forerunners are the firms which are most efficient in using the economic resources they have at hand for their production of goods and services. We also follow how these innovations in products, services, production methods, distribution methods, marketing methods and so on are extended and taken up by other firms. The main focus in our analysis has been the difference between industries in both these respects: the movement of the production frontier and the distance in the productivity level to the followers.

Does innovation create forerunners?

Finally we have also tried to detect if there are any relationships between these developments and the innovation output measured in the innovations studies and also the patenting pattern among the manufacturing industries. In the whole study we use microdata and all industry aggregates will be un-weighted. This means that small and large firms will influence the industry figures equally. So the industry concept we will be discussing is the behaviour of most firms in the industry and not the total production or value added of that industry. It also means that we will not try to capture if the market function well, so the more efficient firms gain market shares.

What is technical change?

Our perception is that the productivity development in an industry can be split into two different parts. The most important part is the development of the technology frontier. That is, the best practice production methods that are used by the most efficient firms. This best practice is a combination of products and services these firms offer to their customers, their production technology, staff composition, organisation, marketing and so on. In other words, it is about both technical and non technical factors. Still, we will use the term technical change for this process. The production frontier is normally created by a number of firms that are excellent in different ways. One firm could have the best productions process, another the best distribution, yet another the best product development. The common factor for the firms that together make up the frontier is that no other firms in the industry produce more with the same inputs or use fewer of any inputs to produce the same output as any of the frontier firms.

Technical efficiency is also of great importance for industry productivity

At least in the long run, productivity in an industry depends on the creation of new practices in all different aspects of firm activities. However, if there is only one firm that creates everything new and none of the other firms take this up, the developments in this industry will be limited. In most industries new ways to do things will spread to non-frontier firms. This catch-up effect is thus of great importance. Here it is called technical efficiency or the slack. This means that multifactor productivity firm average in an industry can change in two ways: firstly by the shift of the production frontier due to the leading companies having developed new ways to do things and secondly due to other firms having picked up some of the earlier developments.

What we have done

For the period 1997-2006 the production frontier has been estimated for each year in 32 different industries. These best practices have been used as a benchmark to calculate the average slack or distance to these frontiers. Finally the developments of these frontiers and efficiencies have been estimated.

The general pattern is as expected: productivity in industries is primarily driven by the development on the production frontiers. The primary force is that the best firms are doing things in a better way. This does not mean that the frontier consists of the same firms year after year. And as already mentioned, the rest of industry normally picks up the new things in the same way as it develops. However, there is always a lag in time and also in substance that will create an inefficient distribution, which varies among industries and over time.

The business cycle blurs the picture

Productivity is also affected by the business cycle since the capacity utilisation of both capital and labour are not the same at the different stages of the business cycle. In slumps most firms have an overcapacity in machinery and buildings and also mostly of personal. These development causes the production frontier to jump up and down over the years. If the change in demand affects all firms to the same degree, then the slack will be unchanged. However, if the best firms are less affected we will expect the distance to the frontier to increase in the downturns. On average of course, the frontier firms are expected to have a better capacity utilisation which will bias the estimation of the slack level upwards.

The data and theoretical base

The dataset

Multifactor productivity is estimated by decomposing productivity growth into two components which are referred to as technical efficiency and technical change. Firstly, we have studied the change in these two components in Sweden over 10 years from 1997-2006 and secondly we have investigated the relationship between the change in multifactor productivity and innovation.

We have used data from business registers in Sweden and also data from the Community Innovation Survey (CIS) made by Statistics Sweden concerning innovation activities in Swedish companies. We have used CIS 4 and CIS 5 which together contains data for 4428 firms during the period 2002-2006. Data on the number of patents in Swedish firms has also been used as an alternative measure of innovation.

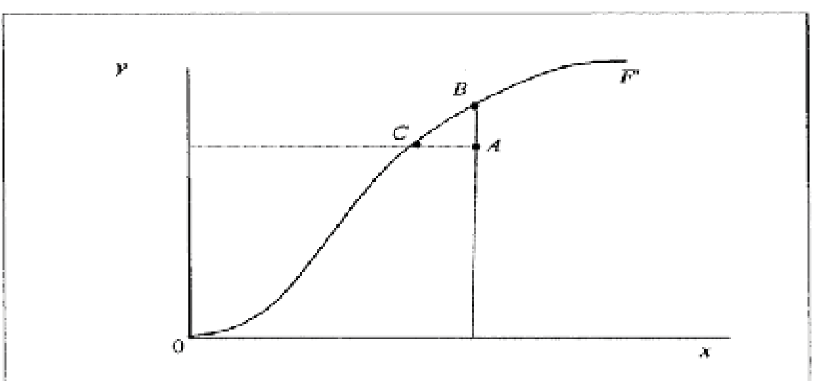
The first part of this paper gives the background for the stochastic frontier analysis method. The next section contains a description of the data, followed by a description of the model and the method used. In the final section of this part of the paper the results are presented. This is followed by another small part with additional analysis on innovation and finally comes the main results again.

The underlying mathematical theory for the model and some of the developments can be found in Appendix A.

The concept of production frontier

The productivity of a firm is defined as the ratio of the output that it produces to the inputs that it uses. We often talk about multifactor productivity (MFP) which is a productivity measure involving all factors of production.

Figure 1. The Production Frontier

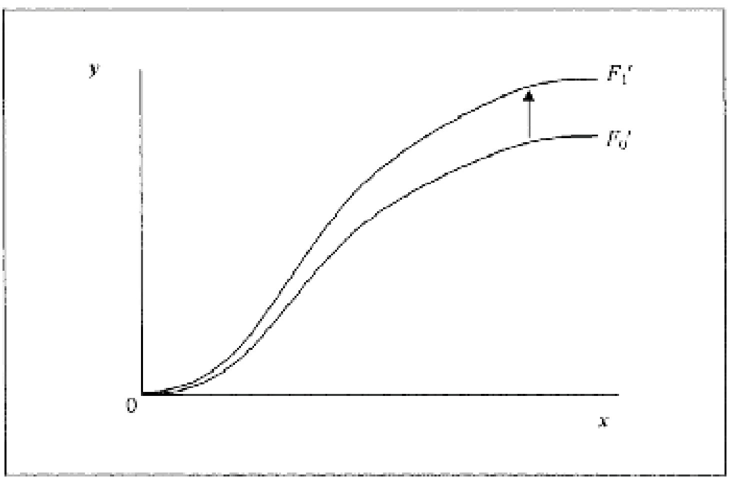


A is technically inefficient since it could reduce input (x) and operate at point C or increase output (y) and end up at point B. Both points B and C are technically efficient.

The production frontier may be used to define the relationship between the output and the input. As already mentioned, the frontier represents the maximum output attainable from each input level, meaning that it represents the current state of technology in the industry. Technical efficiency measures a firms' ability to produce the maximum output from given input. Firms in the industry are technically efficient if they operate on that frontier and technically inefficient when they operate beneath the frontier since they could increase output without requiring more input (or decrease input and still produce the same output).

If we also include a time component, it is possible to study productivity over time. This gives an additional source of productivity change called technical change (TC) which is represented by shifts in the production frontier. If the frontier shifts upward between period 0 and 1 it means that all firms technically can produce more output for each level of input in period 1 relative to what was possible in period 0.

Figure 2. A shift of the production frontier in case of technical progress



When technical progress occurs, the production frontier shifts upwards. In the case of technical regress, the frontier will shift downwards.

If a firm has increased its productivity from one year to the next, it may have been because of improvements in technical efficiency, due to technical change or a combination of these factors. There are also other possible sources for productivity growth such as returns to scale and allocative efficiency (which is not discussed in this paper).

There are different approaches to estimating the frontier functions. One method frequently used is the nonparametric Data Envelopment Analysis (DEA). The stochastic frontier analysis (SFA) which is used in this paper is a parametric method using econometric techniques. This approach was developed independently both by Aigner, Lovell and Smith (1977) and by Meesen and Van den Brock (1977).

Stochastic frontier analysis

The stochastic frontier production function is of the form:

$$\ln y_i = \beta_0 + \sum_n \beta_n \ln x_{ni} + v_i - u_i$$

$$y_i = \underbrace{\exp\left(\beta_0 + \sum_n \beta_n \ln x_{ni}\right)}_{\text{deterministic component}} \times \underbrace{\exp(v_i)}_{\text{noise}} \times \underbrace{\exp(-u_i)}_{\text{inefficiency}}$$

where

- y is the output
- $\boldsymbol{x}$ is a 1×N-vector of inputs
- u_i is a measure of technical efficiency as the distance from the efficient frontier of the i^th^ observation
- v_i is a symmetric random error to account for statistical noise such as measurement errors and other random factors.

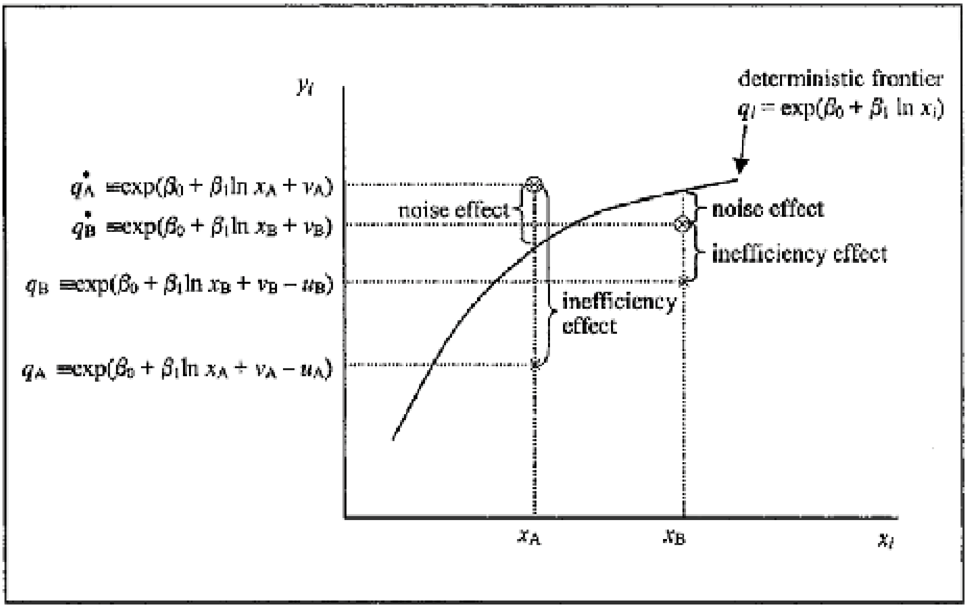
This model is called a stochastic frontier production function because the output values are bounded from above by the stochastic variable $\exp(\beta x_i + v_i)$. If we simplify the production function to firms that produces one output y using only one input, *x*, it is easier to illustrate the model graphically in figure 3 where q is the logarithm of output y.

The technical efficiency (TE) is the ratio of observed output to the stochastic frontier output:

$$TE_i = \frac{y_i}{\exp(x'_i \beta + v_i)} = \frac{\exp(x'_i \beta + v_i - u_i)}{\exp(x'_i \beta + v_i)} = \exp(-u_i)$$

It takes a value between 0 and 1 and measures the output of the i^{th} firm relative to what could be produced by a fully-efficient firm using the same input vector. Efficiency change is a measure of how well the firm is adjusting its production efficiency to the existing state of technology.

Figure 3. The stochastic frontier

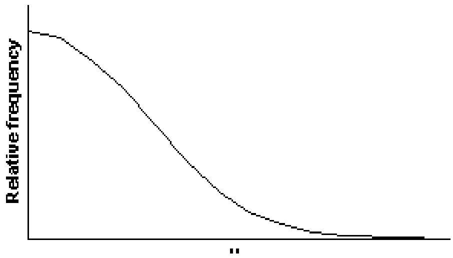


One way to estimate the parameters in the model is to make some distributional assumptions for the two error terms and use the maximum likelihood (ML) method.

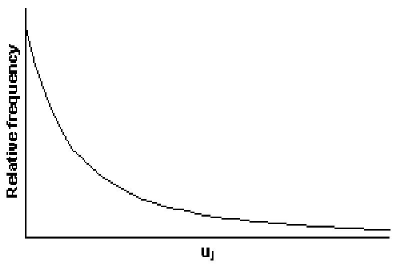
The two-sided error term v is associated with things outside firm control and the one-sided inefficiency term u is associated with factors under control of the firm. Common assumptions are that the v_i s is independently and identically normal distributed with zero mean and variance σ_v^2 which is the same as for the error term in the classical linear regression model. The u_i s are often assumed to be identically and independently distributed half-normal variables with parameter σ_u^2 . In addition the different v_i and u_i are assumed to be independent of each other.

The half-normal distribution is a truncated version of the normal distribution with zero mean. Other common distributional assumptions for the inefficiency term are exponential, truncated normal (with mean μ different from zero) and gamma. The last two are more flexible since they involve one additional parameter but can be more complicated to estimate.

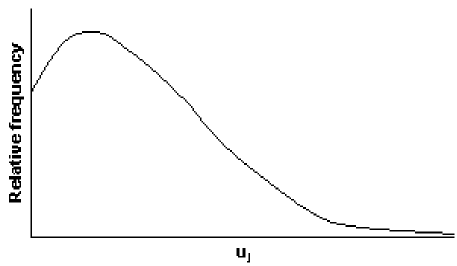
Figure 4 . Alternative efficiency distributions



Half-normal distribution



Exponential distribution



Truncated normal distribution

When we have access to cross-section data over time the stochastic frontier production function can be written as:

$$\ln y_{it} = \beta_0 + \sum_n \beta_n \ln x_{nit} + v_{it} - u_{it}$$

The only difference from the earlier model is that we have added a time subscript "*t*" to represent time. y_{it} is the output for the ith firm in the t^{th} time period.

Instead of the Cobb-Douglas production function we can use the more flexible Translog production function. This is a second order (all interactions included) log-linear form which is the most frequently form used in stochastic frontier analysis. We also include a time component to account for technical change. There are several different methods to model the technical change through time. One way is to use a single time trend. You can also include quadratic terms in the time trend and interactions of time with inputs for a more flexible form which can also measure non-neutral technical change. Another way is to introduce time dummy variables to represent each year in the data set. This method has the advantage that no *a priori* structure of the time trend must be assumed. A Translog production function with time dummy variables would be of the form:

$$\ln y_{it} = \beta_0 + \sum_n \beta_n \ln x_{nit} + \frac{1}{2}\sum_{n=1}^{N}\sum_{i=1}^{N} \beta_{nj} \ln x_{nit} \ln x_{nit} + \theta_t D_t + v_{it} - u_{it}$$

In this specification the time dummies for 1997 to 2006 are denoted D_t having the value of one for the t time period and zero otherwise. β_j and θ_t are parameters to be estimated. We obtain the conditional expectation of $\exp(-u_{it})$ given the value of

$$\varepsilon_{it} = v_{it} - u_{it} .$$

The use of time dummy variables allows the time effects to vary flexibly from year to year. They can switch from positive to negative and back to positive. The technical change between two periods is the difference of the coefficients for the time dummies, θ_t , for the two given periods.

$$TC_{t-1,t} = \theta_t - \theta_{t-1}$$

The technical change measures the shifts in the production frontier from year to year. The most productive firms at a point in time determine the technical frontier. Technical change is the growth (or decline) in a firm's productivity between two time periods.

Heteroscedasticity is the key to the estimation

It is also possible to allow the parameters in the distribution of the inefficiency term to vary with factors such as firm-specific variables or time. This accounts for heteroscedasticity in the model.

It has been shown by Caudill, Ford and Grouper (1995) that heteroscedasticity in the model leads to biased estimates. Specifically, when the model is estimated by maximum likelihood, heteroscedasticity leads to overestimation of the intercept and underestimation of the slope coefficients. The inefficiency measures are also affected; not accounting for heteroscedasticity leads one to overestimate inefficiency for small firms and underestimate inefficiency for large firms.

There are different ways to include heteroscedasticity in the frontier model. In this study we have incorporated the heteroscedasticity directly into the variance of the one-sided error term which is a method also suggested by Caudill, Ford and Gropper. Then $\sigma_{ui}^2 = \exp(\delta z)$ which means that variances are firm-specific. (We then drop the assumption that the different u_i are identically distributed.) If we include a constant term in z, the expression can be written $\sigma_{ui}^2 = \exp(\delta z)$. This means that the final level of efficiency depends on the basic random variable *u* and on $\exp(\delta z)$ as well. The LR-test can be used to test the presence of heteroscedasticity in the model. This is called the scaling property. The scaling factor stretches or shrinks the horizontal axis, so that the scale of the distribution of *u* changes but its underlying shape does not. The heteroscedastic frontier model allows us to consider the individual characteristics of firms and their influences on the efficiency.

The result can be used to calculate the efficiency change component in the multifactor productivity measure. The technical efficiency change (TEC) between period s and t is calculated as:

$$TEC_{i,ts} = TE_{it} / TE_{is}$$

The efficiency change is a measure of how well the firm is adjusting its production efficiency to the existing state of technology. It is positive, zero or negative depending if technical efficiency declines, remains unchanged or increases over time. TEC can be thought of as the rate at which producers move away from or towards the frontier (which itself may be moving). If technology has a positive effect on an industry's productivity growth, efficiency change can be seen as a measure of how well the firm is "catching up" to the changing state of technology. These two measures of efficiency change and technical change can be added together to obtain the growth (or decline) in multifactor productivity.

$$MFPC = TEC + TC$$

Ignoring the scale component means that we measure the change in productivity by examining the rate at which output changes while holding inputs unchanged.

Our industry break-down

The data used in this analysis comes from Statistics Sweden's registers and contains micro-level data on all firms in Sweden during the years 1997-2006. The firms are sub-divided into groups after industries by two-digit NACE-codes. Industries with few observations are either excluded or aggregated into larger groups resulting with 32 different groups of industries in the analysis.

Table 1. Industries

SNI	Name of industry
01-05	Agriculture, forestry and fishing
10-14	Mining and quarrying
15-16	Food product, beverage and tobacco industry
17-19	Textiles, clothing and leather industry
20	Industry for wood and wood products
21	Industry for pulp and papers
22	Publishers and printers
24	Industry for chemicals
25	Industry for rubber and plastic products
27-28	Industry for basic metals and fabricated metal products
29	Industry for machinery and equipment n.e.c.
30-33	Industry for electrical and optical equipment
34-35	Industry for transport equipment
36-37	Manufacturing industry n.e.c.
40-41	Electricity, gas and water works; sewage plants
45	Construction industry
50	Motor trades
51	Wholesale trade
52	Retail trade and repair
55	Hotels and restaurants
60	Land transport companies
61	Shipping companies
62	Air transport companies
63	Service companies supporting transport
64	Post and telecommunication companies
65-67	Financial institutions and insurance companies
70	Real Estate
71	Renting companies
72	Data consultancy and data service companies
73	Research and development
74	Other business services
80-85	Educational, health and social work establishment

Of these industries the following manufacturing industries are considered to be more high-tech, namely: 24, 27, 30-33 and 34-35. In the same way, six of the service industries rise above the rest when it comes to the knowledge level. These are: 64, 65-67, 72, 73, 74 and 80-85. Both the manufacturing and service industries that just have been mentioned are expected to behave in a somewhat more dynamic way.

As output we have used gross production (Y) measured as the net sales of the firm. The three main inputs are number of employees (L) calculated as full-time equivalents, capital stock (K) and intermediate goods and services (I). These are deflated using industry-specific price indexes for each input and output variable with 1997 as reference year. The logarithms of these variables are used in the model.

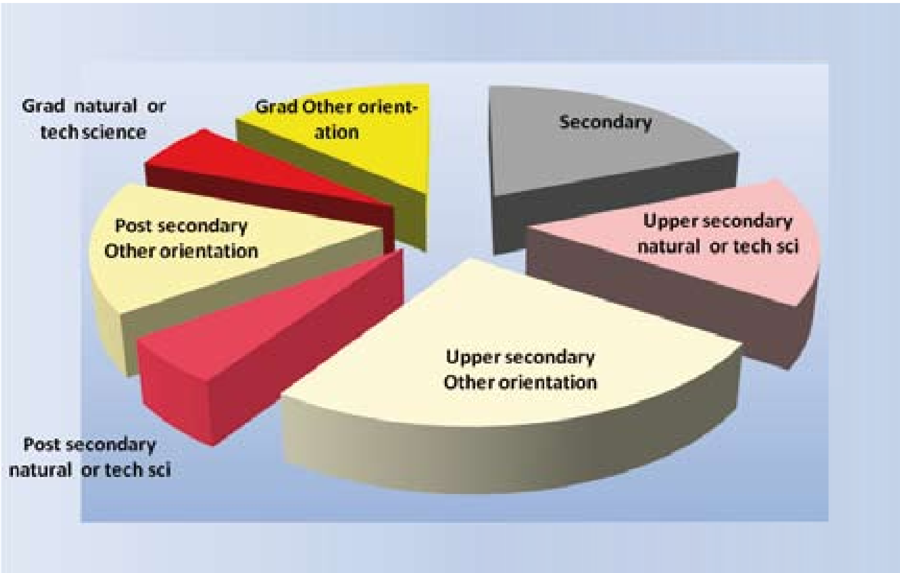
Y	Gross production	is measured as net sales
L	Number of employees	in full time equivalents
K	Capital Stock	measured as the book value of material capital
I	Intermediate goods and services bought from other firms	

In addition to these variables we have looked at the education of the employees and divided it into 7 subcategories depending on the highest education level and if the orientation is nature/technical or other. The result is the following groups:

Z1	Secondary education
Z2	Upper secondary education within natural or technical sciences
Z3	Upper secondary education within other fields
Z4	Post secondary education within natural or technical sciences
Z5	Post secondary education within other fields
Z6	Graduate with within natural or technical sciences
Z7	Graduate within other fields

These are obtained from data sets containing information on individuals. For each individual available data describes the highest level of education, within which field and the firm where the person is employed. These are aggregated and merged with firm data to obtain how many persons of each category that are employed at the firm.

Figure 5. Education levels in mean percentages of each education category



Then they are divided with the total number of employees to obtain shares and included as additional variables in the production function. The first variable, secondary education (Z_1), is excluded to avoid multi collinearity problems.

We have only studied the business sector. Firms with less than 10 employees or non-positive net sales, capital assets or intermediate goods and services are excluded. This limit is chosen because it seems to be the most commonly used in similar studies and is also the same limit that is used in the innovation survey used later in this paper. This is done to avoid a lot of noise in the estimation of the frontier. The final number of firms represented each year in the data set varies from 23 354 in 1997 to 27 900 in 2006. The total number of observations used in the analysis is 256 369.

The summary statistics reveal that the number of firms, gross product, capital stock and intermediate service and goods increased during the period while the mean number of employees decreased.

Table 2. Summary statistics of the output and the main inputs in the production function, mean values of the variables

	No of firms firms	Mean Gross Product	Mean No of Employees	Mean Capital Stock	Mean Intermediate Good and Services
1997	23 354	118 558	65	75 693	85 870
1998	24 360	119 273	64	77 538	85 946
1999	24 590	125 936	65	83 868	89 954
2000	25 073	131 129	66	84 989	94 700
2001	25 642	128 192	64	82 727	96 909
2002	26 580	123 408	62	81 493	91 543
2003	26 099	129 576	61	88 415	94 469
2004	26 017	131 060	60	94 232	95 188
2005	26 766	134 104	60	90 616	97 576
2006	27 900	133 196	59	88 641	96 002

The production model

We tried different versions of the production function to estimate the frontiers, from the simplest Cobb-Douglas form to the more flexible Translog with all interaction terms. Many models ended up with convergence problems in Stata which limited our selection. The"xtfrontier"function in Stata takes into account the panel structure of the data but was not possible to estimate with our data. The models were tested against each other using the likelihood ratio test (LR-test) and also Aikaikes information criteria (AIC). Adding the education variables makes it too complex to include all interaction terms but still the Translog seem to give a much better fit. Therefore we have chosen to use a semi-Translog production function which is Translog in L, K and I but not in the education variables ($Z_2,\ldots,Z_7$) and the time dummies ($D_2,\ldots,D_{10}$) representing the years from 1998 to 2006. The choice of this model is confirmed by the LR-test and AIC.

$$\ln Y_{it} = \alpha + \beta_L \ln L + \beta_K \ln K + \beta_I \ln I + \beta_{LL} \ln L^2 + \beta_{KK} \ln K^2 + \beta_{II} \ln I^2 + \beta_{LK} \ln L \ln K + \\ + \beta_{KI} \ln K \ln I + \beta_{LI} \ln L \ln I + \theta_t D_t + \gamma_j Z_j + v_{it} - u_{it}$$

We have also included explanatory variables for the variance of the inefficiency term u to account for heterogeneity among firms in the industry. These are the number of employees as a measure of the size of a firm and also the capital stock and intermediate goods and services relative to number of employees. Including these variables allows the variance of the inefficiency term to vary with the firm-specific characteristics. Time is also included to allow the parameter in the half-normal inefficiency distribution to vary with time.

$$\sigma_u^2 = \exp(\delta_0 + \delta_1 \ln L + \delta_2 \ln(K / L) + \delta_3 \ln(I / L) + \delta_4 t$$

Different assumptions for the distribution of *u* were examined but in the final model the half-normal distribution is used. Since we wanted to estimate the frontiers for a wide number of industries, we needed a model that worked well for all different groups in the analysis. The truncated normal distribution is more difficult to estimate since it involves two parameters instead of one. This resulted in convergence problems for many of the industries. For those industries where the frontier was possible to estimate using the truncated normal distribution, the LR-test and AIC did not indicate that the truncated normal would give a much better fit. However, the estimates of the efficiency and the technical change differed. The Exponential distribution gave results similar to the half-normal model but was slightly harder to estimate and tests did not show of a generally better fit than the half-normal model. The Gamma distribution was never estimated since it is not included in Stata's frontier function.

Estimates show that the change in returns to scale for our data set has very little effect on the change in MFP, and therefore we assume constant returns to scale in our calculations. We also disregard change in allocative efficiency since we don't have access to input price data.

For each sector a stochastic frontier is estimated using the above model. Then the yearly technical change (TC) and change in technical efficiency (TEC) are calculated according to the method described in section 2. These two factors are added together to obtain the change in multifactor productivity (MFPC).

In this analysis all observations from a firm are treated as independent observations. We assume that firms within an industry are operating in the same environment and account for the firm specific characteristics in the inefficiency model.

Estimation of the stochastic frontier production function for all industries

The semi-translog production function described earlier was estimated for the micro-data of the individual firms.

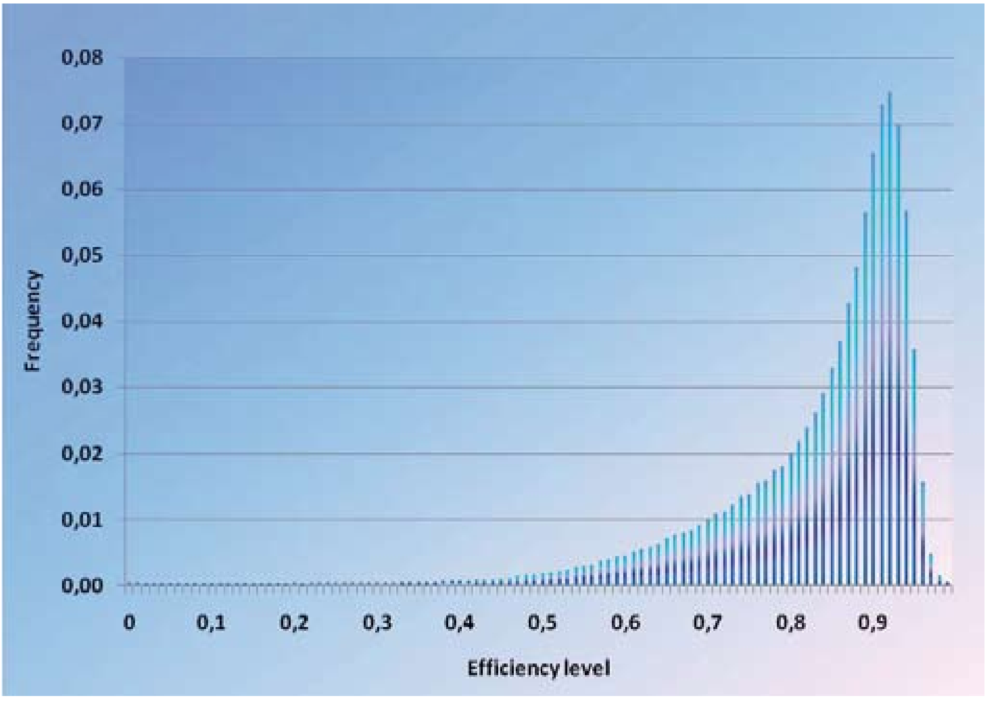
First we estimated the frontier for all firms in the data set using industry dummy variables in both the production function and in the inefficiency model to get a picture of what the development looks like for the whole population of firms. The industry dummy variables represent 12 different groups of industries that are assumed to have similar developments. Estimates of the parameters in the stochastic frontier production function were obtained using the frontier function in STATA 10.

All coefficient estimates in the stochastic frontier production function and also in the inefficiency model are significant at the one percent level. The significance of the cross-product terms suggests that there are interactions among the variables. This also implies that the Translog model specification is more appropriate than the linear Cobb-Douglas production function.

The coefficients for KL and LI (actually K*L and L*I) are both negative, indicating that substitution between those factors are a possibility. Capital and labour are used in the firm's own production process so more input of these production factors will generate more output. The alternative for the firm to produce everything by themselves is to buy goods and services from other firms to use as intermediate inputs. This means that both capital and labour are substitutes for intermediate inputs.

Figure 6. Distribution of technical efficiencies for all firms

Technical efficiency is calculated as (exp(-u)) conditional on $\varepsilon = v - u$.



Since all our statistics are un-weighted, the data for the whole business sector are dominated by a few industries that have many firms. About half of the firms are actually from construction, trade, hotels and business service. All these industries are characterized by limited productivity developments, evident in the tables and figures presented below.

As can be seen from figure 6, only a handful of firms are very close to the technological frontier. However, most of them are still not far away, since most are found in a narrow band with efficiency-levels around 85 to 95 percent of the frontier firms.

The development of the efficiency is far from continuous. The varying sign of the time dummy coefficients (see Appendix) indicate that the dummies are not only a measure of technical progress, because we expect the advancement of technology over time to be positive. The values of the year dummies also reflect the macro-economic conditions since they decrease between 1999 and 2002 due to the crisis in the ICT industries and stock market collapse that created an economic slump.

Figure 7. Technical efficiencies level 1997 to 2006

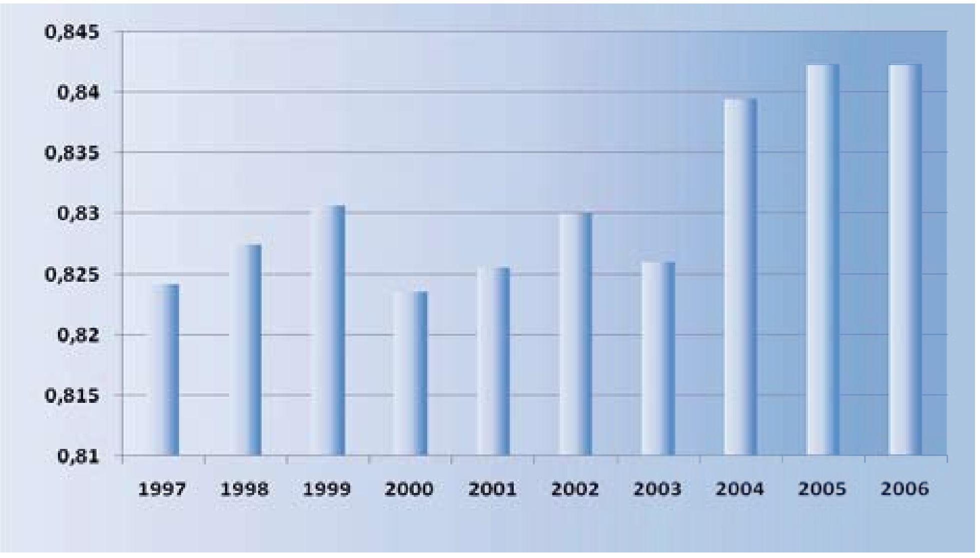


Table 3. Technical efficiency levels and changes 1997-2006

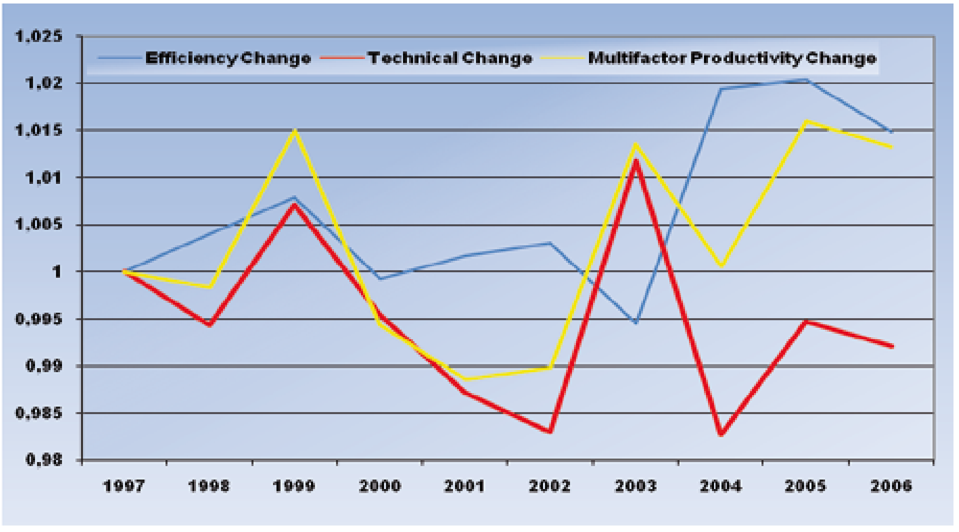
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
TE	0.824	0.827	0.831	0.824	0.826	0.830	0.826	0.839	0.842	0.842
ΔTE		0.004	0.004	-0.009	0.002	0.005	-0.005	0.016	0.003	0.000

When it comes to the estimated parameters for the education variables, we find that the coefficients for graduates with an education in natural/technical sciences have the highest estimate, closely followed by graduates within other fields and post secondary education with natural/technical sciences. This indicates that higher levels of employees with a university degree and especially those who have a more technical orientation are more favourable for firms for their technological and productivity development.

For the inefficiency component we see that the coefficient for time is negative. This means that the variance of the inefficiency term u decreases with time, indicating that efficiency increases over time. However, two years are marked as considerable setbacks for the efficiency development, namely 2000 and 2003. Figure 7 shows the mean technical efficiency for all firms by year.

The estimation of this total development is not that enlightening because all observations are un-weighted, as already mentioned. The figure is only an illustration of how the development of multifactor productivity can be decomposed in the development in technical change and technical efficiency. The overall change in MFP and its components is small during the period, as was expected and is due to the dominance by a few industries.

Figure 8. Technical efficiency, technical change and multifactor productivity for all industries between 1999 and 2006



The results from the stochastic frontier analysis differ when we use the whole sample of firms and when we estimate the stochastic frontier production function separately for each industry. A problem with the first model specification is that all industries are expected to follow the same development pattern, which is probably not true.

Technical development differs substantially between industries

The analysis of whole datasets gives some principal insights, but what is more interesting is to analyse industry by industry and compare the results with each other. We have thus estimated the stochastic frontiers for 32 industry groups separately. This analysis is based on the assumption that each industry is quite homogenous and that all firms work in a similar environment under the same conditions. Considering this, 32 industries could seem to be too small and the industry to broad. Due to the small size of the Swedish economy and our cut-off limit, which by the way is chosen in order to harmonize the firms somewhat, this was the level for which it was possible to generate econometric results. It was still impossible to make the estimation program to converge if each year was estimated separately. This means that all the combination of firms and years were thrown in together. So the frontier consists of some firms that appear several times with observations from different years and others just once. However, a time dummy is used in the regression. This means that an observation of a firm from a certain year that has on average a higher productivity level, normally a more recent year, has to be more productive than an observation from a year with a lower productivity average to be picked as an observation of a frontier firm.

The model generally has a high degree of explanation. For all industries R^2 is between 0.90 and 0.99, indicating a very good fit. Earlier studies show that this is typical of the translog production function. Most variables in the production function are significant but it varies between the groups. The three main inputs labour, capital and intermediate inputs and their interactions are almost always significant at the one percent level with only a few exceptions. The time dummy coefficients are mostly significant and generally show an increasing trend indicating that technical progress has occurred during the period.

The education category that is most favourable for the firms varies between industries; however, the education category that most frequently has the highest coefficient in the production function is the group of graduates with natural or technical sciences as the main subject. This is followed by graduates with other specialization. That is, this result still stands from the aggregate estimation.

In the inefficiency equation almost all coefficients for firm size are positive, which implies that efficiency decreases as the number of employees increases. The coefficients for the time trend are mostly negative so efficiency is generally increasing over time.

In many industries when the technical change increases, meaning that the frontier shifts upward, the technical efficiency in the industry decreases. If the firms in the frontier become more technically advanced, the average firm increases its distance to the frontier.

The electric industry is a very special case with a particularly high rate of technical progress and a major decrease in technical efficiency. A problem with the estimation of the model for this industry is that it went through extensive restructuring during this period, which decreased the number of firms significantly. This makes the estimates less reliable and its extreme values affect correlation and regressions when the different industries are the observations significantly. That is the reason why it has been excluded from the summary statistics and the following analysis.

Table 4. Summary of industry means of the productivity variables

Variable	Mean	Std dev	Min	Max
Average annual TEC	0.00090	0.0081	-0.024	0.019
Average annual TC	0.0063	0.020	-0.028	0.075
Average Annual MFP	0.0072	0.017	-0.023	0.052
Mean TE	0.85	0.11	0.54	1.0

The relationship between technical change, efficiency and MFP

The correlation analysis of the change in multifactor productivity during the ten year period and its two components technical change and technical efficiency give a highly significant positive relationship between the annual technical change and the change in multifactor productivity. This could be interpreted as technical change, i.e., shifts in the production frontier are the main source of development of multifactor productivity.

We also find a significant negative relationship between the change in technical efficiency and technical change. This effect is probably due to shifts in the frontier that create shocks to the rest of the firms that increase or decrease the firms' distances to the frontier. A rapid technological development from the firms in the frontier increases the average firms' distance to the frontier and therefore its technical efficiency level decreases. Another way to look at it is that the rest of the firms follow the frontier quite closely, since multifactor productivity is rather similar to the increase of the technologic frontier in almost all industries.

Table 5. Correlations between the yearly TEC, TC and MFPC (P-values within parentheses)

	MFP annual	TC annual	TEC annual
MFP annual	1	0.91	-0.089
		(<0.0001)	(0.63)
TC annual	0.91	1	-0.49
	(<0.0001)		(0.0047)
TEC annual	-0.089	-0.49	1
	(0.63)	(0.0047)	

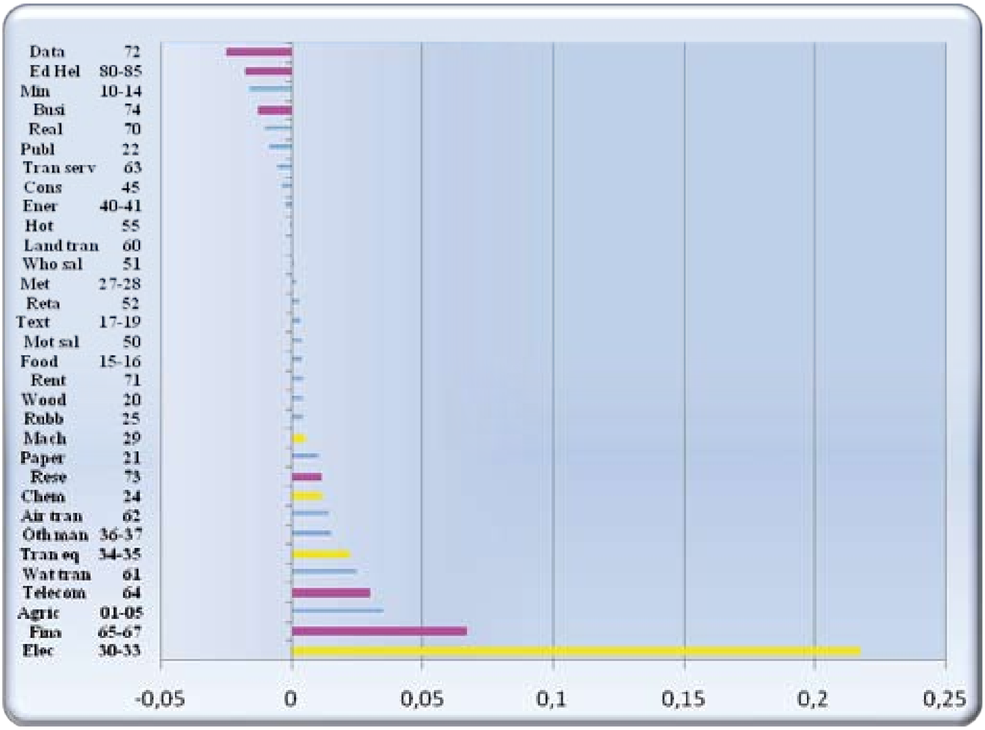
Large industry differences in technological change and technical efficiency

Electro industry is, as already mentioned, the industry that by far has increased its production frontier most. The other technological advanced manufacturing industries have also as expected grown more than most other industries.

However between the electro industry and these other squeeze in rank two knowledge intensive service industries dominated by large firms. These industries are the financial sector and telecom operators. More surprising is that two transport industries, water and air, have expanded their efficiency frontiers substantially. Agriculture and Pulp- and Paper industries seem also to have done surprisingly well.

The other end of the scale industries that have shrunken their production possibilities during this time period can be found. For this development there could be a number of possible reasons, mostly industry specific. One general factor is as already been mentioned the business cycle. If a certain industry was booming in business cycle terms 1997 and fell into a slump 2006 this would affect the technical change measurement negatively. This is probably true for the data industry and also for mining, but probably not for the rest. Education and health as well as business service industries have expanded very fast due to increased markets during these years which could have changed their composition negatively. That is, less productive firms have entered the market due to low barriers to entry and rapidly increasing demand.

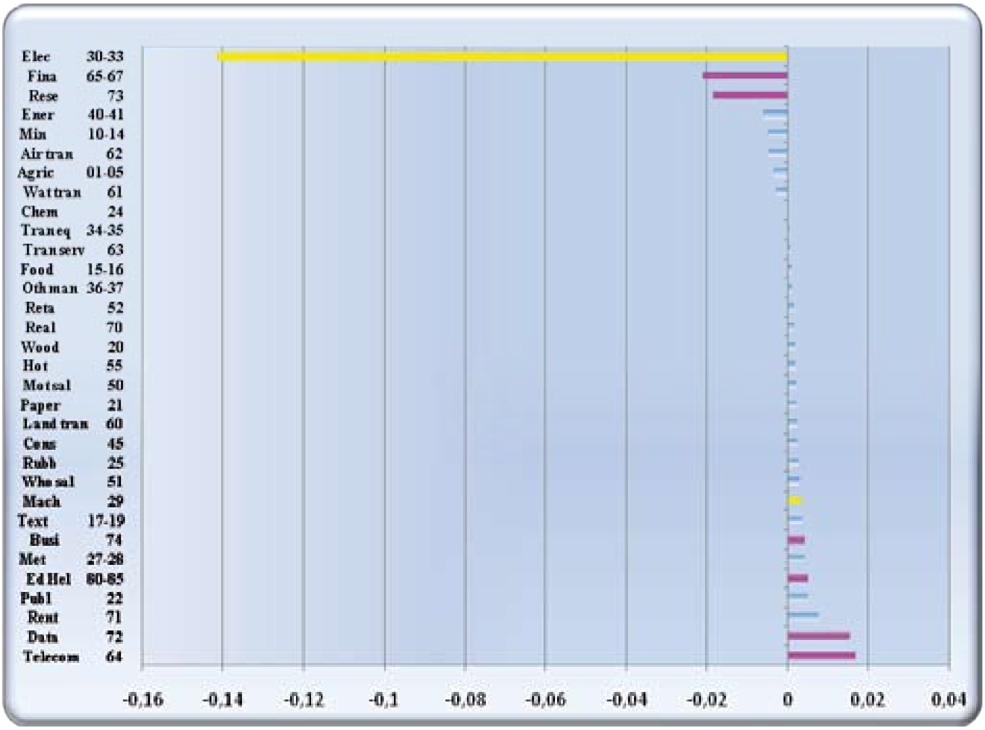
Figure 9. The technological change 1997-2006



Hard for the average firm to keep up with rapid technological change

Our general hypothesis is that in industries where the rate of the technological change is fast, efficiency is lower and even decreasing. This means that we expect the average firm to be less efficient compared to the frontier firms in these industries. This is in concordance with our hypothesis, since it should be easier to keep the distance to the frontier when it moves not that fast. This hypothesis was also confirmed by the simple correlation coefficient that has already been presented. The extreme observation, the electro industry is in line with this. The distance to the frontier has increased substantially. However part of the explanation to this extreme observation both when it comes to the rate of technological change and the increased slack, is as already mentioned. It is due to the very large restructuring that has taken place in this industry which has drastically reduced the number of firms.

Figure 10. Technical efficiency 1997-2006



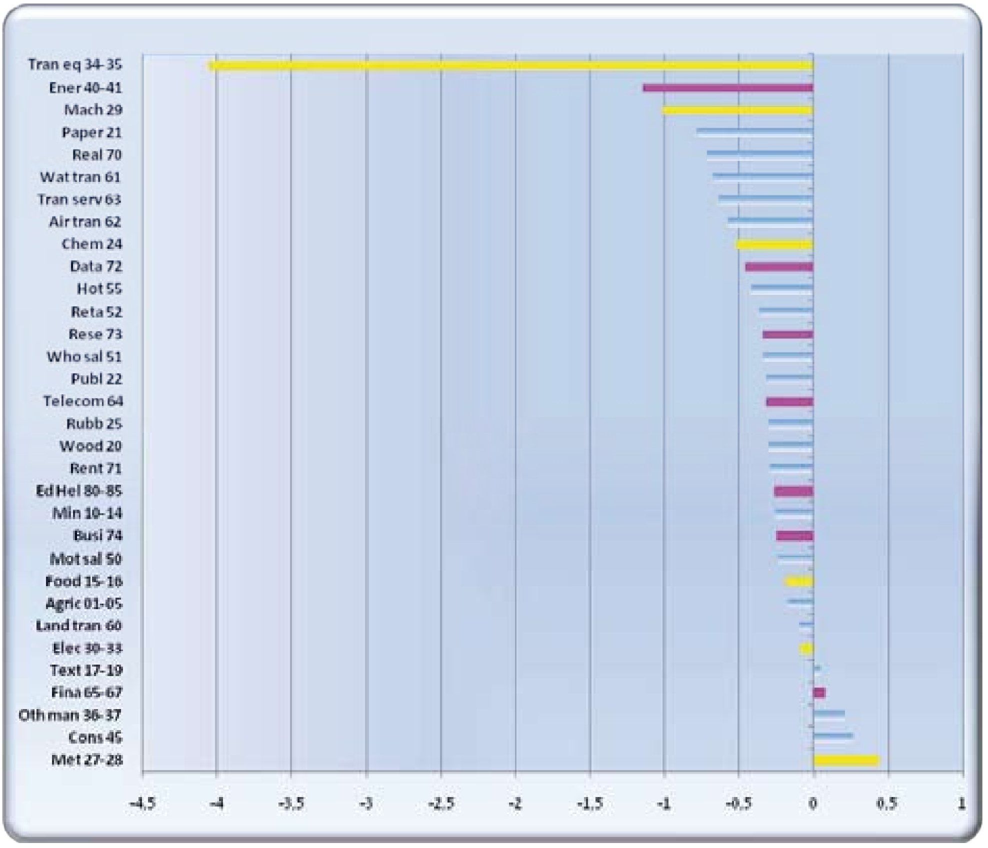
The two knowledge-intensive service industries that had undergone a fast technical change during this period, the financial sector and the research industry, also confirm the general result by being the two industries that have increased their slack markedly. That the energy sector has increased its slack at the same time that it has undergone a quite low degree of technical change is a confirmation of the general perception of this industry as being a stagnant industry with a low competitive pressure. On the other end of the scale are two high-tech service industries, the data industry and the telecom-operators. That data industry is one of these industries that develop as could be expected since not only has its frontier stagnated but also the competitive pressure has been considerably more severe, especially in the middle of the time-period. Apparently, the competition has also been very tough in the market for telecom services, since this industry has undergone a rapid technological change and still reduced it slack much more than the average industry.

The regression results give three dimensions of the distribution of slack or inefficiency in the different industries. These estimates are based on the inefficient equation.

Large firms are more efficient

The first one is the size dimension, measured by the number of employees. In most industries the large firms are closer to the frontier than the smaller ones.Large firms are more efficient in almost all industries. This is especially true for the for transport equipment industry and to a lesser degree the industry for machinery and the energy sector. In the other end of the scale there are just three industries where the small firms are on average more efficient: the metal producing industry, the construction industry and the manufacturing industry for n.e.c.

Figure 11. Technical efficiency 1997-2006, the scale factor.



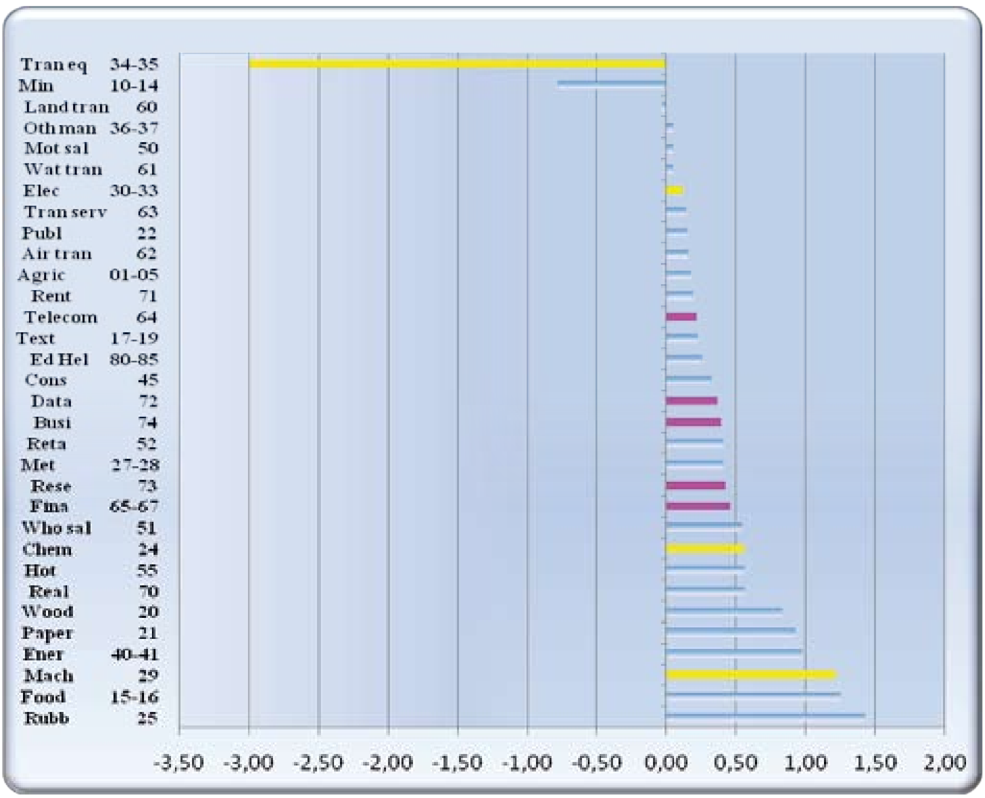
That means that there is a general tendency in the technologically advance industries, as well as in most other industries, that the large firms are closer to the frontier. The opposite tendency exists in just a handful of not so advanced industries. In total, only five out of the 32 industries the large firms are on average less efficient.

Efficiency change varies with capital intensity

The second dimension is the capital intensity, that is, the book value of machinery and buildings etc. per employed. A different picture appears here. Since size measured by employment is included in the regression, the capital intensity has no size dimension. Normally there is a strong tendency that large firms are more capital-intensive. So in this context the capital-intensive firms are those firms in an industry that are more capital-intensive on average given their size.

The general picture is quite clear since in all industries but three, the firms that are more capital intensive are on average less efficient. There are many industries where this tendency is quite strong. These industries are an odd mixture with some low-tech manufacturing such as the industries for rubber and plastics, food and wood.

Figure 12. Technical efficiency 1997-2006, capital intensity



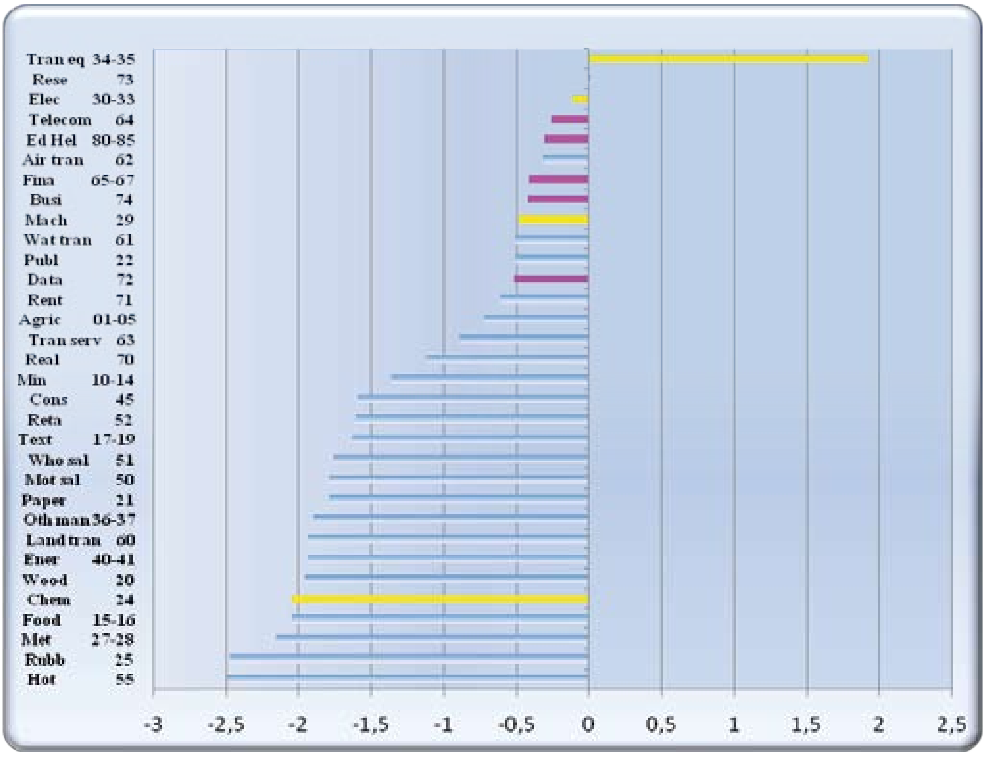
However, some very capital-intensive industries such as pulp and paper industry, energy producers and real estate, are among these. Even more technological advanced industries, namely machine producers can be found among them. Another medium high-tech industry, transport equipment is the most extreme exception to the general role, but since the other extreme exception is mining there is no pattern found here at this end of the scale.

Specialisation and efficiency

The third dimension is specialisation, here measured by the intermediate input of goods and services per employed. All but one industry have a positive relationship between specialisation and efficiency.

Again it is manufacturing of transport equipment that takes on an extreme position. This is perhaps not that extreme since the advantage of specialisation is less obvious for all the other more technological advanced industries. Instead it is industries such as hotels and restaurants, industry for rubber and plastics and the food industry that seem to get most out of specialisation. The only exception to this rule that the high-tech industries do not seem to benefit much on specialisation is the chemical industry.

Figure 13. Technical efficiency 1997-2006, specialisation

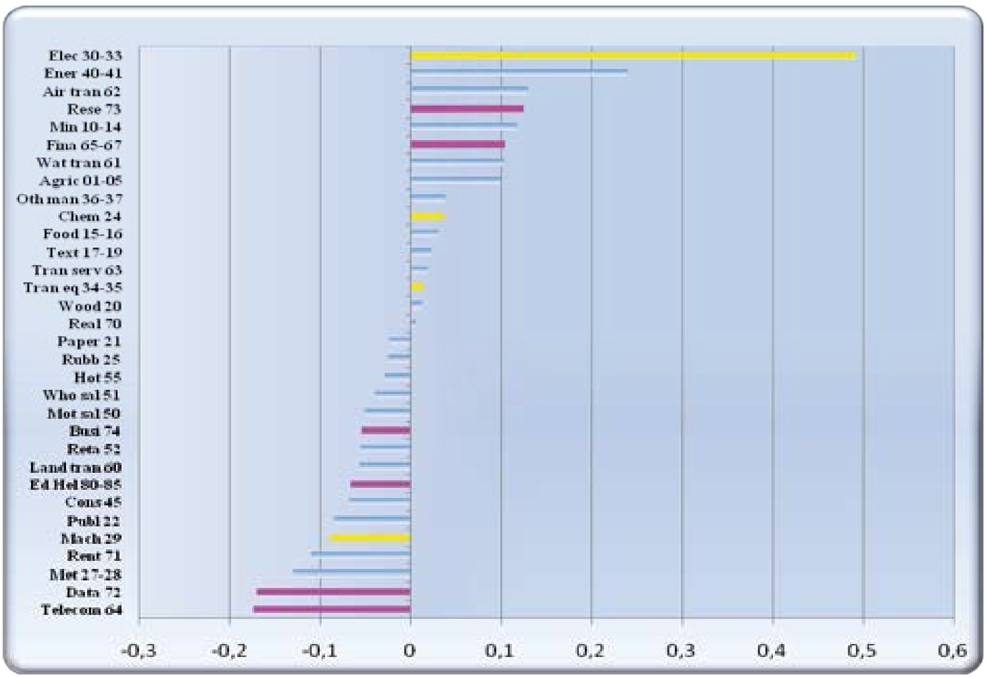


In search relationship between these three dimensions we found two rather weak ones. The industries that have a rather large effect for capital intensity also tend to have rather large size effects and specialisation effects and the reverse. That is, the industry where the capital intensity is a larger disadvantage for efficiency also seems to have a larger than average advantage for specialisation and size.

No time trend in efficiency

Finally there is also the time dimension. There is no general tendency for the efficiency to increase or decrease over the time period 1997-2006. Half of the industries have increased efficiency and half have decreased it.

Figure 14. Technical efficiency 1997-2006, the time dimension



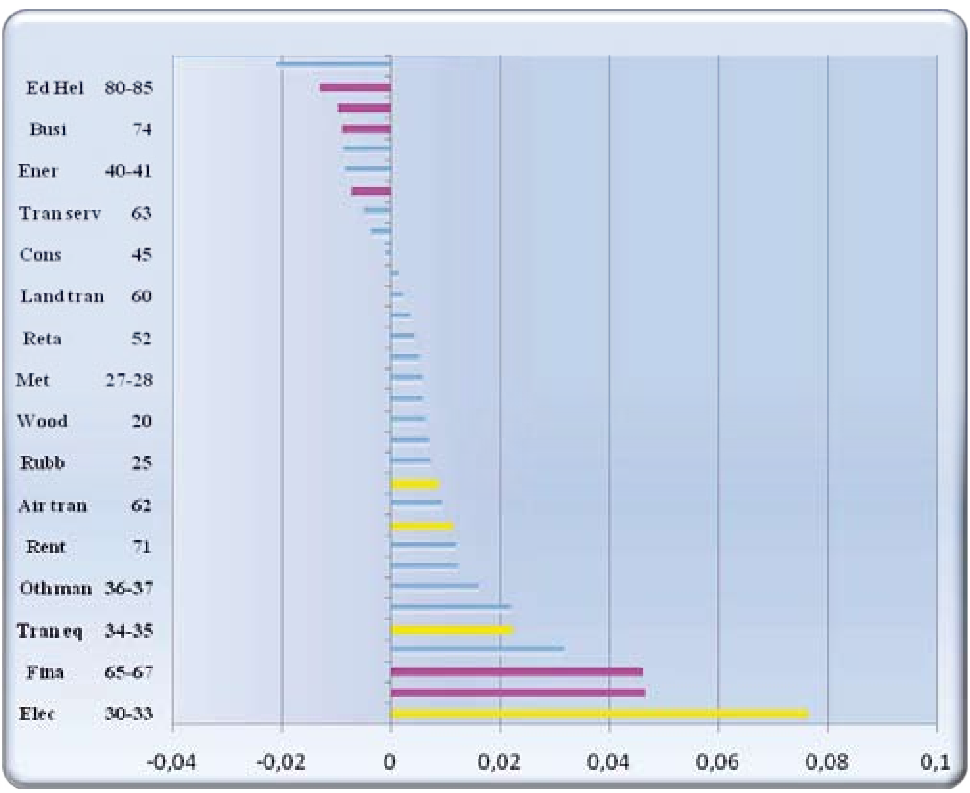
Normally one could expect the high-tech industries where the production frontiers move faster to have increased their spread between the frontier and the average firm. This is generally true as we already have shown. Still these industries are found at both ends of the scale. The producers of electric equipment including telecommunication products is the industry in which the inefficiency has exploded while in contrast the main user of these products, the telecom-operators, is s the industry that has reduced its inefficiency most.

Technical change and efficiency equals multifactor productivity

Together the technologic change and the technical efficiency add up to the multifactor productivity. The multifactor productivity is the change in production when all the changes in production factors are taken account of. However, this does not mean that we are sure that there is no additional production factor that we have not captured. If this is the case, then the MFP-measurement will of course be biased upwards.

The electric industries do outperform all other industries in multifactor productivity growth in spite of the large increase in inefficiency. That the large scale knowledge intensive service industries; the financial and telecom operators, share the second place in the ranking comes as no great surprise. But that the agriculture industry, water transport and pulp and paper beat the chemical and machinery industries in multifactor productivity increase are not that self-evident. In large the figure is a mirror of the same for the technical change. For one industry, mining, the technological frontier as well as the efficiency have move in the wrong direction and increase the average slack, which makes the drop in multifactor productivity substantial.

Figure 15. Multifactor productivity 1997-2007



Do investments in innovation and patents influence the development of the production frontiers?

In this part of the paper we will present a simple analysis of the relation between different measures of innovation output and the stochastic frontier estimation results. Two different sources of information are used. One of these is the community innovation surveys that cover the innovation activities 2002-2004 respectively 2004-2006. The other source is a register the Patstat, an OECD constructed database with all patents, over which Swedish firms that hold an active patent or have applied for one year 2007 anywhere in the world.

The Community Innovation Survey

The first innovation measure comes from the European standardized Community Innovation Survey (CIS) which is conducted every two years and contains questions about innovative activities in enterprises and their determinants and effects.

CIS is sent out to about 5000 manufacturing and service firms with more than 10 employees which are classified in the industries SNI 10-74. As indicators we have picked two variables of all possible CIS indicators; if the firm has introduced a new or significantly improved service or product that is new to the market respectively the percent of the firms' total turnover that consists of these products and services.

We have used CIS 4 which contains data for 3 201 firms during the years 2002-2004 and CIS 5 with 3 016 firms during the years 2004-2006. Both surveys together include data for a total of 4 428 individual firms. Since the CIS data set is a not that large sample of firms used in the earlier analysis we have restricted us to calculate un-weighted industry means of innovation. One variable is then the share of firms in the industry that have been innovative and produced products and services new to the market (new_market). The other variable is measuring the mean firms' part of the turnover that comes from these new products and services in its total output (turnover_market).

The innovation data sets contain information on 31 out of the 32 industry groups used in the earlier stochastic frontier analysis. Industries with low representation in the survey are excluded resulting in 26 remaining groups for the analysis. (The limit was set to less than 10 percent of the firms or less than 8 firms). If a firm is represented in both CIS 4 and CIS 5 the mean value for these two variables is used. Since the data from CIS covers only the years from 2002-2006 all the data was limited to just these years. Also in this analysis the electric industry was excluded. The correlation coefficient between the annual change in multifactor productivity and the percentage of the total turnover that comes from new or significantly improved goods or services became highly significant and positive. This was also the case for annual technical change. However the correlation with the yearly change in technical efficiency was not significant.

In addition, the share of firms that has been innovative in the industry is positively correlated with technical change, and changes in multifactor productivity became significant at the one percent level. The mean technical efficiency level during the five year period is negatively correlated with the share of the total percent of new market products and services of total turnover. The explanation could be due to the fact that innovative industries have a frontier that lies far from the average firm. The correlation results can be seen in table 14.

Table 6. Correlations between the productivity variables and the innovation variables

	MFP annual	TC annual	TEC annual	TE mean
Turnover_market mean	0.57	0.61	-0.029	-0.73
	(0.0031)	(0.0013)	(0.89)	(<0.0001)
New_market mean	0.46	0.35	0.29	-0.10
	(0.020)	(0.084)	(0.16)	(0.63)

Patents as a measure of innovation

The second type of innovation measure is based on patent statistics. We have tested two different indicators on the industry level; the first one is the relative frequency of firms in the industry that owns or has applied for one or more patents, and second one is the number of patents per employed person in the respective industry. The number of firms that has one or more patents was 4 179 year 2007.

These indicators of innovation are merged together with the productivity data in order to study the relationship between technical change, technical efficiency change, multifactor productivity growth and innovation.

Table 8. Summary statistics, patenting firms

Variable	Mean	Std devMin	Max
Mean Annual Technical Efficiency Change	0.0011	0.011-0.044	0.022
Mean Annual Technical Change	0.013	0.026-0.060	0.088
Mean Annual Multifactor Productivity Change	0.014	0.027-0.075	0.077
Patents per employee	0.093	0.240	1.1
Firms with patents in industry	0.067	0.0960	0.46

Further, we have only used the productivity development during 2002-2006 for the analysis using patents. There are no significant relationships with the number of patents per employee, even if the negative relationship with technical efficiency was just above the line. The correlation coefficient for firms with patents and technical change was significant and positive. The other correlation coefficients were not significant. The linear regression result was just significant.

Table 9. Correlation between productivity variables and patent measures

	TE	TC	MFP
Patent per employee in industry	-0.52	0.22	0.14
	(0.102)	(0.52)	(0.68)
Share of firms with patents in industry	-0.38	0.55	0.51
	(0.25)	(0.08)	(0.108)

The number of patents as a measure is not a straightforward measure of innovation output, but more of an innovation intermediate somewhere between input and output. The meaning of a patent also differs greatly among industries. For example, patents are essential in the pharmaceutical industry while not nearly as important for the car industry.

If one wants to explain technical efficiency it is generally suggested to include the explanatory variables directly into the inefficiency model in the stochastic frontier estimation. Not accounting for the exogenous influences in the first step will induce a persistent bias in the estimates that are carried forward into the second step. Assumptions on distributions and choice of model seem to have a big influence on the results. There are no rules for how the model should be built and it has to be considered from case to case which model would fit the data best.

Technology drives the economy

- Large differences in technical change and efficiency among industries
- No general trend in the changes in technical efficiency
- The change in efficiency is negatively correlated with technical change
- Technical change is a necessary but not a sufficient force for productivity
- Industry productivity also depends on the non-frontier firms
- Non-frontier firms almost kept pace with the frontier firms
- Large firm are more efficient
- Capital-intensive firms, given their size, are less efficient
- Specialised firms are more efficient
- Positive relation between innovation output and the technical change
- Share of patenting firms is correlated with technical change

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Appendix A

Density of a half-normal distribution:

$$f(u_i) = \frac{2}{\sqrt{2\pi\sigma_{ui}}} \exp\left\{ -\frac{u_i}{2\sigma_{ui}^2} \right\}$$

The parameters σ_{ui}^2 vary systematically as a function of variables that influences the efficiency, $\sigma_{ui}^2 = g(\delta\,;z_i)$.

u and *v* are assumed to be independent so the joint density function is the product of their individual density functions:

$$f(u,v) = \frac{2}{2\pi\sigma_u\sigma_v} \exp\left\{ -\frac{u^2}{2\sigma_u} - \frac{v^2}{2\sigma_v} \right\}$$

Since $\varepsilon_i = v_i - u_i$, the joint density function for *u* and ε is

$$f(u,\varepsilon) = \frac{2}{2\pi\sigma_u\sigma_v} \exp\left\{ -\frac{u^2}{2\sigma_u} - \frac{(\varepsilon+u)^2}{2\sigma_v} \right\}$$

The marginal density function of e is obtained by integrating *u* out of *f(u,* ε).

When the one-sided error is assumed heteroscedastic the density function of the composed error term, $\varepsilon_i = v_i - u_i$, can be written:

$$f(\varepsilon_i) = \frac{2}{\sigma_i} \phi\left(\frac{\varepsilon_i}{\sigma_i}\right)\left[1 - \Phi\left(\frac{\varepsilon_i\lambda_i}{\sigma_i}\right)\right] \qquad -\infty < \varepsilon_i < \infty$$

where

$$\sigma_i = \quad \sigma_{ui}^2 + \sigma_v^2$$

$$\lambda = \sigma_{ui} / \sigma_v$$

and ϕ is the probability density and Φ is the distribution function of a standard normal variable.

The log likelihood for a sample of n firms expressed as

$$\ln L\left(y \mid \beta, \lambda, \sigma_v^2, \delta\right) = \text{constant } - n\ln\sigma + \sum_i \ln\Phi\left(-\frac{\varepsilon\lambda}{\sigma}\right) - \frac{1}{2\sigma^2}\sum_i \varepsilon_i^2$$

can be maximized to obtain estimates of β,δ and σ_v^2.

Appendix B:

Estimation of one stochastic frontier production function for all industries in the data set.

STATA output:

Stochastic Frontier normal/half-normal model

Number of observations	256369
Wald chi^2 (36)	7748505.76
Log likelihood	43030.578
Prob > chi^2	0.0000

	Coef.	Std. Err.	Z	P>|z|	[95% Conf. Interval]	
Production function						
Dependent variable: ln Y						
Explanatory variables:						
lnL	1.180896	.0036994	319.21	0.000	1.173645	1.188146
lnK	0.1066015	.0015371	69.35	0.000	0.10359	.109614
lnI	-0.2635639	.0028398	-92.81	0.000	-0.26913	-.257998
lnL^2	0.0614475	.0005266	116.68	0.000	0.0604153	.0624796
lnK^2	0.0097034	.0000926	104.81	0.000	0.009522	.0098849
lnI^2	0.0742284	.0002071	358.36	0.000	0.0738224	.0746344
lnK×lnL	0.0020984	.0003506	5.99	0.000	0.0014113	.0027855
lnK×lnI	-0.0210982	.000215	98.12	0.000	-0.0215197	-.0206768
lnL×lnI	-0.1289722	.0005611	-229.84	0.000	-.130072	-.1278724
D2	-0.0056887	.0017286	-3.29	0.001	-.0090768	-.0023006
D3	0.0070975	.0017313	4.10	0.000	.0037042	.0104909
D4	-0.0046699	.0018806	-2.48	0.013	-.0083559	-.000984
D5	-0.0128343	.0018977	-6.76	0.000	-.0165537	-.0091149
D6	-0.0170147	.001917	-8.88	0.000	-.0207719	-.0132574
D7	.0116947	.0019743	5.92	0.000	.0078251	.0155643
D8	-.0173285	.0019985	-8.67	0.000	-.0212455	-.0134115
D9	-.0053097	.0020283	-2.62	0.009	-.0092851	-.0013343
D10	-.0079665	.0020754	-3.84	0.000	-.0120342	-.0038987
Z2	.0924052	.0039129	23.62	0.000	.0847361	.1000744
Z3	.0771678	.0036917	20.90	0.000	.0699322	.0844034
Z4	.1902999	.006446	29.52	0.000	.1776659	.2029338
Z5	.0504986	.0044299	11.40	0.000	.0418162	.059181
Z6	.2099869	.0057868	36.29	0.000	.1986449	.2213288
Z7	.2006514	.0037947	52.88	0.000	.1932139	.2080889

ind1	-.3727869	.0077898	-47.86	0.000	-.3880545	-.3575193
ind2	-.42173	.007566	-55.74	0.000	-.4365591	-.4069009
ind3	-.1574342	.0077948	-20.20	0.000	-.1727117	-.1421566
ind4	-.31541	.0089646	-35.18	0.000	-.3329802	-.2978397
ind5	-.4341698	.0076317	-56.89	0.000	-.4491277	-.4192119
ind6	-.3224956	.0075254	-42.85	0.000	-.3372452	-.3077461
ind7	-.5035216	.0077402	-65.05	0.000	-.5186921	-.4883511
ind8	-.3702015	.0075934	-48.75	0.000	-.3850844	-.3553186
ind9	.1636275	.0185132	8.84	0.000	.1273423	.1999126
ind10	-.1639146	.0079047	-20.74	0.000	-.1794075	-.1484216
ind11	-.1911485	.0076611	-24.95	0.000	-.206164	-.1761331
ind12	-.4369772	.0078772	-55.47	0.000	-.4524162	-.4215382
const	5.877371	.0141839	414.37	0.000	5.849571	5.905171
Two-sided error term:						
ln σ^2_v						
_cons	-4.016043	.0046763	-858.81	0.000	-4.025208	-4.006877
Inefficiency model:						
ln σ^2_u						
lnL	-.1789497	.0057501	-31.12	0.000	-.1902197	-.1676797
ln K/L	.3244896	.0026524	122.34	0.000	.3192911	.3296881
ln I/L	-.6983521	.0047143	-148.14	0.000	-.7075919	-.6891122
time	-.0356878	.0018048	-19.77	0.000	-.0392252	-.0321505
ind1	-2.866259	.0359393	-79.75	0.000	-2.936699	-2.79582
ind2	-3.668717	.0315166	-116.41	0.000	-3.730488	-3.606945
ind3	-1.128375	.0278071	-40.58	0.000	-1.182876	-1.073874
ind4	-3.278079	.0673239	-48.69	0.000	-3.410032	-3.146127
ind5	-3.6618	.0339523	-107.85	0.000	-3.728345	-3.595255
ind6	-2.560363	.0264748	-96.71	0.000	-2.612253	-2.508473
ind7	-2.858241	.0325881	-87.71	0.000	-2.922112	-2.794369
ind8	-2.946535	.0295509	-99.71	0.000	-3.004453	-2.888616
ind9	.3992319	.0663175	6.02	0.000	.2692521	.5292118
ind10	-.913638	.027188	-33.60	0.000	-.9669254	-.8603505
ind11	-1.094638	.0257423	-42.52	0.000	-1.145092	-1.044184
ind12	-2.789907	.0331513	-84.16	0.000	-2.854882	-2.724932
cons	3.235801	.041491	77.99	0.000	3.15448	3.317121

Integrated Productivity Accounts: Contributions to the Measurement of Capital

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1. Introduction

Measures of productivity are derived by comparing outputs and inputs. The System of National Accounts (SNA) provides a useful framework for organizing the information required for comparisons of this type. Integrated systems of economic accounts provide coherent, consistent alternate estimates of the various concepts that can be used to measure productivity.

In Canada, multifactor productivity measures are derived from a set of industry accounts. These industry accounts are integrated and consistent with the expenditure side of the National Accounts (see Wilson, 2007). Using this approach, a variety of productivity series at the industry level are constructed using alternate measures of output along with their corresponding inputs. This approach permits the construction of multifactor productivity measures for the aggregate business sector as a weighted average of industry productivity growth rates, where the weights are defined in terms of the ratio of industry current dollar 'output' to the current dollar bottom-up GDP. And these estimates can be reconciled completely to estimates derived from the final expenditure accounts.

The bottom-up industry approach relies on a detailed set of production accounts. In Canada, the expenditure and the production accounts are integrated within a unified framework defined by the input-output tables (IOT). These IOT are used to derive the estimates of output and inputs by industry and major sectors in current and constant prices as well as the construction of final demand GDP and the cost of primary inputs for the aggregate business sector.

These various components are brought together in Canada into a consistent whole that facilitates productivity estimation. They also support studies that advance our understanding of the role of capital – both tangible and intangible – in the production process. This paper describes how these integrated accounts and the analytical program in the National Accounts have made progress in several different areas.

2. The Canadian Productivity Accounts (CPA)[1]

The CPA begins with the available production and expenditure accounts for the business sector that are available from the CSNA and supplements them with coherent measures of labour services and capital services.

Output and GDP

Data on output and inputs in current and constant prices are obtained from the existing production and expenditure accounts available from the IOT. The Canadian IOT consists of five matrices that outline the disposition or production on the one hand and the use of goods and services and primary inputs on the other hand (see Lal 1986 and Statistics Canada 1990). The make matrix shows the details of the industries and the commodities they produce. The use and the final demand matrices provide information on the goods and services purchased for intermediate use and final demand, respectively. The remaining two matrices show the details of the primary inputs used by industries and purchased by final demand categories.

These tables cover about 300 industries with data on gross output, value added, materials inputs, energy and services – both in current and constant dollars. These data are created mainly from establishment surveys and are establishment based. They also contain compensation data that consist of a) labour income, b) mixed income of unincorporated business enterprises, c) other operating surplus, d) taxes on products, e) other taxes on production, f) subsidies on products, and g) other subsidies on production. Sources here come mainly from enterprise tax files that are then spread to industries to be compatible with the establishment production data. Accompanying the industry data are make and use commodity tables that contain about 700 commodities. The final demand tables contain about 170 categories of final demand.[2]

For the productivity accounts, time series are created to provide a consistent long-run time series for a smaller set of industries. For the period 1961-1997, the labour productivity estimates are produced at various levels of detail provided by the input-output tables for business or commercial industries. Business-sector multifactor productivity estimates were produced at the P (123 industries), M (47 industries)

1 *For more information on methodology, see http://www.statcan.ca/english/concepts/15-204/appendix.pdf.*

2 *The number of industries and commodities in the input output tables has changed over time with the use of different industry and commodity classification systems.*

and S (16 industries) levels.[3] With the introduction of the North American Industrial Classification system (NAICS), the granularity of the industry divisions changed somewhat so that, for the 1961 to 2007 period, multifactor productivity estimates correspond to the P-level (88 industries measured at 4-digit NAICS), M-level (52 industries measured as 3-digit NAICS) and S-level (17 industries measured at 2 digit NAICS).

Commodity by final demand categories cover personal expenditure, gross fixed capital formation, additions to (the value of physical change in) inventories, government expenditure on goods and services, and exports. Data on imports are also available.

The production accounts are constructed so as to meet several basic identities. These are:

1. **Industry accounts basic identity:** The gross output of any industry equals its total intermediate inputs plus its total primary inputs.
2. **Commodity accounts basic identity:** The total output of any commodity equals its total use as an intermediate input and for final demand.
3. **Primary inputs and final demand identities.** Given the equality of the gross supply and disposition of commodities and that interindustry intermediate purchases and sales of commodities are identical, it follows that final demand is equal to cost of primary inputs. The former is derived by subtracting intermediate inputs from total use of commodities and the latter by deducting intermediate inputs from total supply of commodities. Hence, total gross domestic product at market prices (income based) equals total gross domestic product at market prices (expenditure based).

All of these identities hold for both current price and constant price tables.

Industry value added is calculated as the difference between the gross output of industries and the total of intermediate inputs and taxes less subsidies on production (net taxes on production). These components of income include all personal income and corporate income taxes. Summed across all industries, these estimates of value added are equal to the GDP calculated from market price final expenditures less taxes on products less subsidies on production.

The set of industry accounts represented by the IOT is valuable for several reasons. First, it benchmarks the rest of the National Accounts, including the final demand GDP. As such, the CPA's productivity estimates at the industry level are consistent with those at the more aggregate level. Second, considerable effort is spent in

[3] *The finest level of industry detail for multifactor productivity estimates is less than for labor productivity because investment data are not available for the L level.*

checking the concordance of industry-level measures of outputs and inputs and in valuing outputs and inputs consistently. Since the IOT are at the core of the statistical system, it provides an audit tool that permits the statistical system to monitor the various sources that are used in different parts of the process that builds data on expenditure, on factor income and on commodity production and use. Third, as we point out here, these data, when combined with information on labour, capital and other series provide the base for analytical studies aimed at providing new statistical products – either in the form of data products or an understanding of issues that suggest directions that the statistical system needs to take.

Labor

The CPA is responsible for constructing labour estimates from various sources that accord with the recommendations of SNA 1993 and that are consistent with the data that are produced by the production accounts. Estimates of jobs and hours-worked are produced at a detailed industry level and by class of workers (see Baldwin et al. 2004). Changes in the skill level of the labour force are not captured in a simple sum of hours worked across all workers. To obtain a measure of productivity that excludes the effect of changing skill levels, the CPA adjusts hours worked for changes in the quality or composition of the labour force by making use of relative wages as aggregation weights in order to take into account differences in relative productivity of different groups of workers. Its labour estimate therefore takes into account changes in labour composition or labour"quality".

Details on the construction of the labour data can be found in Gu et al. (2003). Briefly, the Censuses of Population provide detailed benchmark data on employment, hours, and labour compensation across demographic groups in census years. The annual Labour Force Survey (LFS) and other data are used to interpolate across intervening years.

The demographic groups include 56 different types of workers, cross-classified by class of workers (employee, self-employed or unpaid), age (15-17, 18-24, 25-34, 35-44, 45-54, 55-64, 65+), and education (0-8 years grade school, some or completed high school, post-secondary education below a bachelors degree, and a bachelors degree or above). Adjustments to the data include allocations of multiple job-holders and an estimation procedure to maintain consistent definitions of demographic groups over time. These detailed data allows us to estimate the quality of labour input for the private business sector as well as for individual industries down to the 3-digit (L) level of the IOT.

Capital Services

The CPA are also responsible for developing internally consistent, coherent estimates of capital services. The CPA takes investment data and modifies them to meet the boundaries of the National Accounts. Here, the CPA rely on investment data first from the Income and Expenditures Accounts for final demand GDP and then from input-output accounts that are built from industry survey data obtained from the Investment and Capital Stock Division. Investment expenditures are acquired from the latter Division from an establishment survey that provides even more asset detail than are available from the Industry Accounts and are used to produce detailed industry data that are reconciled to the aggregate data.

The CPA begins with investment data, estimates capital stocks using the perpetual inventory method, and aggregates capital stocks using rental prices as weights. This approach, originated by Jorgenson and Griliches (1967), is based on the identification of rental prices with marginal products of different types of capital. The estimates of these prices incorporate differences in asset prices, service lives and depreciation rates, and the tax treatment of capital incomes. Service lives are derived from special questions on the Investment Survey. Depreciation rates are derived from used asset prices (Microeconomic Analysis Division, 2007). A broad definition of capital is employed, which includes tangible assets such as equipment and structures, as well as land, and inventories. A service flow is then estimated from the installed capital stock.[4]

The CPA approach to capital services generates a complete time series of investment derived from over 150 investment types reclassified into 28 private assets (18 types of equipment and software, 6 types of non-residential structures, and 4 types of residential structures). Capital stocks are then estimated using the perpetual inventory method and a geometric depreciation rate based on age-price profiles developed in Depreciation Rates for the Productivity Accounts.

Capital services at the industry level are then estimated as the weighted sum of capital stock using their rental prices as weights. Capital services for the aggregate business sector are constructed by aggregating capital services at the industry level based on the industry share of total user costs.

[4] *See Harchaoui and Tarkhani (2002) for methodology.*

3. Testing the Assumptions Used to Estimate Capital Services

An integrated set of Productivity Accounts is useful not just for estimating productivity statistics. It also permits a statistical agency to monitor the internal consistency of the data used for the estimates. In this section, we demonstrate that it can be used both to test the sensitivity of the estimates to alternate assumptions and to ask whether the estimates are internally consistent. We do so by asking how sensitive multifactor productivity estimates are to alternate ways of estimating the user cost of capital.

Multifactor productivity growth measures have been developed as summary statistics to measure the amount of this progress. They do so by comparing actual growth rates in GDP with the increase in GDP that would have been expected from an increase in inputs using pre-existing or current production techniques.

The basic production model on which productivity estimates are based is written:

$$GDP_t = A(t)F(K_t, L_t) \tag{1}$$

By taking the total derivative with respect to time and assuming competitive markets the change in GDP with respect to time can be represented:

$$GDP_t = A_t + \omega_{l,t} L_t + \omega_{k,t} K_t \tag{2}$$

where the elasticities of capital and labour growth are their respective income shares.

MFP growth, A_t, is measured as a residual:

$$MFP_t = A_t = GDP - \omega_{l,t} L_t - \omega_{k,t} K_t \tag{3}$$

Rewriting this is in terms of income shares gives

$$MFP = Q - \sum \frac{P_i X_i}{PQ} X_i = Q - \sum s_i X_i \tag{4}$$

where s_i is the factor i's share in value of GDP (PQ).

Estimates of multifactor productivity from (4) require measures of the change in GDP (Q), capital (K), and labour (L) and factor shares. In a world where all assets have the same marginal product, changes in capital may be estimated by simply summing the value of all assets and calculating changes therein over time. But factors (either workers or types of capital assets) may differ in terms of their marginal product and then it is inappropriate to simply sum the factors. If there are m types of factor i, each with a different marginal product, then the appropriate formulae for estimating the effect of a change in a factor is

$$s_i X_i = \sum_{k=1}^{m} s_{ik} X_{ik} \ , \tag{5}$$

where s_{ik} can be approximated by the share of total GDP

that goes to each type of the factor i and

$$s_i = \sum_{k=1}^{m} s_{ik} \tag{6}$$

This can be transformed to

$$X_i = \sum_{k=1}^{m} (s_{ik} / s_i) X_{ik} \ , \tag{7}$$

and then substituted into equation 5.

The appropriate weights then to aggregate changes in a type of factor are the relative shares of each type of factor in the total compensation received by that factor. In order to estimate these shares, we need to calculate the unit price of each type of factor. In the case of prices for labour, the task is relatively straightforward. Transactions are observed continuously in labour markets that can be used for this purpose. In the case of capital, we need comparable prices. While the price of the capital good is available, the price of the services that the capital good yields, when it is used over a period that is shorter than its length of life, is not usually observed and needs to be inferred.

The user cost of capital can be thought of as the price that a well functioning market would produce for an asset that is being rented by an owner to a user of that asset. That price would comprise a term reflecting the opportunity cost of capital (r_t) (either the opportunity cost of using capital or the financing costs), a term reflecting the depreciation of the asset (δ), and a term reflecting capital gains or losses from holding the asset (reflecting changes in the market price of an asset, $q_1 - q_{t-1}$). Jorgenson and Griliches (1967) demonstrate that the formula for the rental price of a unit of capital that costs q is

$$c_t = q_{t-1} r_t + q_t \delta - (q_t - q_{t-1}) \tag{8}$$

The implementation of this formula requires estimates of depreciation, capital gains resulting from holding the asset and the rate of return expected, Depreciation rates can be estimated from trajectories of used asset prices and capital gains from the price indices of different assets collected by the agency. But one area in which practice has not coalesced is that of the measure of the rate of return.

Exogenous versus Endogenous rates of return

The debate here has revolved around whether the rate of return should be calculated endogenously or taken from exogenous sources.[5]

Rates that are calculated endogenously make use of data from the national accounts on capital income and estimates of capital stock to solve for the rate of return.

Alternatively, the rate of return can be taken from other sources – a rate of return observed in financial markets, for example. Here, there are several choices—a risk-free rate of return such as a government bond rate, a corporate debt rate that takes into account the risk of the business sector, or a weighted average of corporate debt and corporate equity rates that recognizes that the corporate sector is financed by a mixture of debt and equity.

The advantage of using the method that employs endogenous rates is that it is provides a fully integrated set of accounts. The surplus is taken directly from the National Accounts that provides the underlying data for the productivity accounts. Capital is directly estimated from the investment flows that are also part of the System of National Accounts. In Canada, investment flows are integrated with the input-output tables and are thus, consistent with GDP at the industry level. These flows can be used to estimate capital stock using the perpetual inventory method and together with the surplus yield a rate of return earned in each industry.

Equally important, the assumptions that are required to make use of the surplus in estimating capital services are fully compatible with the assumptions that underlie the non-parametric productivity estimates – that of a competitive economy with a production process subject to constant returns to scale.

Choosing an exogenous rate of return allows the assumption of constant returns to scale to be relaxed. And it does not require that the assets used completely exhaust capital income, thereby recognizing that some assets may be excluded in existing estimates. It also allows an analyst to presume that the economic system is not perfectly competitive and that the corporate surplus may include more than just the cost of capital services – for example, monopoly profits.

Since the use of an exogenous rate of return does not guarantee that the corporate surplus is completely exhausted, it permits the estimation of a residual (the difference between corporate surplus and capital services). This difference could arise because of monopoly profits. It could arise because the list of factors that is included in the multifactor productivity estimates is incomplete (for example, assets like land, inventories, natural resources or intangibles are excluded). It could arise

[5] *See Schreyer, Diewert and Harrison (2005).*

because there are economies of scale and therefore, paying factors their marginal revue product does not completely exhaust total product.

While using the exogenous rate overcomes several potential problems, it gives rise to others. The problem with using the exogenous rate is that it is not obvious what rate should be used. And choice of an incorrect rate will lead to an error in the estimates of multifactor productivity.

In the case of an exogenous rate, there is a wide range of rates that have been suggested – from short to long rates, from lending to borrowing rates (Diewert, 1980). The interest rate in the cost of capital formula should reflect risk-adjusted rates of return (since it is these that govern investment decisions). This requires a variation in the return by industry or by asset to reflect varying degrees of risk.[6] This problem, in turn, requires that the analyst make use of information that would help to adjudicate differences in risk. When this is done, there may, in the end, be little difference between the rates yielded by an endogenous and an exogenous system.

In this paper, as in the official Canadian Productivity Accounts, we use capital income from the Canadian National Accounts to derive the internal rate of return. Capital income is defined here as current dollar gross domestic product except for labor compensation (wages, salaries, supplementary compensation, and a portion of proprietors income attributable to labour). Capital stock estimates are taken from the productivity accounts data base of Statistics Canada. It is created from investment flows using the perpetual inventory method.

For the exogenous rate of return, we have used a weighted average of debt costs and the equity rate of return, where the weights are the proportion of debt and equity that is used to finance business capital.[7] For the debt rate, we have used the 90 day commercial paper rate.[8] For the equity rate, we have used the rate of return on equity as derived from the gain in the index of the Toronto Stock Exchange plus the dividend yield.[9] The resulting exogenous rates of return are inclusive of the overall inflation rate and thus represent the nominal rates of return. These nominal rates are then deflated by the consumer price index. The resulting series of real exogenous rates are averaged over the period 1961 to 2001 to yield a constant rate

6 See Schreyer, Diewert and Harrison (2005, p. 43) who stress that practitioners should therefore use industry-specific rates of return that reflect that some investment in fixed capital is riskier than others.

7 These proportions are taken from the Industrial Organization and Finance Division of Statistics Canada.

8 See Canadian Economic Observer, series 122491 We use the commercial rate rather than the long-term corporate bond rate to reflect the fact that it is the after-tax rate that we need and the commercial rate, which is below the corporate rate, to capture much of the tax effect needed. Future versions of this paper will explore alternatives.

9 See Canadian Economic Observer, series 122620 and 122628.

of return of 4.7%. For the user cost specification (14) based on the exogenous rate of return, we will set the real rate of return r_t^* to a constant, 4.7%.

Alternate specifications of rate of return

To examine the effect of alternative approaches to the estimation of capital services and multifactor productivity, we compare two sets of estimates. The first (M1) makes use of an estimate of capital gains using the instantaneous change in asset prices. The second (M3) ignores the capital gains term since it is not clear whether there are ways that holding-period gains arising from differential rates of inflation can be harvested – especially for investment goods. Both variants include the impact of taxes. (See Baldwin and Gu, 2007a).

Table 1 A comparison of alternative capital rental cost formulae in the business sector, 1961 to 1981

	Endogenous		Exogenous	
	M1	M3	M1	M3
Mean statistics over years 1961-81				
Average nominal rate of return	0.15	0.13	0.11	0.11
Annual MFP growth (%)	1.00	1.24	1.48	1.50
Mean statistics over years 1981-2001				
Average nominal rate of return	0.10	0.11	0.09	0.09
Annual MFP growth (%)	0.12	0.21	0.25	0.38

Source: Canadian Productivity Accounts.

In order to assess the effect of the alternate scenarios, we compare the average rates of return that are produced by each, and the growth in MFP. They differ by the choice of the rate of return and the choice of expected capital gains. Summary statistics in each of these areas can be found for the period 1961 to and for 1981 to 2001 in Table 1.

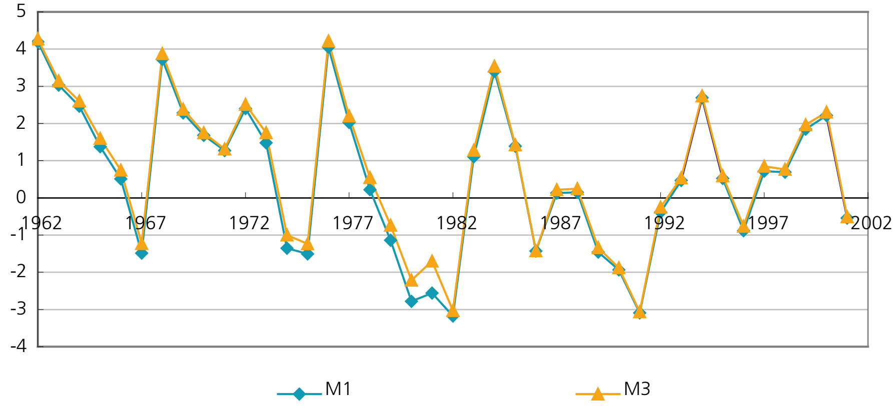
The nominal rates of return that are produced by the endogenous method are generally higher than those for the exogenous method.[10] Over the 1961 to 1981 period, the endogenous rate that excludes asset price changes as a measure of capital gains (M3) is 13%, while the comparable exogenous rate averages only 11%. Over the 1981 to 2001 period, the endogenous rate estimated from M3 is 11% while the comparable exogenous rate averages 9%. The difference is not large – around 2 percentage points in both periods when we consider M3 the method that excludes asset price changes as measures of capital gains.

[10] *We have employed the user cost formula based on real rates in estimating the exogenous user cost of capital. For the presentation of the results, we use nominal rates of return. The nominal rates of return are computed as the sum of the real rates of return plus a 5-year moving average of change of the consumer price index.*

Turning to the difference in MFP growth rates across the two alternatives, it is apparent that MFP growth is faster when we use the exogenous rate of return rather than endogenous rate of return – though as Figure 1 demonstrates, it is difficult to distinguish one method from another in the annual data.

This difference arises for two reasons. The first is that the endogenous rate of return is lower than the exogenous rate of return. The level of the nominal rate of return affects MFP growth in two ways – via its effects on what is referred to as capital composition (the difference between the growth of the simple sum and the weighted sum of individual assets) and its effect on the measure of the cost share of capital. The use of a lower rate in the user cost estimation leads to higher growth of capital composition and lower cost share of capital service in the MFP growth accounting framework. The former leads to a decline in the MFP growth estimate while the latter leads to an increase in the MFP growth estimate. The overall effect of the two offsetting factors is an increase in the MFP growth rate as the effect of changes in capital share tends to dominate the effect of changes in capital composition.

Figure 1 Multifactor productivity growth in the business sector (percent)



Source: Canadian Productivity Accounts.

But the second reason is that the use of an exogenous rate of return imposes an equality in the rate of return across industries that does not exist for the endogenous method. Part of the growth in GDP in a world where returns differ across industries can come from the reallocation of resources from industries where the marginal product of capital is lower to those where it is higher. Baldwin and Gu (2007a) show that much of the difference between the endogenous and the exogenous rate methods stem from this phenomenon. That is, if the average endogenous rate were to be applied across all industries, the resulting MFP increases to about the same level as the MFP estimate from the exogenous method.

In conclusion, using the Productivity Accounts in this way provides a validation of the internal consistency of the data base. It has shown that the rate of return that falls out of the exercise is very close to the actual rate return earned by the business sector. More importantly, it has demonstrated why the alternate method sometimes used to estimate MFP when integrated industry accounts are not available (when exogenous rates of return are chosen) are likely to lead to upward biases in MFP estimates – because they miss part of the causes of growth – the reallocation of resources across industries from less productive to more productive uses.

4. Infrastructure Capital

One of the benefits of having an integrated set of productivity accounts is the ability to produce productivity measures that incorporate different sources or types of capital. In Canada, the productivity accounts focus on the business sector and examine the efficiency with which that sector transforms the labour that it hires and the tangible capital (machinery and equipment, buildings) that it purchases into output. Recently, the Productivity Accounts have been extended to examine what happens when public capital is incorporated in the analysis.

Public capital is comprised of assets like roads, bridges and water and sewage plants (Baldwin and Dixon 2007). In Canada, roads are the largest component of the public capital stock. These assets are currently not treated as an input for the business sector, and do not explicitly contribute to productivity, because investments in roads are not performed by the business sector.

Incorporating the Impact of Infrastructure on Multifactor Productivity

The standard index number approach to measuring MFP starts with a production function that uses capital services, K_t, and labour services, L_t, to transform inputs into outputs. The MFP term is incorporated as a shift parameter, $A(t)$, that represents changes to the level of the production function as technology changes (See for example: Baldwin and Gu 2006).

As noted in the previous section, the conventional estimate of MFP is written:

$$MFP_t = GDP - \omega_{l,t} L_t - \omega_{k,t} K_t \tag{9}$$

where the elasticities of capital and labour growth are their respective income shares.

In order to extend this framework to take into account infrastructure investment, public capital can be assumed to enter the production process as an exogenous input that leads to increasing returns to scale across all input but leaves private sector agents facing constant returns to scale:

$$MFP_t^* = GDP - \omega_{l,t} L_t - \omega_{k,t} K_t - \varpi_g G_t \qquad (10)$$

$$\omega_{l,t} + \omega_{k,t} = 1 \quad \omega_{l,t} + \omega_{k,t} + \varpi_g \geq 1$$

The model that includes public capital is related to the standard MFP estimate produced by the Canadian Productivity Accounts through the identity:

$$MFP_t = MFP_t^* + \varpi_g G \qquad (11)$$

The MFP estimates from (9) and (10), therefore, provide a method for assessing the extent to which current MFP estimates are biased because they include not just technological change, but also the contribution from public sector investment.

Estimating the Output Elasticity of Public Infrastructure

In order to take into account the impact of public infrastructure on business sector GDP, an estimate of the elasticity of public capital is required. While shares can be used for private inputs, this is not possible for public capital. It is difficult for statistical systems to measure the value of government GDP because there are limited, if any, markets for government services.

Without markets for the sale of outputs, it is difficult to find reliable elasticity estimates for public capital that can be used to apply to the increase in public capital or that can be used to approximate just how much business sector GDP should be expected to increase as a result of additions to public capital. To date, there is no consensus about what constitutes a reasonable output elasticity for public infrastructure, or what estimation method is most appropriate (see for example Aschaeur 1989; Munnel 1990a, 1990b; Shah 1992; Berndt and Hanson 1992; Lynde and Richmond 1992; Nadiri and Mamuneas 1994; Conrad and Seitz 1994; Morrison and Schwartz 1996; Harchaoui 1997; Fernald 1999; Pereira 2000; Harchaoui and Tarkhani 2001; Ramirez 2004; Bader and Faden 2005; and, Macdonald 2007).

To pursue this issue, two areas were addressed using the integrated Canadian Productivity Accounts. In the first instance, estimates were derived for the elasticity of the business sector with respect to public capital; in the second, public capital was introduced as an explicit argument in the production function of the Canadian business sector and an experimental MFP estimate was produced that excludes the effect of public capital's input.

The input-output system that lies behind GDP, as well as Gross Output and Intermediate Input estimates that form the basis of the productivity accounts allow us to do this in two ways. The first employs cost function estimates to derive a return from increases in public capital. Harchaoui and Tarkhani (2003) used industry data and a translog cost function. This approach makes use of share equations and demand functions to estimate a system of equations. Their paper made use of data coming from the Productivity Accounts on the values of Gross Output, the cost of labour, capital services and intermediate inputs for 37 SIC industries in the Canadian business sector during the period 1961-1997. The data from the productivity accounts was combined with public capital data derived from the same investment source that was used for building the business sector capital stock.

Macdonald (2007) also employs a cost function to examine the impact of public investment on private costs. This paper uses a GDP function to explore the sensitivity of estimation procedures to aberrant observations like outliers, and to different time series specifications. Macdonald followed Fernald (1999) in assuming that public capital expenses are proportional to transportation costs. This assumption allowed Macdonald to calculate an instrumental variable for public capital costs for businesses that varies by industry. The data was taken from the commodity data of the input-output accounts from which the productivity accounts are constructed.

In addition to cost-function estimates, Macdonald (2007) also estimates the dual production function. The production function estimates are formed from a panel of provincial datasets where GDP, capital and labour variables are consistent with the data used to produce the productivity accounts, and with a public capital variable derived from the same investment data as Harchaoui and Tarkhani (2003).

The two approaches are used to 'triangulate' on a likely range of values for the elasticity of public infrastructure. Macdonald (2007) compares the cost function to the production function estimates and the respective average rates of return derived therefrom, as well as to other estimates in the literature. This produces an elasticity of business sector GDP with respect to increases in public capital of 0.05 to 0.15 that is centered on 0.1. These values correspond to a range for the rate of return to government capital that spans values from 5 percent to 29 percent, centered on 17 percent. The range of the estimates includes the average rate of return on public debt and the combined average return on private debt and equity.

Through the integrated set of productivity accounts, the elasticity and rate of return estimates can be incorporated into productivity measures to either create total economy productivity measures or to re-estimate productivity measures like multi factor productivity (MFP) after including public capital as an explicit argument in the business sector's production function. Here an experimental MFP measure for the business sector is discussed because it represents an adjustment of the currently produced MFP measure widely used in Canada (see Gu and Macdonald 2008 for more information). Moving to a total economy MFP measure produces a similar result when a positive rate of return to public capital is included.

For purposes of examining how public infrastructure affects productivity growth, estimates of labour productivity growth are decomposed into their component sources. Within the growth accounting framework, equation 9 can be written in discrete time where all variables are measured in logarithms as:

$$\Delta\left(GDP_t / Hours_t\right) = \Delta MFP_t + \beta_L \Delta\left(L_t / Hours_t\right) + \beta_K \Delta\left(K_t / Hours_t\right) \qquad (12)$$

Where:

$GDP_t / Hours_t$	= Labour productivity
$\beta_L \Delta\left(L_t / Hours_t\right)$	= Contribution from labour composition changes
$\beta_K \Delta\left(K_t / Hours_t\right)$	= Contribution from increased capital intensity (capital deepening)
MFP_t	= Contribution from technology change and factors difficult to measure or include

When examining the role public capital growth plays in private sector productivity growth, the results are presented following the components in equation 12. However, MFP growth is decomposed as:

$$MFP_t = MFP^*_t + \varpi_g \Delta G_t \qquad (13)$$

Initially, the ϖ_g elasticity estimate of 0.1 is employed. Later, a sensitivity analysis is provided based on the 0.05 to 0.15 elasticities obtained from Macdonald (2007). Throughout this section, the assumption of a competitive economy is maintained. The competitive assumption coincides with assumptions imposed on the traditional MFP estimates from the Canadian Productivity Accounts where an internal rate of return is employed for calculating capital services. It is, therefore, a natural starting point.

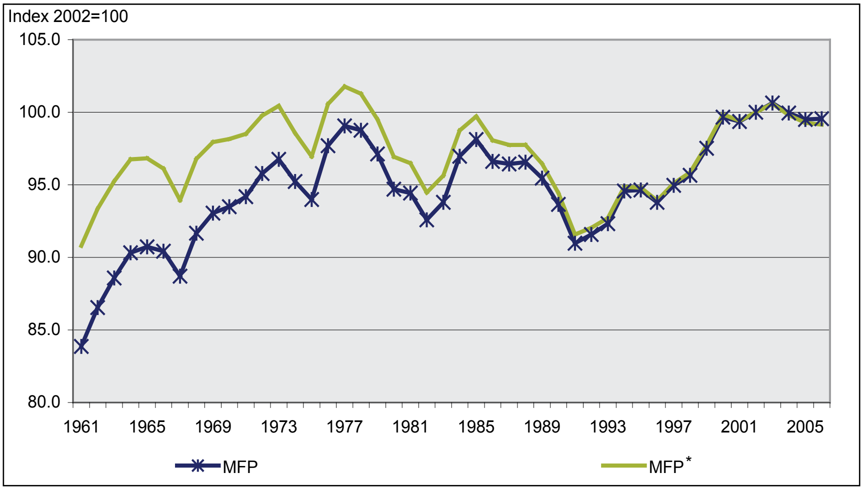
Results

The effect of removing the influence of public capital on MFP is seen most strongly in the earlier half of the sample period from 1961 to the early 1980s (Figure 2). After the mid-1980s, and particularly following the 1991 recession, there is little difference between MFP and MFP*.

The difference between MFP and MFP* largely occurs during the period when Canada's inter-provincial highway system is constructed. Once the impact of public capital is accounted for, the estimate of MFP* shows less growth over time than the standard estimate of MFP that includes the impact of public capital.

The difference in MFP growth rates can be seen succinctly when changes in labour productivity are decomposed into changes in capital intensity (capital contribution), labour composition changes, changes in public capital provision and MFP*. This is done in Table 2 where the first three rows show labour productivity growth, the capital contribution and the labour composition contribution. They are the same as produced by earlier studies examining the Canadian Productivity Accounts and are presented for completeness (Baldwin and Gu 2004). The last three rows contain the decomposition of MFP. They show the decomposed effects of public capital and MFP. The traditional MFP growth estimate is the sum of the contribution from public capital and the revised MFP growth estimate MFP*.

Figure 2: *MFP** **Index** ($\varpi_g = 0.1$)



Source: Statistics Canada

Table 2: Labour Productivity Growth by Source

	1962-2006	1962-1966	1967-1973	1974-1979	1978-1988	1989-1999	2000-2006
Labour Productivity	2.1	3.9	3.2	2.0	1.1	1.5	1.4
Capital Contribution	1.3	1.6	1.7	1.7	1.0	1.0	0.9
Labour Composition Contribution	0.4	0.8	0.5	0.2	0.4	0.4	0.4
Public Capital Contribution	0.2	0.4	0.3	0.2	0.1	0.1	0.1
MFP*	0.2	1.2	0.6	-0.2	-0.4	0.0	0.0
MFP	0.4	1.5	1.0	0.1	-0.2	0.1	0.2

Source: Statistics Canada

Over the entire period, 1962-2006 including the impact of public capital halves the contribution of MFP growth to labour productivity growth. MFP rises by an average of 0.36% per annum while MFP* rises by 0.17% per annum. Public capital contributes importantly, adding 0.19% per annum to labour productivity growth from 1962-2006.

Public capital's contribution to labour productivity growth varies over time. Public capital had the largest contributions in the 1960s and 1970s. These decades saw a sizeable expansion of the intra/inter-provincial highway system as well as the construction of the Trans-Canada Highway. They constitute a period during which the network of public capital expanded rapidly.

In subsequent years, public capital stock growth slows as the highway expansion ends and governments eliminate operating deficits. The contribution to labour productivity from public investment slowed in tandem. Estimates of MFP and MFP* both slow in the late 1970s, and are on average negative.

During the 1990s, and into the 2000s, MFP* grows at approximately the same rate as MFP. Both MFP estimates show the resurgence in productivity growth that occurred in the late 1990s, as well as a similar post-2000 slowdown.

Robustness Checks

The elasticity estimate employed to investigate public capital's contribution to labour productivity is measured with uncertainty. Estimates of public capital's elasticity are subject to normal statistical uncertainty as well as uncertainty that arises from errors in variables problems associated with estimating its depreciation rate, rate of return, and to uncertainty based on estimation methodology. These sources of uncertainty can have significant impacts on the associated elasticity estimates.

To assess the importance of the uncertainty, the elasticity estimate of 0.1 from Macdonald (2007) is adjusted up and down by 0.05. Macdonald (2007) argues that this represents a reasonable range for public capital's elasticity that is consistent with most estimates from cost-function based studies.

The long-term government bond rate can be employed as an alternative method for calculating public capital's marginal product. When public capital's return is assumed to equal the average long-term government bond rate, the corresponding elasticity estimate is around 0.06. This estimate of the elasticity is consistent with the lower end of the confidence interval outlined above.

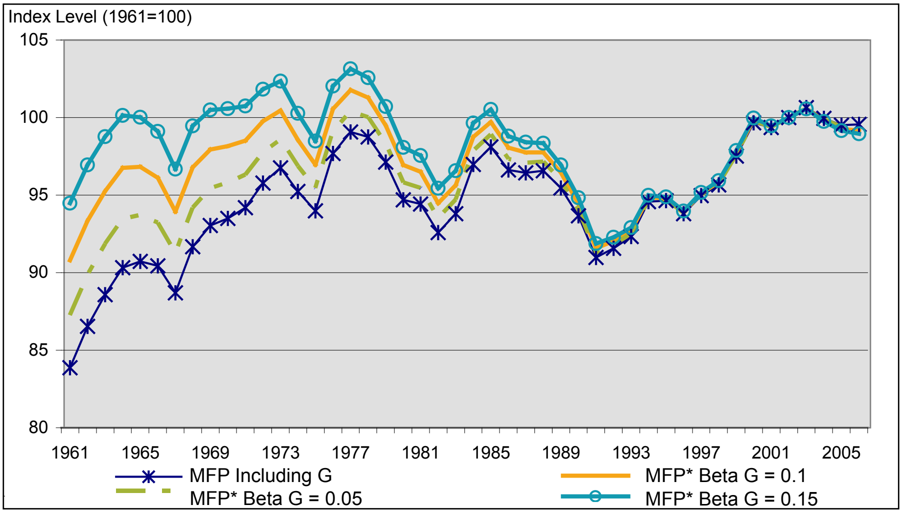
Estimates of public capital's contribution and MFP* are influenced by the elasticity estimate employed (Figure 3 and Table 3). The influence is greatest during the period spanning approximately 1961 to 1980. This is the period when the conventionally derived estimates of MFP were highest. After 1980, there are only minor differences that occur.

For each 0.05 increase in the elasticity estimate, public capital's contribution to labour productivity growth rises by around 0.1 percentage points for the 1962-2006 period. The effect of increasing the elasticity estimate is larger during the earlier half of the period than the latter half, which is consistent with the growth rates of public capital stock.

For all three elasticity estimates, the contribution of MFP to labour productivity growth is lower during the 1960s and 1970s. Regardless of the estimate used, the MFP growth slowdown between of the post-1980 period becomes less pronounced.

In effect, when the impact of public capital is disentangled from MFP growth, MFP growth is lower, has less of trend, but continues to show cyclicality across eras.

Figure 3: MFP index across public capital elasticity assumption



Source: Statistics Canada

Table 3: MFP and public capital contributions to labour productivity across elasticity estimates

	1962-2006	1962-1966	1967-1973	1974-1979	1978-1988	1989-1999	2000-2006
Public Capital contribution							
Beta = 0.05	0.09	0.18	0.17	0.11	0.07	0.04	0.06
Beta = 0.10	0.19	0.37	0.34	0.22	0.13	0.09	0.12
Beta = 0.15	0.28	0.55	0.50	0.33	0.20	0.13	0.18
MFP contribution							
Beta = 0.00	0.36	1.53	0.96	0.06	-0.22	0.09	0.16
Beta = 0.05	0.27	1.35	0.80	-0.05	-0.29	0.04	0.10
Beta = 0.10	0.17	1.17	0.63	-0.16	-0.36	0.00	0.04
Beta = 0.15	0.08	0.98	0.46	-0.27	-0.42	-0.05	-0.02

Source: Statistics Canada

5. Intangible Capital

The integrated set of productivity accounts produced by Statistics Canada has also been used as a foundation for developing experimental estimates of investments that the Canadian economy makes in intangible assets. Intangible assets are broadly defined as knowledge based assets, organizational assets and assets relating to reputation.

Studies of the underlying factors behind growth have tended to focus on tangible assets such as machinery and equipment, building and engineering construction (dams, railways, communication systems). But most firms make expenditures in a wide range of other areas where the value of the expenditures to the firm lasts more than one year and therefore should be classified as an investment. Many of these are referred to as knowledge assets that support the innovation process.

Types of Intangible Assets Investigated

One such intangible asset that has received much attention arises is research and development (R&D), which consists mainly of expenditures on the wages of R&D scientists – and produces knowledge capital that is critical for innovation. But innovative activity is not restricted to this area. While R&D scientists create new knowledge that is embedded in brand new products, other types of scientists – engineers – adapt new products and materials into the production process. Production engineering involves expenditures that are generally not classified as R&D but that have many of the same properties in that they create long-lived assets and they involve substantial scientific effort.

Firms may invest in new scientific knowledge by hiring R&D and production oriented engineers and producing that knowledge themselves – or they can buy it. Knowledge investments are made by purchasing R&D, patents, licences, and technological know-how from other companies.

In the resource sector, exploration provides new information that is useful for production many years after it is made. Early stage exploration expenditures are used to develop knowledge about where mineral resources are found and on the economic properties of mineral or petroleum reserves. R&D can be viewed as early stage investments in innovation that are meant to reduce uncertainty. Exploration expenditures do the same for the resource sector of an economy.

Similarly, advertising expenditures provide firms with a reputation that if it extends beyond the present and has an impact on the value of the firm should be considered an investment in intangibles. They provide brand value that has long been recognized as a valuable intangible asset.

The set of intangible assets that our research has examined for Canada cover several categories – i.e., advertising, mineral exploration, software, own-account research and development, purchased research and development and own-account science and engineering expenditures. This research makes use of data that are derived from internally consistent, comprehensive and reliable Statistics Canada data sources. For software and mineral exploration, the productivity accounts already include the intangible asset in measures of capital input. For other assets, data is drawn from the input-output tables used as the basis for the productivity accounts, from the Census of Population and from labour market surveys. The latter two use industry categories and definitions that allow the data to be integrated into the industry accounts that underpin the Productivity Accounts.

While other studies included a larger set of categories (in particular by extending the data to management and training)[11], the quality of the data in these areas make the evaluation of the conclusions derived therefrom somewhat problematic. In some cases, other studies have had to make use of third-party sources on research and development or advertising that are not integrated into the industry estimates coming from the Systems of National Accounts.

The estimates of intangible expenditures for Canada are linked directly to the industries in the Canadian productivity accounts which facilitate business sector and industry level analysis[12]. The integrated productivity measurement system provides a well established reference against which the intangible expenditures can be compared, as well as allowing for a straightforward reallocation of mineral exploration and software expenditures out of the currently used investment series and into intangibles expenditures.

Estimates of Investment in Intangibles

The shares of intangible investments are presented in Table 4 by three main categories-advertising, mineral exploration and all science (R&D, Software, Other Science Own Account, and Purchased Services). Science and innovation intangible expenditures are the most important – accounting for an average of 77.4% of total intangible investments over the period 1981 to 2001. Science related innovation expenditures have increased their share over time, rising from 76.5% in 1981 to 78.4% in 2001. Advertising is second with an average share of 18.3% and its importance varies procyclically. Mineral exploration is third, making up on average 4.3% of intangible expenditures. The share of mineral exploration fell from its levels

11 See for example Corrado, Hulten and Sichel 2005, 2006.

12 The business sector defined for intangibles consists of all industries except NAICS 61 (Education), NAICS 62 (Health Care) and NAICS 91 (Public Administration).

of the early 1980s to lower levels in the mid 1980s but has steadily grown since then (Figure 4).

Investment in software is the smallest component of all intangibles for the sample period, having a share of 2.5% in 1981 and increasing to 6.7% by the end of the period. In keeping with the onset of the computer revolution, the share of this component more than doubles over the period.

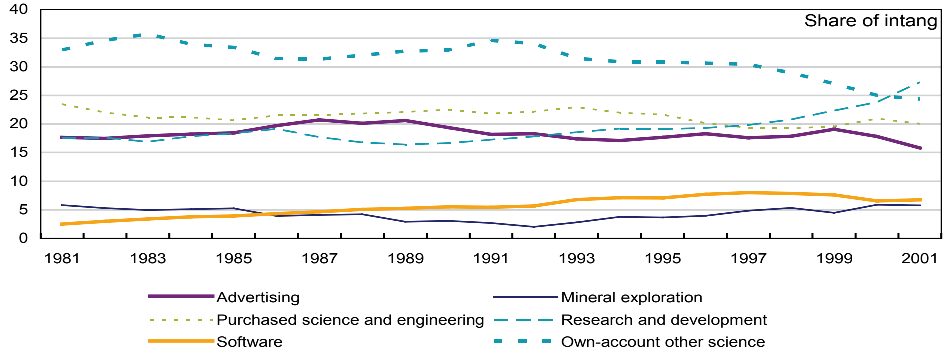
While R&D garners most of the attention in innovation studies, it accounts for only between 17.6 and 27.3 percentage points of total intangible investments, although its share grew in the late 1990s. The Own-account other science-related investments are considerably more important than R&D. Even the purchased science and engineering component is at least as large as R&D. A portion of this comes from imports of software.[13]

Table 4: Share of Intangible Investments by Asset Category (Current $)

	Advertising	Mineral exploration	Total science	Total science			
				Purchased science and engineering	Own-account		
					Research and development	Software	Own-account other science
	percent						
1981	17.7	5.8	76.5	23.4	17.6	2.5	33.0
1985	18.4	5.2	76.3	20.6	18.4	3.9	33.4
1990	19.4	3.1	77.6	22.5	16.6	5.5	32.9
1995	17.7	3.7	78.7	21.7	19.1	7.1	30.8
2001	15.8	5.8	78.4	20.1	27.3	6.7	24.4
Average	18.3	4.3	77.4	21.3	19.0	5.6	31.4

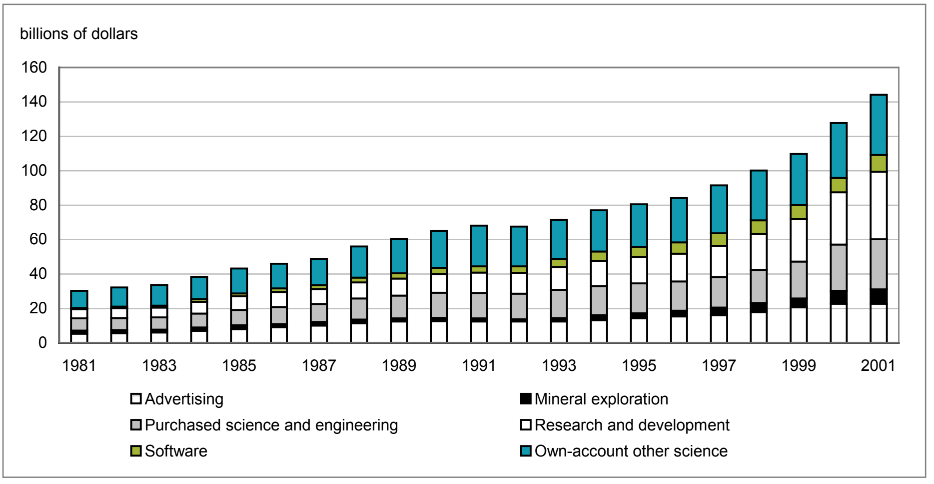
[13] *The importance of R&D would be even smaller if exports of R&D were removed from the Own-account R&D expenditures, as is done in some satellite accounts of R&D.*

Figure 4: Share of Intangible Investments: 1981-2001



Intangible investment in Canada has expanded by an average of 7.7% per year from 1981 to 2001, rising four fold from around $24 billion in 1981 to $98 billion in 2001 (Figure 5). Software investment expanded the fastest, averaging 13.3% per year. Investment in mineral exploration had the second highest annual average growth rate (10%), followed by R&D (8.5%), advertising (7.7%), purchased science and engineering services (7.3%) and own account science and engineering services (3.9%).

Figure 5: Intangibles composition



The Own-account other science, after increasing in the early 1980s, fell slightly thereafter – going from 33.0% in 1981 to 24.4% by the end of the period. Investment in machinery and equipment (outside ICT) has tracked the expenditures on other scientists closely over this period. Purchased engineering also declined slightly through the period – from 23.4% of the total in 1981 to 20.1% in 2001. Although the three categories (R&D, Software, and Other Science Own-account) have a relatively stable average share in the total over the time period, there has been a slight shift over the period. The share of Own-account science expenditures and purchased science decreased during the 1990s while R&D and software increased slightly.

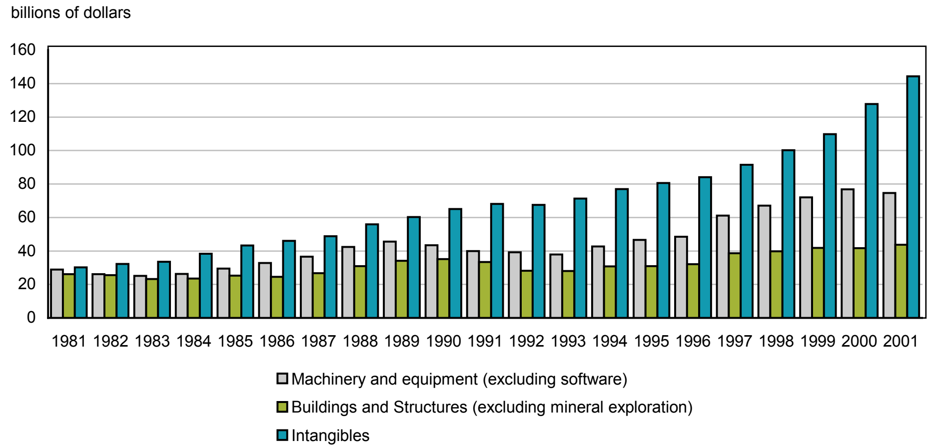
The decline of other Own-account science comes mainly from a switch in the proportion of total scientists to the software category. This is in keeping with other findings that investment in machinery and equipment over this period switched from more traditional investment goods to ITC (Baldwin and Gu 2007).

Intangible investment in Canada has expanded by an average of 8.2% per year from 1981 to 2001, rising four fold from around $30 billion in 1981 to $144 billion in 2001 (Chart 3). Software investment expanded most rapidly, with an average annual growth of 13.9% per year. R&D investment had the second highest annual average growth rate (10.8%), followed by mineral exploration (10.4%), advertising (7.7%), purchased science and engineering services (7.5%) and Own-account science and engineering services (6.6%).

Analysis of the determinants of economic growth often focuses exclusively on investment in tangibles. Recent studies on the knowledge economy suggest that expenditures on knowledge workers have grown more quickly than total employment (Beckstead and Vinodrai 2003; Baldwin and Beckstead 2006). Since many knowledge workers produce intangibles, growth in intangibles that come from wage payments should also have been relatively high. At issue is the extent to which it is larger than the growth in investments in tangible assets, like machinery and equipment, buildings, and engineering structures. If so, the omission of intangibles from total investment will underestimate the rate at which overall investment has been growing.

Investments in tangible capital, machinery and equipment or buildings and structures, has not kept pace with intangible investment. Investment in machinery and equipment rose at an average rate of 5.2% while buildings and structures only increased at an annual average of 2.9% over the period (Figure 6). As a result, although expenditures on all three capital types are roughly equal in the early 1980s, by the late 1990s and early 2000s, investments in the intangible assets considered here are around approximately double those in machinery and equipment, and four times greater than investments in buildings and structures. Moreover, investments in intangibles are less cyclical than investments in tangibles. The recession of the early 1990s saw a relatively larger pullback in investment in tangibles than intangibles. By the end of the decade, the difference between the absolute level of investment in intangibles and tangibles had widened considerably since the 1980s.

Figure 6: Investment by type



In their study of the Canadian innovation system, Baldwin and Hanel (2003) stress that inputs to the innovation process differ by industry: with some relying more on R&D scientists and others relying more on other people, such as engineers. Concomitant with the differences in the innovation profiles across industries, the type of intangible knowledge that is key to innovation in each industry also varies.

At the aggregate business-sector level, R&D is dominated by the other Own-account and purchased science services categories. This is also generally true at the industry level, even in those industries that account for most of the R&D. Other Own-account science and engineers is most important in Agriculture and Forestry; Utilities; Manufacturing; Wholesale; Information and Culture; Transportation; Finance; and Administrative Support.

Professional, Scientific and Technical Services is the one sector where R&D is the most important category – though even here Own-account other science comes second. R&D is also relatively important in Manufacturing and Wholesale.

Although all industries are engaged in intangible investments, when viewed as a share of total business sector expenditure, the investments tend to be concentrated in a smaller number of industries. The largest share of total R&D is found in Manufacturing (39.2%), followed by Professional, Scientific and Technical (26.7%), FIREL (Finance, Insurance, Real Estate and Leasing) (8.9%). Combined, these three industries account for 74.8% of all R&D expenditures. Similar concentrations are found in other intangible categories. The top three industries account for 60.1% of advertising investment; 84.5% of purchased science and engineering investment, 53.7% of software investment, and; 68.1% of Own-account other science investment.

Despite the concentration of intangible expenditures in particular industries, the innovative activities implied by those expenditures are spread across the entire business sector. Intangibles are prominent in both the goods and services sectors. A larger share of advertising and software investments is made by service sector industries, while a larger share of purchased science and engineering and mineral exploration expenditures occur in the goods sector. The goods and services sectors account for about the same share in R&D and Own-account other science.

The fastest growth in intangible expenditures comes from investments in software. In the overall business sector, investment in software has grown most rapidly thereby increasing its share of total science expenditures. This is also the case across most industries. The rate of growth of software expenditures is as high or higher than most other categories in Utilities, Construction, Manufacturing; Transportation and Warehousing; Professional; Scientific and Technical; Arts and Entertainment; Accommodation; Food and Beverages; and Other Services. Since software expenditures supported the introduction of Information and Communications technologies, the fact that growth was rapid everywhere bears testimony to the widespread impact of the ICT revolution.

At the aggregate level, expenditures on tangibles like machinery and equipment are more cyclical than expenditures on intangibles. Intangibles grew more or less monotonically over the entire period, while tangibles fell back during the recession of the early 1990s. Inputs that involve higher adjustment costs have less cyclicality. Skilled labour tends to be hoarded in downturns as it is costly to hire and train this type of worker because of the non-codifiable knowledge that is embedded in a firm which must be imparted to skilled labour in order for the firm to take advantage of its capabilities. Intangibles also share some of the same properties, perhaps because they are complementary factors to skilled workers.

6. Human Capital

Counterparts to physical capital exist for the labour force since substantial investments are made in developing skills. And the Canadian Productivity Accounts recognizes the importance of skill upgrading in its estimates of labour inputs when it corrects for the differential in labour productivity across worker groups (see Baldwin and Harchaoui 2003; Gu et. al, 2003). The CPA constructs a measure of labour input and labour composition that focuses on differences in educational attainment and experience of the Canadian workforce. This labour input is disaggregated by age, education attainment and class of workers (paid vs. self-employed workers). These measures capture the increase in the flows of labour services that result for investments in human capital. Over the last forty-five years, increases in the 'quality' of the labour force as measured by these compositional shifts accounted for a quarter of labour productivity growth in Canada (Baldwin and Gu, 2007).

Given the importance of human capital in productivity growth and sustainable development, there has been renewed interest in measuring the total stock of human capital in OECD countries (Wei, 2008 for Australia, Le et al., 2005 for New Zealand, O'Mahony and Stevens, 2004 for U.K, and Kokkinen for Finland).

Interest in the degree of capital invested in workers also stems from recent developments in the sustainable development literature where it has been suggested that a capital approach be used to provide statistical measures of sustainability. The capital approach is seen by some to provide objective measures of the degree to which an economy is maintaining and preserving capital assets of different forms for future generations. Those assets include physical capital, natural resource, human, and social capital.

Having an integrated set of productivity accounts gives us the ability to construct an estimate of human capital stock for Canada. The labour input data in the productivity accounts provide data on hours worked, employment and labour compensation for workers cross-classified by age, education attainment and class of workers (paid vs. self-employed workers. The labour data provide the core database for this exercise, and are combined with data on student enrolment and population counts by different groups of the Canadian population to construct measures of human capital stock.

Methodology

For this exercise, we follow the methodology developed by Jorgenson and Fraumeni (1989, 1992a, and 1992b) who estimate the value of human capital stock as the expected future lifetime income of all individuals. This approach treats an individual as embodying capital with a "price" given by their lifetime labour income.[14]

The approach used to measure human capital is quite different than that used to measure physical capital – but both have their foundation in straightforward economic principles. For physical capital, the value of the asset is observed directly from market transactions in investment goods and the cost of capital services from the asset is derived using the user cost of capital equation. With well functioning markets, the net present value of the future stream of earnings should equal the cost of producing investment goods and using the latter provides an estimate of discounted future earnings. In contrast, observable asset prices do not exist for human capital. But the flow of services (the cost of labour services or wages) can be observed and the value of the asset can be estimated as the net present value of the wage trajectory over a lifetime (or lifetime labour income).

To provide an estimate of the stock of human capital in Canada, market lifetime labour income is estimated for all individuals aged 15 to 74 using cross-sectional data. Expected incomes of individuals in future periods are assumed to equal the incomes of individuals of the same gender and education, with future incomes being adjusted for increases in real income. Lifetime incomes can be calculated by a backward recursion, starting with age 74, which is assumed to be the oldest age before retirement. The expected income for a person of a given age is their current labour income plus their expected lifetime income in the next period times a probability of survival. For example, the present value of lifetime income of 74 year olds is their current labour income. The lifetime income of 73 year olds is equal to their current labour income plus the present value of lifetime income of the 74 year-old, adjusted for assumed increases in real income.

The nominal value of human capital stock is the sum of lifetime labour incomes for all individuals in the working-age population. The volume index of human capital stock is constructed from data on number of individuals in the population and average lifetime income per capita of individuals, cross-classified by gender, age, education.

This approach can be used to examine the effect of demographic changes in population, aging and rising education levels on human capital per capita. Changes in human capital stock per capita occur as the composition of the population changes, either as a result of shifts in the average age or education of the population that are associated with changes in lifetime earnings.

14 Jorgenson and Fraumeni assume that human capital such as skills, knowledge and competencies embodied in an individual with given gender, education and age group does not change over time. To account for such change in "quality" of human capital in an individual would require the use of hedonic methods as in the estimation of price indexes for computers and semiconductors (Wei, 2008).

Formally, human capital stock per capita (CK) is calculated as aggregate human capital per capita:

$$CK = K / L, \tag{1}$$

where L is the number of individuals in the population and K is human capital.

To examine the contribution to the change of human capital stock per capita from population characteristics such as gender, age, and education separately, partial indices of aggregate human capital stock are constructed that correspond to those characteristics. For example, a partial index of the volume of aggregate human capital stock corresponding to gender is defined as follows:

$$\begin{aligned} \Delta \ln K^{sex} &= \sum_s \bar{v}_s \Delta \ln L_s \\ &= \sum_s \bar{v}_s \Delta \ln \sum_e \sum_a \left(L_{s,e,a} \right) \end{aligned}, \tag{2}$$

where K denotes the volume indices of aggregate human capital stock, $L_{s,e,a}$ the number of individuals with gender s, age a, and educational level e, and Δ denotes a first difference, or change between two consecutive periods and $\bar{v}_s$ is the two-period average human capital share of men or women in the nominal value of human capital stock:

$$\bar{v}_s = \frac{1}{2}\left[v_s(t) + v_s(t-1) \right],$$

$$v_s = \sum_e \sum_a v_{s,e,a}$$

The partial volume index corresponding to gender captures the shift of the population between the two genders alone. Similarly the partial volume indices for education and age measure the shift between age groups, or between educational levels, respectively.

The difference between the growth of the partial indices of aggregate human capital for each characteristic (gender, age and education) and the growth of the number of individuals in the population measures the contribution of that characteristic to the compositional change of human capital. The sum of the contribution that each characteristic makes to the compositional change of human capital will differ from the compositional change, as the sum of the contribution of characteristics represents the first-order approximation to the index of the compositional change.

Similar to physical capital stock, the change in human capital stock can be decomposed into three components: investment in human capital, depreciation on human capital and revaluation of human capital (Jorgenson and Fraumeni, 1989). Human capital investments include the rearing of children, formal schooling, vocational and on-the-job training, health and migration. At the moment, our measure captures human capital investment arising from the rearing of children, formal education, and migration. This is estimated as the sum of changes in lifetime incomes due to education, lifetime incomes of all individuals that reached working age and the effect of immigration on human capital.

The second component of the change in human capital is the depreciation of human capital, which is the change in human capital stock due to aging, death and emigration. It is calculated as the sum of changes in lifetime labour incomes with age for all individuals that remain in the working-age population and lifetime labour incomes of all individuals who die or emigrate.

The third component of the change in human capital is the revaluation of human capital which represents the change in human capital over time for individuals with a given set of demographic statistics – sex, education and age. It is calculated as the sum of changes in lifetime labour incomes from period to period for individuals with a given set of demographic statistics. An example of such change is provided by Picot and Heisz (2000) who document a decline in participation rates and slow growth in worker earnings in Canada during the early 1990s, particularly for younger male cohort. This will give rise to a small or negative revaluation term for human capital in that period, particularly for the younger male cohort.

Results

The annual growth rates of aggregate human capital stock for Canada are presented in Table 5.

Table 5. Average annual growth in human capital, working age population and human capital per capita)

	1970-2007	1970-1980	1980-2000	2000-2007
Human capital stock	1.7	3.0	1.2	1.1
Working-age population	1.5	2.1	1.2	1.3
Human capital per capita	0.2	0.9	0.0	-0.2
First-order indices of human capital per capita				
Gender	0.0	0.0	0.0	0.0
Education	0.9	1.4	0.8	0.6
Age	-0.4	-0.1	-0.5	-0.6

Over the period 1970 to 2007, aggregate human capital rose at an annual rate of 1.7% in Canada. Most of the growth in human capital is due to the increase in the number of individuals in the working-age population aged 15 to 74. Of the 1.7% growth in human capital, 1.5 percentage points is due to the growth in the working-age population, the remaining 0.2 percentage points is due to the effect of the compositional shift or the growth in human capital per capita.

The growth of aggregate human capital was highest in the 1970s, a period that coincided with the entry of baby-boomers to the working-age population and the increase in the education levels of the Canadian population. The growth of aggregate human capital was lower after 1980 due to the slower growth and aging of the working-age population. The aging of the working-age population has a negative effect on the growth of human capital per capita as a result of a shift towards older individuals with lower lifetime income due to fewer remaining years of work.

The relative contribution of age, gender and education to changes in capital stock per capita is presented in the bottom half of Table 5. Rising education attainment in the Canadian population makes a positive contribution to the growth in aggregate human capital. It adds 0.9% to annual growth in human capital stock over the period 1970 to 2007.

The ageing of the Canadian population after the early 1980s made a negative contribution to the growth in the human capital stock, and it lowered the annual growth in human capital by 0.5% in the 1980-2000 period and 0.6% in the 2000-2007 period.[15]

There are little changes in human capital per capita in Canada after 1980. This is the net result of a rising education level that increased human capital per capita and population aging that reduced human capital per capita.

[15] *Boothby and et al. (2003) discussed the effect of the aging of the Canadian population on the skill level of the working-age population in Canada.*

The share of women in the working-age population was virtually constant over time. As such, gender has little effect on the growth in the composition of human capital stock. This occurs despite large increases in labour force participation rates of women and increases in discounted lifetime labour income of women.

As described, the change in aggregate human capital stock is decomposed into investment in human capital, depreciation and revaluation. Investment in human capital in a period is the sum of and changes in lifetime incomes due to education, lifetime incomes for the individuals that reached working age and the effect of immigration on human capital. Depreciation of human capital is the sum of changes in lifetime labour incomes due to aging for all individuals that remain in the working age population and lifetime labour incomes of all individuals who die or emigrate. Revaluation of human capital is the sum of changes in lifetime labour incomes from period to period for individuals with a given set of demographic statistics – sex, education and age.

Table 6 presents an account of human capital accumulation in current dollars. The change in human capital is equal to the sum of gross investment net of depreciation and revaluation. Both revaluation and the change in human capital stock show a large fluctuation over time, which is due to the variations in the rate of change in the average lifetime income. The change in the value of human capital mainly reflects the revaluation of human capital stock. Gross investment in human capital made a smaller contribution to the change in human capital than the revaluation of human capital. The revaluation term and change in human capital stock was relatively small in the early 1990s, as a result of decline in participation rates and slow growth in worker earnings in the period.

The nominal value of changes in human capital stock, human capital investment, depreciation and revaluation can be divided into the price and volume components. Table 7 presents gross investment, depreciation, and revaluation in 2002 constant dollars. Gross investment in human capital in constant prices rose at 0.4% per year over the period 1971 to 2007. During that period, net investment in human capital declined at 3.1% per year as the growth of depreciation on human capital exceeded the growth of gross investment in human capital over the period.

The growth in investment in human capital was slower than investment in nonhuman capital. Over the period 1971 to 2007, the growth of investment in produced physical capital was 3.9% per year..

Table 6. Human capital accumulation (billions of current dollars)

Year	Gross Investment	Depreciation	Revaluation	Change in Human Capital
1971	124.0	64.4	133.8	193.4
1972	137.3	72.1	126.9	192.1
1973	151.7	79.9	172.7	244.5
1974	172.7	91.0	279.9	361.6
1975	192.7	101.7	282.0	373.1
1976	210.7	110.9	279.8	379.6
1977	217.6	120.3	141.6	238.9
1978	208.2	128.4	157.6	237.4
1979	223.8	135.2	228.7	317.3
1980	255.0	143.6	335.7	447.2
1981	257.2	167.5	655.8	745.5
1982	274.1	178.7	353.4	448.9
1983	255.4	173.4	84.2	166.2
1984	264.5	189.4	380.3	455.4
1985	274.5	192.2	310.8	393.0
1986	293.5	206.7	366.9	453.7
1987	314.4	217.4	377.6	474.6
1988	314.7	226.3	506.9	595.2
1989	353.9	253.5	440.0	540.5
1990	381.9	313.0	711.2	780.0
1991	433.2	322.3	346.9	457.8
1992	438.8	315.0	-35.1	88.6
1993	437.2	317.0	-310.6	-190.4
1994	453.2	318.0	-18.3	116.9
1995	461.8	325.9	206.3	342.2
1996	426.1	325.0	2.7	103.8
1997	473.0	340.8	162.9	295.1
1998	441.6	367.4	276.8	350.9
1999	459.2	379.1	296.3	376.4
2000	542.0	388.2	359.5	513.3
2001	586.5	418.0	330.2	498.8
2002	541.5	429.8	291.3	403.0
2003	578.0	433.1	276.3	421.2
2004	565.6	454.3	671.0	782.4
2005	636.7	457.6	551.2	730.3
2006	659.0	502.9	676.5	832.6
2007	681.6	521.3	629.1	789.4

Note. Change in human capital is equal to the sum of gross investment net of depreciation and revaluation.

Table 7. Human capital accumulation (billions of 2002 dollars)

Year	Gross Investment	Depreciation	Revaluation	Change in Human Capital
1971	458.7	255.4	116.8	349.2
1972	462.6	260.9	122.4	359.9
1973	469.0	266.3	127.6	370.9
1974	476.0	271.5	132.4	382.1
1975	483.7	276.6	137.0	393.5
1976	490.6	279.5	141.4	404.9
1977	474.5	283.9	145.9	400.9
1978	438.3	290.5	149.7	375.0
1979	438.1	297.4	152.8	375.9
1980	471.4	305.3	155.9	395.7
1981	455.0	308.0	159.9	396.7
1982	441.7	315.0	163.1	394.8
1983	445.2	319.7	166.3	399.0
1984	435.8	322.5	167.3	389.1
1985	428.7	323.5	168.5	386.8
1986	445.8	324.7	170.0	399.2
1987	459.8	328.8	172.2	409.3
1988	459.9	335.6	174.2	409.7
1989	486.3	342.3	175.9	423.3
1990	511.6	345.6	176.6	435.5
1991	436.2	349.5	173.5	380.2
1992	460.8	356.4	175.3	429.5
1993	453.5	360.9	194.3	442.7
1994	521.2	366.9	188.5	479.1
1995	536.3	371.2	205.3	514.9
1996	492.9	371.8	369.9	490.5
1997	462.6	378.5	289.5	367.2
1998	498.8	390.3	280.5	387.1
1999	487.3	397.2	282.5	371.4
2000	490.3	405.8	284.2	368.6
2001	501.5	419.3	287.0	370.8
2002	541.5	429.8	291.3	403.0
2003	513.0	436.9	295.1	371.4
2004	467.8	444.3	299.4	336.3
2005	472.9	452.1	302.4	338.4
2006	513.6	462.1	306.3	361.2
2007	534.4	469.7	309.5	372.6

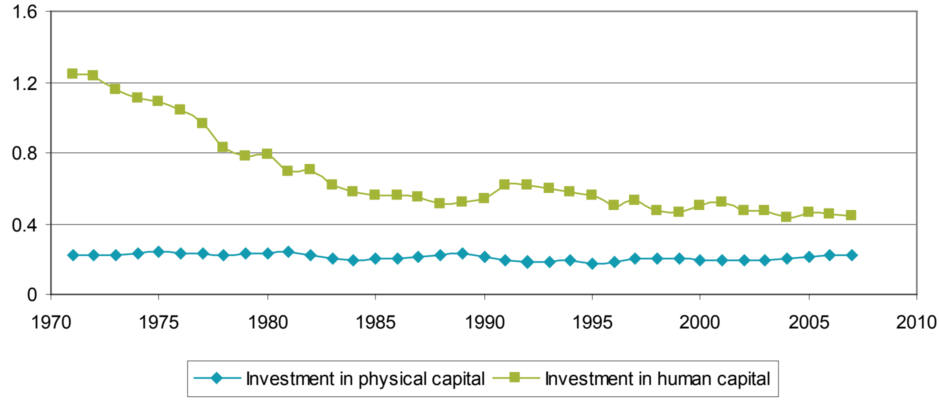
Note. The change in human capital in 2002 dollars is estimated as Tornqvist aggregation of gross investment net of depreciation and revaluation

Figure 7 plots the ratio of investment in human capital to gross domestic product (GDP) in nominal value in Canada. To compare investments in human capital with investments in nonhuman capital, the investment to GDP ratio for physical capital is also plotted.[16] The ratio of investment in human capital to gross domestic product declined from 1971 to the mid-1990s, and changed little after the mid-1990s. The decline in the investment to GDP ratio was fastest during the 1970s, which was due to the rapid growth in GDP in the period. The ratio of human capital investment to GDP was 1.26 in 1971, and it was 0.44 in 2007.[17]

While the ratio of investment in human capital to gross domestic product declined over time, the ratio of investment in physical capital to GDP remained virtually unchanged. Investment in physical capital as share of GDP was about 20% over the period.

In absolute terms, investments in human capital exceed the investment in physical or nonhuman capital. In 2007, investment in human capital was about 2 times as large as investment in physical capital in the Canadian economy. The magnitude of human capital investment relative to nonhuman capital investment was even larger in 1971. In 1971, human capital investment was about 5.7 times the magnitude of nonhuman capital investment.

Figure 7. Ratio of investment to gross domestic product in Canada

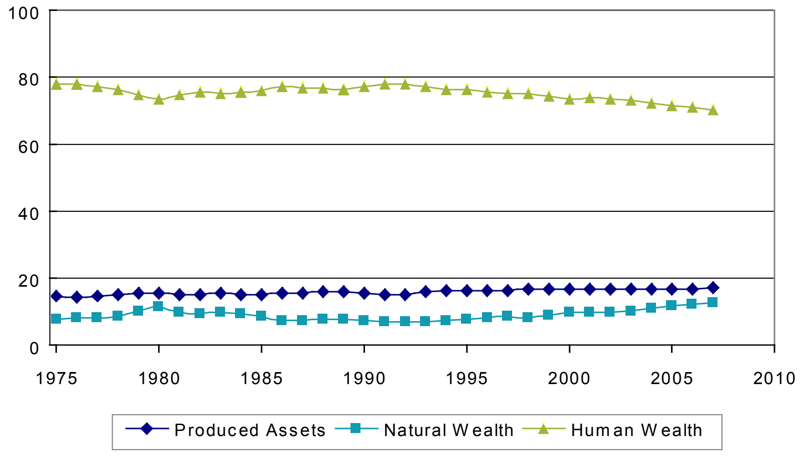


[16] *The data on investment and gross domestic product are obtained from the income and expenditure accounts of Canada from Statistics Canada (CANSIM table 380-0017).*

[17] *In the systems of national accounts proposed by Jorgenson and Fraumeni that include the accumulation of human capital, gross domestic product needs to be adjusted to include investment in human capital. When this is done, the ratio of human capital investment to the adjusted GDP was 0.55 in 1971 and the data on investment and gross domestic product are obtained from the income and expenditure accounts of Canada from Statistics Canada (CANSIM table 380-0017. In the systems of national accounts proposed by Jorgenson and Fraumeni that include the accumulation of human capital, gross investment was 0.31 in 2007).*

The share of human wealth, produced capital and natural wealth is plotted in Figure 8. The largest component of total wealth in Canada is human wealth, followed by produced capital and natural capital. Human wealth accounted for 70% of total wealth in 2007, while produced capital and natural capital accounted for 17% and 13% respectively in that year.

Figure 8. The distribution of total wealth in Canada (percent)



Over the last forty years, the share of human capital in total wealth declined slightly while the share of produced capital and natural capital increased. The share of human capital declined from 78% in 1975 to 70% in 2007, while the share of produced capital increased from 15% to 17% and the share of natural capital increased from 8% to 13%.

The value of human capital exceeds the value of produced capital. But the ratio of human capital relative to produced capital declined over time. In 2007, the value of human capital is about 4 times as large as the value of produced capital. In 1970, the ratio of human capital to produced capital was 5.7.

The growth of human capital in constant prices was slower than the growth of produced assets. For the period 1970 to 2007, human capital in constant prices increased 1.7% per year, while produced capital in constant prices rose at 2.8% per year.

7. Conclusion

The Canadian Productivity Accounts consists of a set of integrated data sets that allow for the development of new statistical products. Ongoing debates about the nature of the growth process and the factors behind productivity growth have led to ongoing demands for new information regarding the nature of the inputs that contribute to long-run productivity growth.

This paper has described how the analytical program at Statistics Canada has contributed to the development of products in this area. The Productivity Accounts build off a set of integrated data sets that start with the input-output tables but add coherent estimates of primary inputs – labour and capital – from other sources collected by Statistics Canada. These include the Census of Population, the Labour Force Survey and special surveys.

The paper describes how the Productivity Accounts can be used to construct various estimates of productivity in a way that both tests the coherence of the Accounts that are used to produce these estimates and to test the robustness of the estimates to alternate assumptions used in developing the analytical estimates of productivity growth. As an example, it discusses the extent to which using exogenous as opposed to endogenous rates of return yield different productivity estimates and at the same time asks whether the differences in the results serve to help us understand the nature of the economic system. The results show that in Canada the endogenous rates of return yielded by the integrated Accounts are quite similar to the exogenous rates—but that the productivity growth rates derived from the two approaches differ because the former takes into account an important factor behind growth that the latter ignores. The exogenous approach does not count the reallocation process that redistributes resources from less productive to more productive uses over time.

The paper demonstrates not only how these Accounts can be extended to deal with ongoing productivity measurement issues but also how they can be used to extend analytical products into new areas.

In the first case, the conventional productivity estimates of the business sector that consider only the contribution made by labour and capital to business sector GDP are expanded to also consider the contribution of public infrastructure, which consist primarily of roads. The analysis indicates that almost half of multifactor productivity growth between 1961 and 2005 arose from the latter source.

The second example demonstrates how an integrated set of Accounts can be used to extend the boundaries of the productivity program in a different area. The most common measure of business-sector capital considers only machinery and equipment, buildings and engineering capital, what is commonly referred to as tangible capital. Other forms of expenditures that are made by firms also yield assets that have a benefit to that firm of more than one year – and therefore should be classified as a form of investment. But these other forms of investments have proven more difficult to measure. The paper makes use of data from the input-output tables that are at the heart of the Productivity Accounts and data on wages and salaries that are integrated into the Productivity Accounts to provide estimates of several core elements of intangible investments. These are expenditures on science-related inputs to innovations, resources exploration and advertising. Over the past thirty years, expenditures in these areas have surpassed those of tangible investments in Canada.

Finally, the paper describes a project that extends the Productivity Accounts into the measurement of the investment that society makes in skills and people. It demonstrates how the data that are brought together on labour inputs in the Productivity Accounts and related data can be used to measure the amount of investment that a society makes in so-called human capital. Once more, it shows that a statistical base can be used to examine this concept from different dimensions – both in terms of inputs and outputs (life-time earnings). The results show that these investments produce a capital stock that is large compared to physical or tangible capital.

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An alternative way to measure competition and the relationship between competition and innovation

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Abstract

There are many possible measurements of competition and also on innovation but no international consensus on how to measure either competition or innovation. In this paper we use an alternative way to measure competition by using differences in prices adjusted for wage increases and multifactor productivity. Our results confirm that too much and especially too little competition seems to hamper innovation. There is an inverted U-shaped relationship between our technology-adjusted competition measurement and R&D intensity. However most observations lie in the part with a downward slope. This means that competition does not give enough incentives to innovate. Hence, investment in innovation seems to be positively influenced by the competitive pressure.

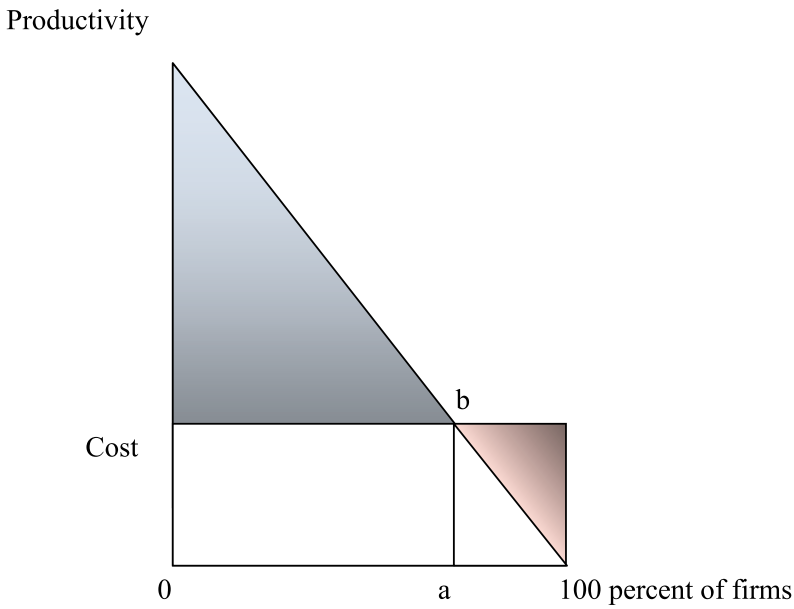
A critical view of competition measurements

Two very important parts of a successful national growth strategy is to promote competition and to promote innovation. However, it has been argued from Schumpeter onwards that too fierce a competitive pressure can prevent firms from innovations due to lack of resources to invest in the innovation process. Schumpeter's view that firms need some degree of market power in order to innovate has theoretical support in models made by Romer and others where higher levels of competition decreases innovation. This has also been confirmed in several empirical studies. However, the opposite results have also been found. This contradiction seems to have been solved by Aghion who in an article published in 2005 found a strong inverted–U relationship in English data between market competition and innovation.

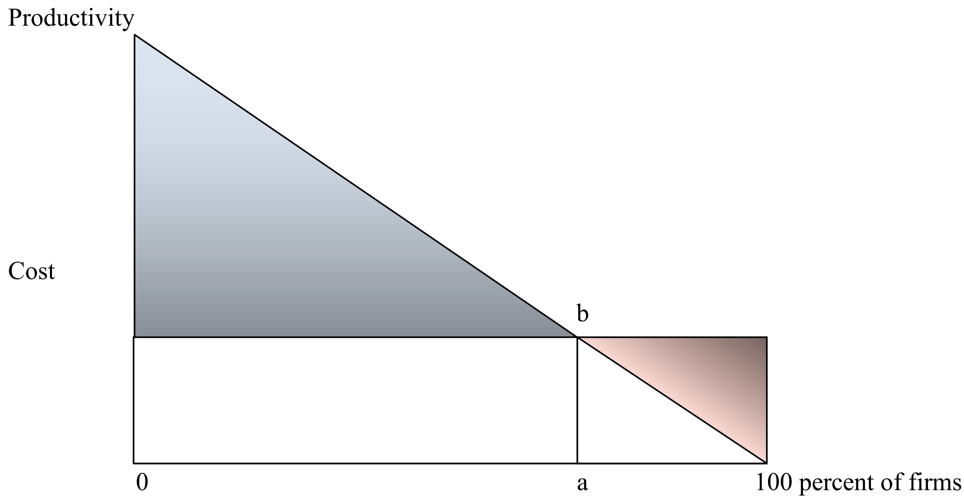
The traditional measurements of competition indicators of market concentration have become more and more obsolete due to globalization which had led to the diminishing importance of the home market. Alternative measurements that have been created are based on the relationship between price, cost and profits. First the

Lerner or the price-cost margin was launched and quite recently the Boon indicator have been presented. The problem with the price-cost margin is that it is not only a reflection of the competitive pressure but also is influenced by earlier innovation activities. However, the Boon indicator, which is based on the profit-elasticity, is also a quite problematic choice for analyzing the relation between competition and innovation, as we will show with a principal figure.

The starting point is the so called Salter curve. This is constructed by ranking all the firms in an industry according to their productivity level with the firm with the highest level to the far right in the diagram. Productivity and cost are measured on the vertical axis and the number of firms on the horizontal axis. All the firms that are to the left of point **a** have a positive profit and those to the right are making a loss. The light blue area above the cost line is proportional to the profits made in the industry and the pink area above the sloping productivity line and to the left of **b** constitutes losses.

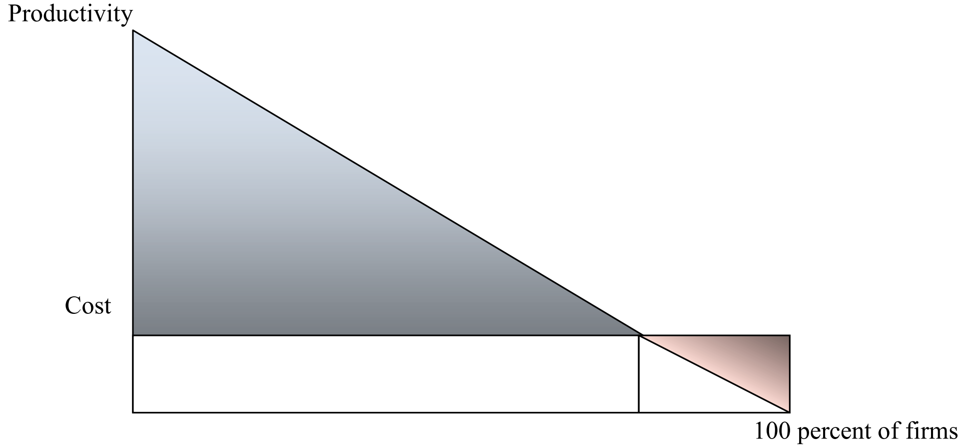


The slope of the line is of course a reflection of the productivity differences in an industry. In the next hypothetic industry (see below) the slope is much less so it has a much more flat shape.



If these two figures are compared it is obvious that an increase in the cost level will affect the firms in the industry with a more flat productivity curve more, so according to Boone this industry is under a more competitive regime.

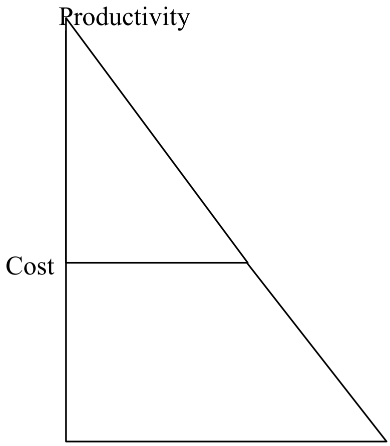
However, the cost line also differs between industries, giving us this third principal industry figure.



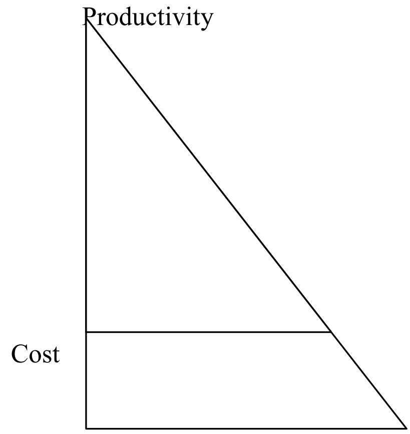
The competitive pressure is much lower in this industry according to Lerner, since the price-cost margins are much higher. The difference according to Boone is much less since the productivity elasticity is the same in both industries. So we make this even clearer with a four part figure. In this figure Boone and Lerner agree that C is a more competitive market than B but disagree on which are the more competitive A or D.

A Principal example:

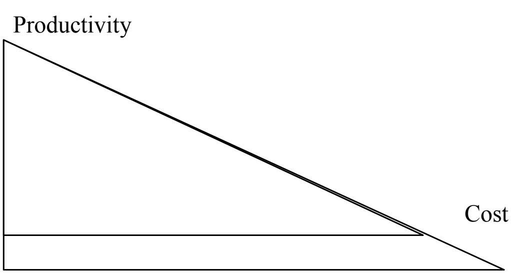
A. Boone: Low competition
Lerner: High competition



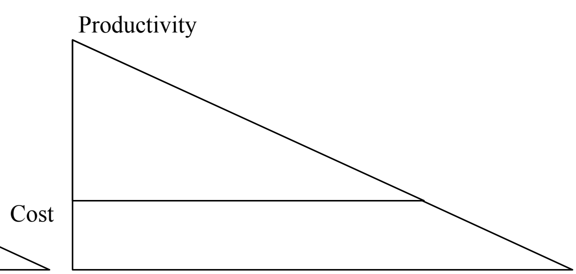
B. Boone: Low competition
Lerner: Low competition



C. Boone: High competition
Lerner: Low competition



D. Boone: High competition
Lerner: High competition



However, the industries in figure A and B are probably the result of historic innovations that have resulted in substantial productivity differences, while figure C and D are more expected to be found in low tech industries where the difference in products and process among firms are fewer. On the other hand the price-cost margin in the Lerner indicator is more a reflection of today's competitive pressure irrespectively of the technology level of an industry. Many empiric results including over our own fresh ones are in line with these differences. And our conclusion is that the Boone indicator is a poor measurement of competition in innovations studies. This has led us to look for a better measurement.

The difference between developments in MFP and prices as an example of an alternative measurement of competition

Background We present multifactor productivity as a concept[1] and an analysis of the relationship between MFP and prices in the Nordic Countries[2] in a separate appendix.

Why are differences in prices and multifactor productivity a good way to measure competition?

> ***Technical change and competition are the main driving forces**[3]*
> *Total factor 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. But let us look at the situation for a single firm. If it is operating in a perfect market all the benefits of an 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 significant market power and huge profits, as did Microsoft in the 1990s and Google in recent years. But most of the submarkets of the ICT market are characterized 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*

[1] *Statistics Sweden's Yearbook on Productivity 2006 http://www.scb.se/statistik/_publikationer/OV9999_2006A01_BR_X76OP0602.pdf*

[2] *http://www.norden.org/pub/webordering/sk/index.asp?txt=Growth+in+the+Nordic&vis=&logic=AND&langChose=all&title=&isbn=&pubnr=*

[3] *The is citation from the Yearbook on Productivity 2006*

customers who have continuously received better products and services for the same or lower prices.

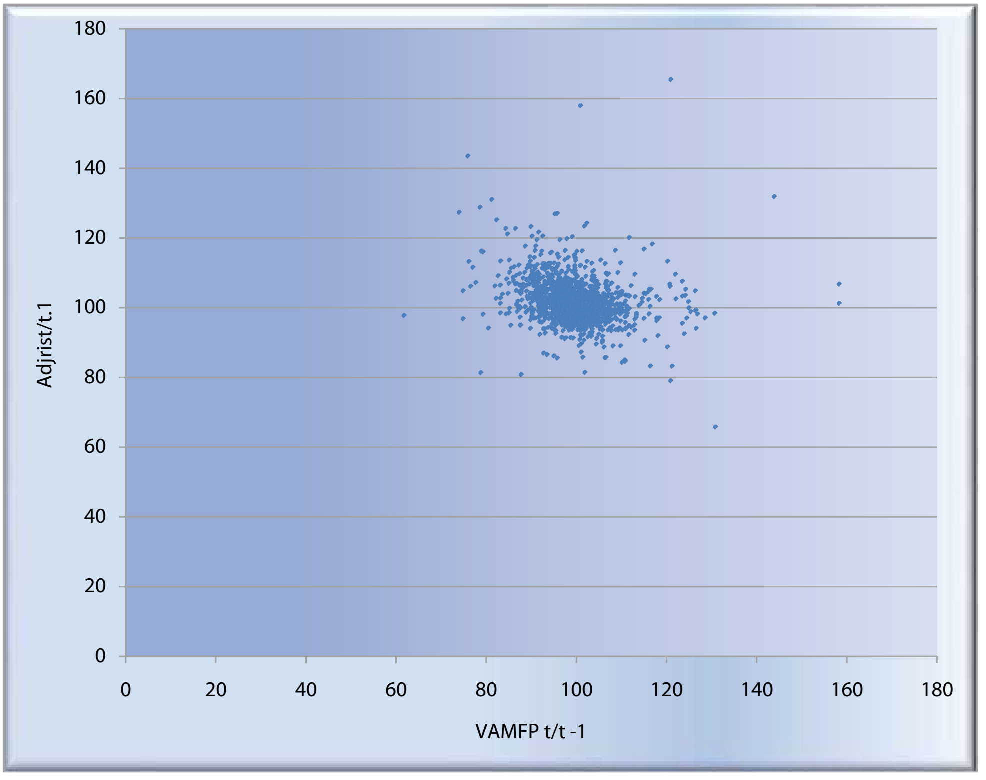
In an industry that is less dynamic and where fewer innovations are taking place, the customer can normally not expect falling prices even if the competition is intense. But if such a market undergoes a dramatic change, for example opens up to international competition, the prices can fall even on a 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 in recent years 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 0.7 percent more per year than the total CPI, but after 1990 it has increased by 1.7 percent less. So there are two major forces that influence price development: technical changes and competition in the market.

Most measurement of competition, both the old concentration measurements and the new one based on price, cost and profits are all trying to capture the competitive pressure in an industry by different indirect indicators. However, the very heart of competition is how the firms change their prices. Most firms experienced increased labour costs which are partly compensated by their productivity increases. This means that their decision on how much of these increases they chose to pass on to their customers is in fact the direct measurement of the competitive pressure they are under. If the competition is weak they will chose to increase prices with more than they actually need to keep their profits due to the increase in labour cost and productivity or the other way around. First we have constructed a measurement which we have called AdjPrice which is the increase in value added prices minus the increase in wages (and indirect wage cost) weighted with the labour cost share in value added.

$$AdjPrice_{t,t-1}=Price_t/Price_{t-1}(LabourCost/VA)_{t-1}*(WageCost_t/WageCost_{t-1})$$

The relationship between changes in price and MFP between two years is shown in figure 1. The relationship is not very strong but it is significant and negative.

Figure 1a. The relation between yearly changes in price respectively with MFP
The change in MFP is measured on the horizontal axis and the price changes on the vertical axis. A 10 percent increase from two years is represented by 110 in the figure and a 10 percent decrease with 90.



We use the value added multifactor productivity to avoid the influences from the price changes in intermediate inputs that of course vary among different industries. This concept is the value added multifactor productivity or MFPVA, and it measures the difference in development of the value added in constant prices and a weighted sum of the changes in input of quality adjusted labour and capital service. These yearly price changes in MFP are seen as an indication of the level of competitive pressure in that year in each respective industry. This pressure will be one of the factors that will affect the decision to invest in innovation. This competition indicator PriceMFPVA is defined as;

$$PriceMFPVA_t = 1 + \frac{AdjPrice_t - AdjPrice_{t-1}}{AdjPrice_{t-1}} - \frac{MFPVA_t - MFPVA_{t-1}}{MFPVA_{t-1}} \quad (1)$$

Consider the case where we want to compare the competitive intensity between two industries, *A* and *B*. If the price increase is five percent between *t-1* and *t* in industry *A* at the same time as the multifactor productivity increases with only two percent, then our indicator produces the value 1.03 for industry *A*. For industry *B* prices increase by one percent and productivity development by six percent. Our measure then gives the value 0.95. Our conclusion is thus that competition intensity is higher in industry *B* compared with industry *A*. Of course it could be argued that this is a complicated calculation when it just as well is the same as tracking the development profit level. However, it is not the same since an increase in profits could have two different causes. One is of course an increase in prices that are more than the increase in wages, which is what we are looking for. The other cause is an increased productivity level and a profit increase because this has nothing to do with competition. Instead, this is what innovation is about.

The data for multifactor productivity that is used comes from the EU KLEMS database and the R&D spending from OECD. This makes it possible to get data for four of the participating countries: Australia, Germany, Netherlands and Sweden. We have also added the US, Japan, the UK and France as reference countries. This also makes the study relatively representative for the OECD countries as a group since these countries represent more than two thirds of the OECD's GDP and represent four continents and different country sizes.

The breakdown of industries is limited to 22, since we have excluded two industries from those that are available from EU KLEMS. The deleted industries are too heavily dependent on the development of oil prices. The large swings in petrol prices which occur now and then of course mainly affect those who own the oil wells but it spills over to the process industries and thus disturbs the pattern. The years which we are studying are from 1995 up to 2005. This gives us a total of 1760 observations. We have 8 countries, 10 years and 22 industries. However, there are a lot of missing values in the R&D data, especially for UK but also for Japan.

In figure 1a we have displayed the development in price related to the development in value added multifactor productivity. Both the scatter plot in figure 1a and the regression results in table 1 are a test of this relationship.

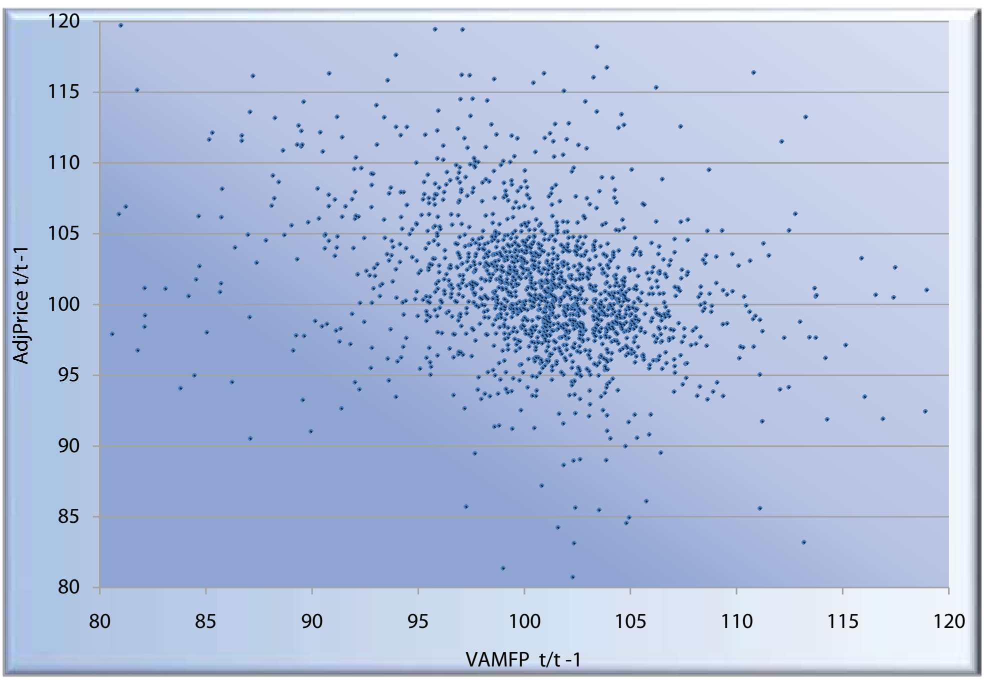
As can be seen in figure 1 the variation is quite large and the relationship is not that strong. But still it exists. We have estimated a simple regression with the standard OLS -method.

Table 1. The relationship between changes in price developments and developments in multifactor productivity
Dependent variable VAPrice
Number of observations = 1936 Adjusted R-squared = 0.06

	Coefficient	T	P>t
MFPVA	-0.22	-15	0.000
Constant	133	60	0.000

If we exclude a few extreme observations, namely those that represent larger yearly changes than 20 percent in either direction, the picture becomes clearer. See figure 1b.

Figure 1b. The relation between yearly changes in Price respectively with MFP
The change in MFP is measured on the horizontal axis and the price changes on the vertical axis. A 10 percent increase from the earlier year is represented by 110 and 10 percent decrease by 90. With some extreme observations excluded.



The actual competition variable we have used is defined as the difference in development between two years (t and t+1), so a five percent increase is measured as 0.05, and the difference between a five percent price increase and a two percent increase in multifactor productivity becomes 0.03=0.05-0.02. We have added 1 to this in order to get mostly positive numbers, so we could have a correct quadric expression. This could also be seen as we add a high inflation which is neutral for all observations. The multifactor productivity should influence the price. Taking that the difference between price changes and MFP-development is a form of double counting, the price adjustments due to wage increases are reduced by productivity increases. However, since this is monotonic function it should not cause any real problem.

The competitive pressure in different industries

This indicator can be used to get some kind of proxy for the competitive pressure in different industries over the OECD-countries. If we estimate an equation with this indicator as a dependent variable and all the industries as independent dummy variables, the coefficients could be used as such an indicator. The average capacity utilisation and other country specific characters should be corrected for by use of country dummies. However, the coefficients for these variables cannot be interpreted as competition indicators since they are more influenced by the general inflation rate in the respective countries. The time trend is also included in the regression. In table 2 the result of a simple OLS -regression is presented.

Table 2.a The difference in value added price developments for some countries

Dependent variable VAPrice

Number of observation = 1936 Adjusted R-squared = 0.065

	Coefficient	t	P>t
Australia	0.6	1.1	0.3
Germany	-0.9	-1.7	0.1
Netherlands	-0.1	-0.1	0.9
Sweden	-1.2	-2.3	0.02
US	-0.3	-0.5	0.6
Japan	-4.4	-8.7	0.00
UK	0	0	1
France	(dropped)		
Constant	101	284	0

2b The same with our adjusted price measurement

VAPrice	Coef.	t	P>t
Australia	.17	0.27	0.8
Germany	.36	0.59	0.6
Netherlands	-.05	-0.08	0.9
Sweden	-.16	-0.25	0.8
US	.32	0.52	0.6
Japan	-1.3	-2.07	0.04
UK	.0	-0.00	1.0

In interpreting these results it is important to bear in mind that all industries have the same weight. Still, from the regression results shown in table 2 it is clear that the price increases in Japan have been significantly lower than in all the other countries. Also, Sweden and Germany have significantly lower price increases than France. Meanwhile, the UK, the Netherlands and the US do not differ from the French developments significantly, nor does Australia, even if it has a very slight tendency to increase its prices even more. However, if instead our adjusted price measurement is used, that takes account of the increased labour cost that the firms experience, when only Japan is singled out with a little more than one percent less yearly price increases.

Industry differences in competitive pressures in the OECD area

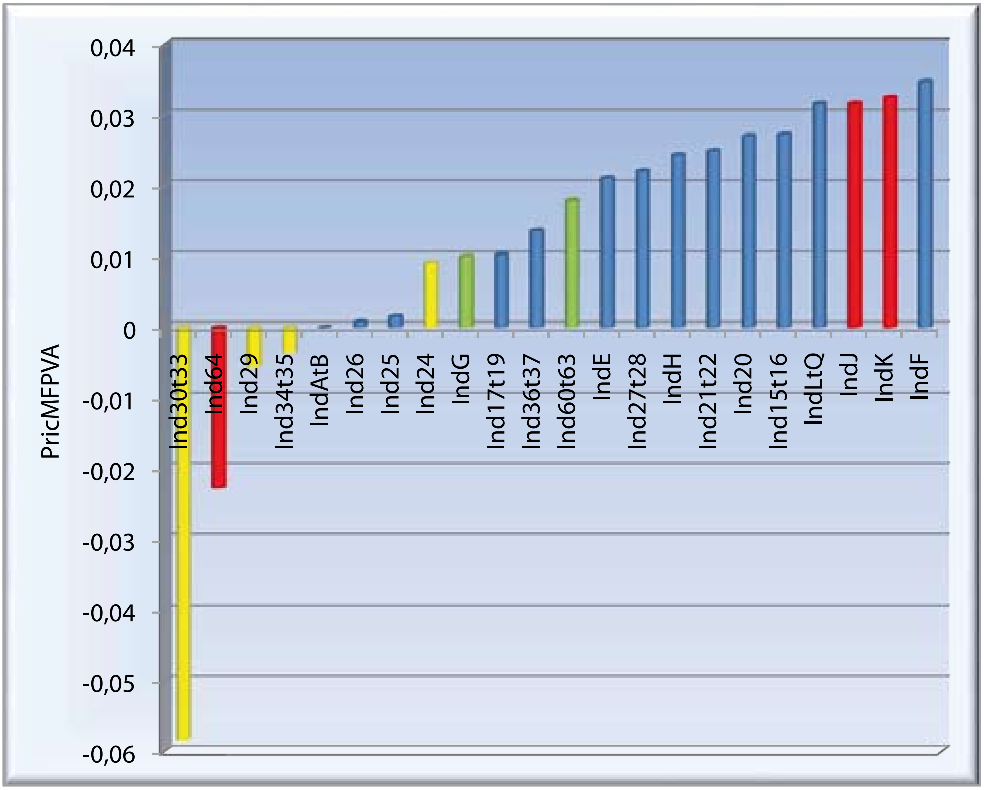
In order to get an indication of the differences in the competitive pressure in different industries in the OECD-area, we have tried to explain our indicator of competition the PriceMFPVA, in a regression, with dummies for the industries, and also controlled for countries and years. The last variable is continued, and not a series of dummy-variables. The regression is of the simple OLS type and the result is displayed in table 3.

Table 3. The difference in value added price and MFP developments for industries

Dependant variable PriceMFPVA		Coefficient	t	P>t
AGRICULTURE, HUNTING, FORESTRY AND FISHING	IndAtB	(dropped)		
FOOD , BEVERAGES AND TOBACCO	Ind15t16	0.06	4.6	0.00
TEXTILES, TEXTILE , LEATHER AND FOOTWEAR	Ind17t19	0.03	2.7	0.01
WOOD AND OF WOOD AND CORK	Ind20	0.06	4.5	0.00
PULP, PAPER, PAPER , PRINTING AND PUBLISHING	Ind21t22	0.05	4.1	0.00
Chemicals and chemical products	Ind24	0.02	1.5	0.12
Rubber and plastics	Ind25	0.02	2.0	0.05
OTHER NON-METALLIC MINERAL	Ind26	0.02	1.4	0.17
BASIC METALS AND FABRICATED METAL	Ind27t28	0.04	2.9	0.00
MACHINERY, NEC	Ind29	0.02	1.5	0.14
ELECTRICAL AND OPTICAL EQUIPMENT	Ind30t33	-0.09	-7.2	0.00
TRANSPORT EQUIPMENT	Ind34t35	0.01	0.9	0.37
MANUFACTURING NEC; RECYCLING	Ind36t37	0.04	3.1	0.00
ELECTRICITY, GAS AND WATER SUPPLY	IndE	0.03	2.8	0.01
CONSTRUCTION	IndF	0.07	5.8	0.00
WHOLESALE AND RETAIL TRADE	IndG	0.03	2.6	0.01
HOTELS AND RESTAURANTS	IndH	0.07	5.4	0.00
TRANSPORT AND STORAGE	Ind60t63	0.04	3.3	0.00
POST AND TELECOMMUNICATIONS	Ind64	-0.04	3.3	0.00
FINANCIAL INTERMEDIATION	IndJ	0.06	4.6	0.00
REAL ESTATE, RENTING AND BUSINESS ACTIVITIES	IndK	0.07	5.2	0.00
COMMUNITY SOCIAL AND PERSONAL SERVICES	IndLtQ	0.07	5.7	0.00
	Year	0.00	3.3	0.00
	Australia	0.02	2.1	0.04
	Germany	0.00	0.6	0.53
	Netherlands	0.01	0.8	0.45
	Sweden	-0.01	-1.9	0.06
	US	-0.01	-0.9	0.35
	Japan	-0.03	-4.0	0.00
	UK	0.01	1.1	0.29
	France			(dropped)
	Constant	4.9	4.1	0

The coefficients for the different industries are used to calculate the competition indicators which are shown in figure 2.

Figure 2. Difference in competitive pressure between industries in the OECD-countries



Then looking at figure 2 one should remember that it is the effect on prices that is displayed in the figure, which means that a negative number is associated with a high competitive pressure and the other way around.

Generally the manufacturing industries (all with number except 60-63 and 64) are expected to experience more effective competition due to the large volume of international trade than the service industries (all with letters beside E and AtB). Fast technological development should also increase the pressure to always improve the product line (the red bars). The industries that the low cost producers are heavily involved in should also be expected to increase the competition.

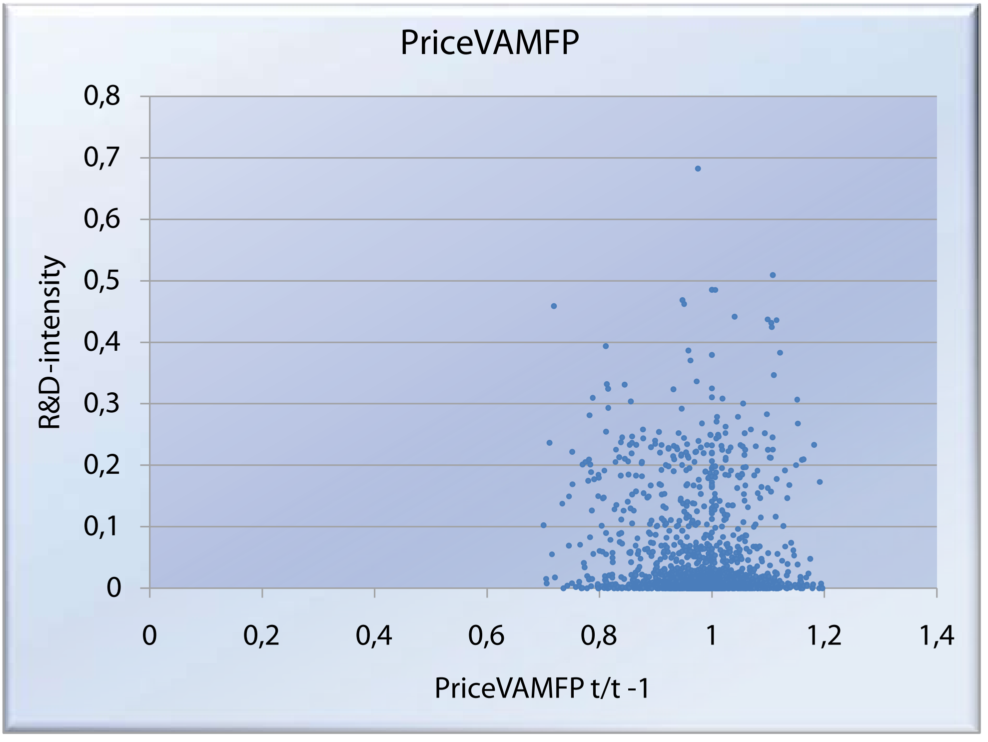
These hypotheses seem to generally be confirmed. So the electric goods producer experiences the fiercest competition, which should not come as a surprise, not even that the telecommunication operators come next in spite of being service providers. As expected transport equipment and machinery then follow. However, they are preceded with a sector that is perhaps a surprise to many: the industry group dominated by agriculture (AtB). This most likely does not give a correct picture since in most OECD countries this industry gets direct subsidies that help them to keep the price increases low.

At the other end of the scale as expected, one can find a number of service industries as business services, community and personal services and the hotel and restaurant industry. The last industry is perhaps not generally believed to be having such low competitive pressure. Among these extremes is also the construction industry (F) found also according to the book. One the other hand two service industries that perform as well as most manufacturing industry are trade and transport (green bars). This is probably due to positive development during this 10-years period.

Investments in innovation and competition

The R&D expenditures are the most available measurement indicator of innovation on industry level, even if the dataset is not complete due to confidentiality and other circumstances in some countries. This variable, which we have related to the value added, is taken from OECD-databases.

Figure 3. The relation between yearly changes in Price and MFP and R&D intensity levels the corresponding years



As can be seen from figure 3 there is a concentration of the observations between the values 0.8 and 1.2 on the horizontal axis. It is also apparent that there are a handful of extreme outliers. Already, values like 0.8 mean that the yearly increase in multifactor productivity is 20 percent higher than the price increase, for example 15 percent and -5 percent.

To further look into these relations, that is, to study how innovation measured as R&D intensity varies due to variations in our competition measurement, we ran regressions with R&D intensity as dependent and the difference in the growth between two consecutive years between value added prices and value added multifactor productivity. Since there is some indication in the literature that too little as well as too much competition hinders the innovation incentives[4] we have also used the quadratic of the independent variable together with the simple form. This means that it is a test of that hypothesis of the U-shape.

The first regression is a simple linear regression estimate with just the changes in AdjPrice t -MFP t+1 and its quadric form as the independent variables without a constant.

Table 4. Estimation of the relationship between R&D intensity and the relationship between changes in prices and MFP development and the quadric of this.

Variable	Coefficient	z	P>ltl
PriceMFPVA	0.30	12.8	0.000
PriceMFPVA2	-0.25	-10.8	0.000

We have also made a GMM (see note 5 and appendix for the specification) estimation and in which we have controlled for years, countries and industries. In table 5 below we see that the differences are still on the same magnitude.

Table 5. Estimation of the relationship between R&D intensity and the difference in price and MFP development and the quadric of that variable, controlling for year, country and industry. The independent variables are lagged two years.

Variable	Coefficient	t	P>ltl
PriceMFPVA (T-2)	0.34	38.1	0.000
PriceMFPVA2 (T-2)	-0.29	-32.9	0.000

Controlled for countries, industries and years[5]

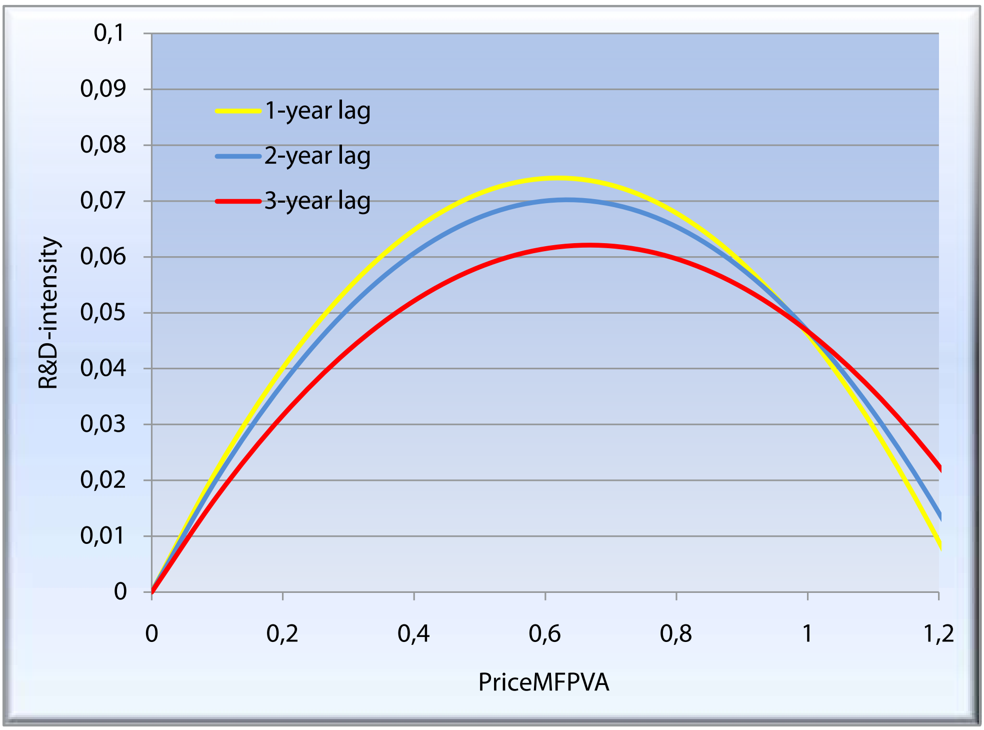
[4] *"U-shaped relationship between vertical integration and competition: Aghion, Bloom, Blundell, Griffith, Howitt, 2005. Competition and innovation: an inverted-u relationship, Quarterly Journal of Economics, May 2005, p 701-728.*

[5] *An Arelljo-Bond GMM estimation Instruments for differenced equation GMM-type: L(2/.).RandDintensity L(2/.).PriceMFPVA L(2/.).PriceMFPVAQuad*

Instruments for level equation Standard: Year Australia Germany Netherlands Sweden US Japan France IndAtB Ind15t16 Ind17t19 Ind20 Ind21t22 Ind24 Ind25 Ind26 Ind27t28 Ind29 Ind30t33 Ind34t35 Ind36t37 IndE IndF IndG Ind60t63 Ind64 IndJ IndK IndLtQ

The competitive environment could of course vary somewhat over the years and the decision on investing in R&D is not based on the situation a single year but more probably on the situation over a number of years. Since it also takes some time to plan and perform research it most certainly is motivated to use some kind of lag in the estimation. So in order to test this we have used a lag. The lags that we have tested are from one up to three years. However, they gave almost the same result. This is most certainly due to the continuous nature of the R&D process as well as the stability of the competitive environment in each industry. The specification with a two years lag fits marginally better. That is why we have presented this result in table 5.

Figure 4. The relation between R&D intensity 2005 and yearly Price-MFP changes during the period 1995-2005

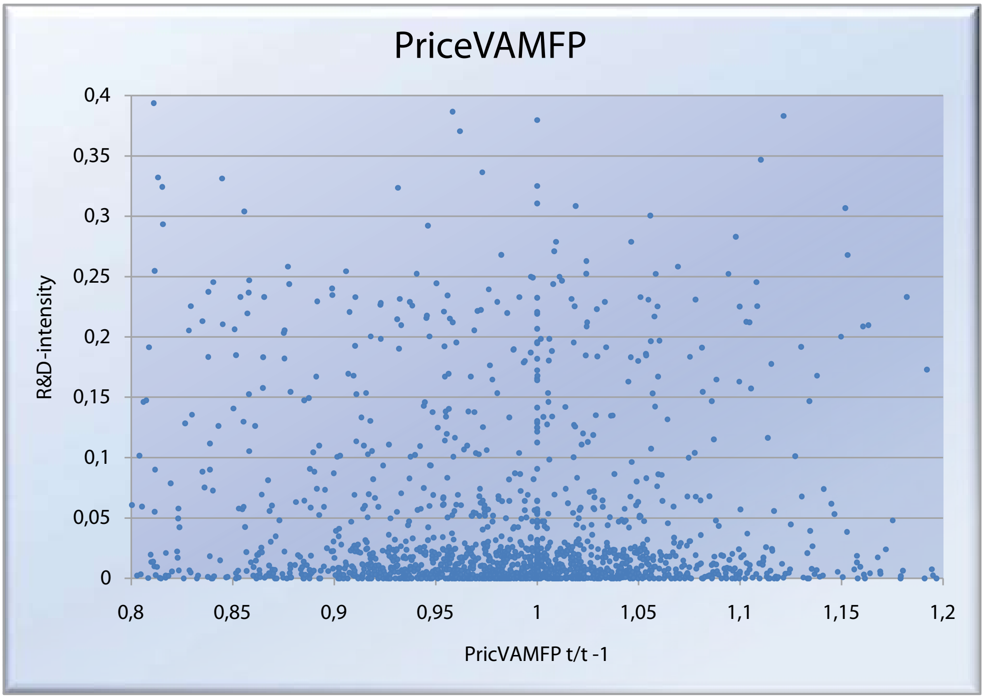


We have used these estimation results to draw a simple figure. And as can be seen in the figure 2 the slope is positive especially from extremely low values on the horizontal axis. This means that it seems as that a too fierce competition can hinder innovation. However such observations are rather infrequent, and with higher values the curves turn down. The estimation results when we used the three different time lags are all represented in the figure, and as can be seen, they are in practise identical.

Sensitivity test without extreme values

As could be seen from figure 3 there are quite a few outliers that probably have influenced this estimation. We have thus made an alternative approach by reducing the number of outliers. All the observations with R&D-intensity over 0.4 was skipped and also all the remaining observations with values of their PriceMFPVA lower than 0.8 and higher than 1.2. This gives us a more compact dataset, see figure 5.

Figure 5. The relation between difference in the yearly changes between Price and MFP respectively the R&D-intensity levels the corresponding years, when the potential outliers are removed.



When this dataset is used to estimate the relationship, the results are very similar to the ones with the extreme values. This can be seen from table 6. The estimates are of course marginally lower, as could be expected, but not that much lower. We have also used a different GMM specification[6] a two-step and robust one which did give almost the same result (see note 6 and appendix).

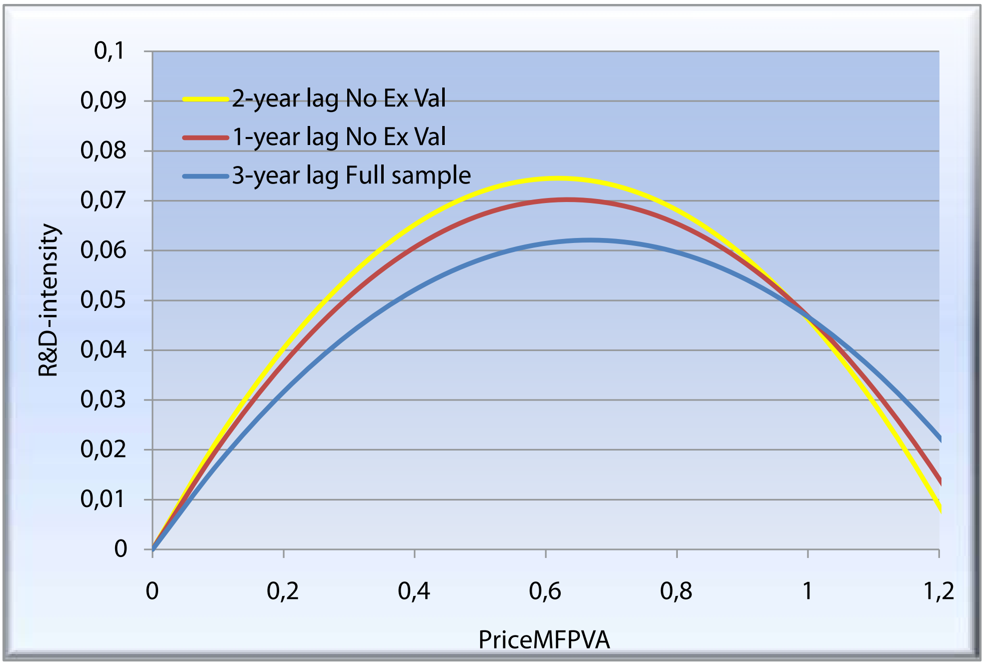
[6] *xtdpd RandDintensity L(1).(PriceMFPVA PriceMFPVA2), noconstant dgmmiv(RandDintensity PriceMFPVA PriceMFPVA2) liv(Year- FranceIndA tB- IndLtQ) vce(robust) twostep*
Instruments for differenced equation: *GMM-type: L(2/.).RandDintensity L(2/.).PriceMFPVA L(2/.).PriceMFPVA2*
Instruments for level equation: *Standard: Year Australia Germany Netherlands Sweden_ US UK France IndAtB Ind15t16 Ind17t19 Ind20 Ind21t22 Ind24 Ind25*
Ind26 Ind27t28 Ind29 Ind30t33 Ind34t35 Ind36t37 IndE IndF IndG Ind60t63 Ind64 IndJ IndK IndLtQ

Table 6. Estimation of the relationship between R&D intensity and the difference in price and MFP development and the quadric of that variable, controlling for year, countries and industries, without extreme observations

Variable	Coefficient	t	P>ItI
PriceMFPVA (T-2)	0.32	38.4	0.000
PriceMFPVA2 (T-2)	-0.27	-33.4	0.000

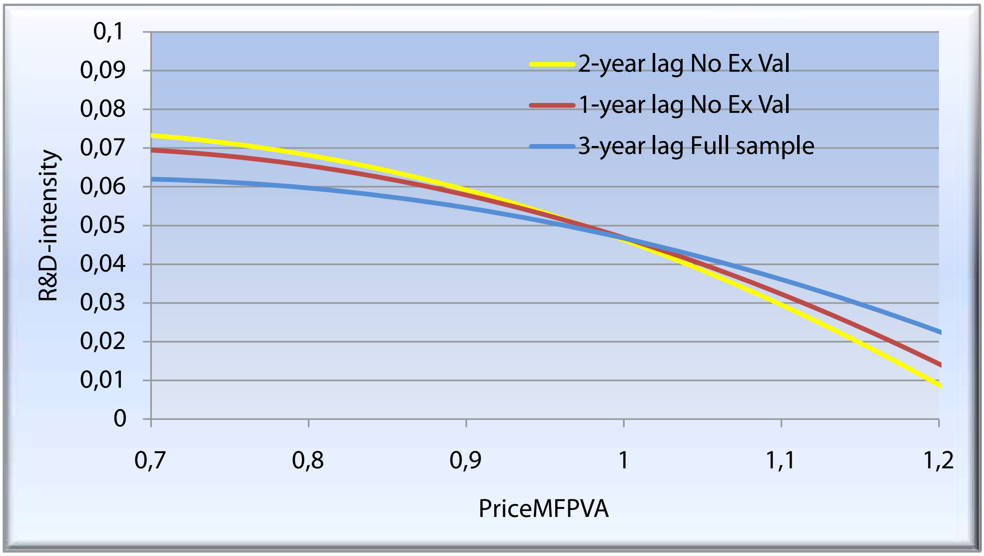
These two estimation results are displayed in figure 6 together with the lowest of the earlier estimations. That is the highest curve in the figure. The conclusion is that our results seem to be quite robust.

Figure 6. The relation between R&D intensity 2005 and yearly Price-MFP changes during the period 1995-2005, with and without the extreme values



However, as already mentioned the number of observations on the first part of the curve are rather few compared to those on the second part of the curve. This means that although the competition can be too strong, it hampers the investments in innovation. However, the most relevant part of the curves are the part to the right, which is displayed in figure 6.

Figure 7. The relation between R&D intensity 2005 and yearly Price-MFP changes during the period 1995-2005. Based and the data without the extreme values. The most relevant part



So in most cases it is more a question of the competitive pressure that is too low to create an incentive to invest heavily in innovation. One must bear in mind that the data are not perfect; investment in innovation in many service industries comes in many different forms, and is not always counted as R&D-investment. These industries are still generally home market industries with weaker competitive pressure. This makes them appear at the end of the curve.

Still, the findings in this study do not indicate that there are any strong conflicts between policies that pursue innovation and competition.

The main findings of the study:

- *It seems that using a new measurement of competition taking into account technological progress, hence price changes due to e.g. improved technology is controlled for, is a meaningful approach.*
- *There is a weak but significant relationship between R&D intensity and this competition indicator.*
- *Hence the result confirms the hypothesis that there is an inverted U-formed relationship between higher competition and higher degrees of R&D intensity.*
- *However, in most cases the relevant part of this inverted U-formed curve is the downward sloping part. So there seems to be no conflict between pursuing innovation and competition.*

Regression results

Price estimations
.regress VAPrice MFPVA

Source		SS	df	MS	Number of obs	=	1936		
					F(1, 1934)	=	109.67		
Model	4747.96604	1 4747.96604			Prob > F	=	0.0000		
Residual	83727.2596	1934 43.2922749					R-squared	=	0.0537
					Adj R-squared	= 0.0532			
Total	88475.2257	1935 45.7236308				Root MSE		=	6.5797

VAPrice	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]	
MFPVA	-.277769	.0265238	-10.47		0.000	-.3297871	-.2257508
_cons	127.902	2.695329	47.45		0.000	122.616	133.1881

. regress VAPrice Australia - France

Source	SS	df	MS	Number of obs =	1936		
				F(7, 1928) =	1.41		
Model	450.173594	7 64.3105134		Prob > F	=	0.1974	
Residual	88025.0521	1928 45.6561473				R-squared	= 0.0051
				Adj R-squared		= 0.0015	
Total	88475.2257	1935 45.7236308				Root MSE	= 6.7569

VAPrice	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]	
Australia	.166531	.6142667	0.27		0.786	-1.038166	1.371228
Germany	.3637588	.6142667	0.59		0.554	-.840938	1.568456
Netherlands	-.0466955	.6142667	-0.08		0.939	-1.251392	1.158001
Sweden_	-.1556025	.6142667	0.25		0.800	-1.360299	1.049094
US	.3163979	.6142667	0.52		0.607	-.8882989	1.521095
Japan	-1.27406	.6142667	-2.07		0.038	-2.478757	-.0693631
UK	-5.11e-15	.6142667	-0.00		1.000	-1.204697	1.204697
France	(dropped)						
_cons	99.79752	.4343521	229.76		0.000	98.94567	100.6494

Competition estimations

regress PriceMFPVA IndAtB - IndLtQ Year - France

Source	SS	df	MS	Number of obs	=		1936	
				F(29, 1906)	=		3.47	
Model	.924462536			29	.031878018	Prob > F	=	0.0000
Residual	17.4954588			1906 .009179149		R-squared	=	0.0502
				Adj R-squared	=	0.0357		
Total	18.4199213			1935	.009519339	Root MSE	=	.09581

Source	SS	df	MS	Number of obs	=	1936		
				F(29, 1906)	=	3.47		
Model	.924462536			29 .031878018			Prob > F	= 0.0000
Residual	17.4954588			1906 .009179149			R-squared	= 0.0502
				Adj R-squared	= 0.0357			
Total	18.4199213			1935 .009519339			Root MSE	= .09581

PriceMFPVA	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]

IndAtB	(dropped)					
Ind15t16	.0578784	.0125967	4.59	0.000	.0331736	.0825832
Ind17t19	.0343842	.0125967	2.73	0.006	.0096794	.059089
Ind20	.0567676	.0125967	4.51	0.000	.0320628	.0814724
Ind21t22	.0516894	.0125967	4.10	0.000	.0269846	.0763942
Ind24	.0194536	.0125967	1.54	0.123	-.0052512	.0441584
Ind25	.0247775	.0125967	1.97	0.049	.0000728	.0494823
Ind26	.017357	.0125967	1.38	0.168	-.0073478	.0420617
Ind27t28	.0368484	.0125967	2.93	0.003	.0121436	.0615532
Ind29	.018461	.0125967	1.47	0.143	-.0062438	.0431658
Ind30t33	-.0901336	.0125967	-7.16	0.000	-.1148384	-.0654288
Ind34t35	.0112644	.0125967	0.89	0.371	-.0134404	.0359692
Ind36t37	.0395879	.0125967	3.14	0.002	.0148831	.0642927
IndE	.0348951	.0125967	2.77	0.006	.0101903	.0595999
IndF	.073403	.0125967	5.83	0.000	.0486983	.0981078
IndG	.0329356	.0125967	2.61	0.009	.0082308	.0576404
IndH	.0676393	.0125967	5.37	0.000	.0429345	.0923441
Ind60t63	.0418107	.0125967	3.32	0.001	.017106	.0665155
Ind64	-.0412412	.0125967	- 3.27	0.001	-.065946	-.0165364
IndJ	.0577763	.0125967	4.59	0.000	.0330715	.0824811
IndK	.0652838	.0125967	5.18	0.000	.040579	.0899885
IndLtQ	.0719257	.0125967	5.71	0.000	.0472209	.0966305
Year	-.0019499	.0006005	- 3.25	0.001	-.0031277	-.0007722
Australia	.015561	.0075961	2.05	0.041	.0006634	.0304585
Germany	-.0047383	.0075961	- 0.62	0.533	-.0196359	.0101592
Netherlands	.0057294	.0075961	0.75	0.451	-.0091682	.0206269
Sweden_	-.0140704	.0075961	-1.85	0.064	-.028968	.0008271
US	-.0070772	.0075961	-0.93	0.352	-.0219747	.0078204
Japan	-.0301855	.0075961	-3.97	0.000	-.0450831	-.015288
UK	.0079831	.0075961	1.05	0.293	-.0069144	.0228807
France	(dropped)					
_cons	4.861576	1.201093	4.05	0.000	2.505982	7.217171
IndAtB	(dropped)					
Ind15t16	.027266	.0144436	1.89	0.059	-.0010609	.0555929
Ind17t19	.0103934	.0144436	0.72	0.472	-.0179335	.0387203
Ind20	.0270763	.0144436	1.87	0.061	-.0012506	.0554032
Ind21t22	.0249191	.0144436	1.73	0.085	-.0034078	.053246
Ind24	.0090803	.0144436	0.63	0.530	-.0192466	.0374072
Ind25	.0015527	.0144436	0.11	0.914	-.0267742	.0298796
Ind26	.000822	.0144436	0.06	0.955	-.0275049	.0291489
Ind27t28	.0219986	.0144436	1.52	0.128	-.0063282	.0503255
Ind29	-.0054872	.0144436	0.38	0.704	-.0338141	.0228397
Ind30t33	-.0583041	.0144436	-4.04	0.000	-.086631	-.0299772
Ind34t35	-.0035407	.0144436	-0.25	0.806	-.0318675	.0247862
Ind36t37	.0137699	.0144436	0.95	0.341	-.014557	.0420968
IndE	.0211009	.0144436	1.46	0.144	-.007226	.0494277
IndF	.0347153	.0144436	2.40	0.016	.0063884	.0630422
IndG	.0101008	.0144436	0.70	0.484	-.018226	.0384277
IndH	.0243221	.0144436	1.68	0.092	-.0040047	.052649
Ind60t63	.0178959	.0144436	1.24	0.215	-.0104309	.0462228
Ind64	-.0226942	.0144436	-1.57	0.116	-.0510211	.0056327
IndJ	.0315887	.0144436	2.19	0.029	.0032618	.0599156
IndK	.0325564	.0144436	2.25	0.024	.0042296	.0608833
IndLtQ	.0315829	.0144436	2.19	0.029	.003256	.0599097
Year	-.0008527	.0006886	-1.24	0.216	-.0022031	.0004977
Australia	.0114923	.0087098	1.32	0.187	-.0055894	.0285741
Germany	.0074335	.0087098	0.85	0.394	-.0096483	.0245152
Netherlands	.0059072	.0087098	0.68	0.498	-.0111746	.0229889

Sweden_	-.0039402	.0087098	-0.45	0.651	-.021022	.0131415
US	-.0014259	.0087098	-0.16	0.870	-.0185076	.0156559
Japan	.0008529	.0087098	0.10	0.922	-.0162289	.0179346
UK	.0079831	.0087098	0.92	0.359	-.0090986	.0250649
France	(dropped)					
_cons	2.673037	1.377191	1.94	0.052	-.0279239	5.373997

Innovation estimations
Full sample

.regress RandDintensity PriceMFPVA PriceMFPVA2, noconstant
Source SS df MS Number of obs = 1718
F(2, 1716) = 351.06
Model 4.50600926 2 2.25300463 Prob > F = 0.0000
Residual 11.0129447 1716 .0064178 R-squared = 0.2904
Adj R-squared = 0.2895
Total 15.518954 1718 .009033151 Root MSE = .08011

RandDinten~y	Coef.	Std. Err.	t	P>t[95%	Conf Interval]	
PriceMFPVA	.2982797	.0233122	12.80	0.000	.2525565	.344003
PriceMFPVA2	-.2501672	.0231407	-10.81	0.000	-.2955541	-.2047802

GMM
xtdpd RandDintensity L(1).(PriceMFPVA PriceMFPVA2), noconstant dgmmiv(RandDintensity PriceMFPVA PriceMFPVA2) liv(Year- France IndAtB- IndLtQ) artests(2)
note: UK dropped from liv() because of collinearity
note: IndH dropped from liv() because of collinearity

Dynamic panel-data estimation Number of obs = 1578
Group variable: Observation Number of groups = 165
Time variable: Year
Obs per group: min = 4
avg = 9.563636
max = 10

Number of instruments = 155 Wald chi2(2) = 12875.46
Prob > chi2 = 0.0000
One-step results

RandDinten~y	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
PriceMFPVA						
L1.	.1917052	.0051083	37.53	0.000	.1816931	.2017172
PriceMFPVA2						
L1.	-.1430712	.0050881	-28.12	0.000	-.1530438	-.1330987

Instruments for differenced equation
GMM-type: L(2/.).RandDintensity L(2/.).PriceMFPVA L(2/.).PriceMFPVA2
Instruments for level equation
Standard: Year Australia Germany Netherlands Sweden_ US Japan France IndAtB Ind15t16 Ind17t19 Ind20 Ind21t22 Ind24 Ind25 Ind26 Ind27t28 Ind29 Ind30t33 Ind34t35 Ind36t37 IndE IndF IndG Ind60t63 Ind64 IndJ IndK IndLtQ

. xtdpd RandDintensity L(2).(PriceMFPVA PriceMFPVA2), noconstant dgmmiv(RandDintensity PriceMFPVA PriceMFPVA2) liv(Year-France IndAtB-IndLtQ) artests(2)
note: UK dropped from liv() because of collinearity
note: IndLtQ dropped from liv() because of collinearity

Dynamic panel-data estimation Number of obs = 1439
Group variable: Observation Number of groups = 165
Time variable: Year
Obs per group: min = 4
avg = 8.721212
max = 9

Number of instruments = 153 Wald chi2(2) = 12296.97
Prob > chi2 = 0.0000
One-step results

RandDinten~y	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
PriceMFPVA						
L2.	.178584	.0052501	34.02	0.000	.168294	.1888741
PriceMFPVA2						
L2.	-.1296845	.0052245	-24.82	0.000	-.1399243	-.1194446

Instruments for differenced equation
GMM-type: L(2/.).RandDintensity L(2/.).PriceMFPVA L(2/.).PriceMFPVA2
Instruments for level equation
Standard: Year Australia Germany Netherlands Sweden_ US Japan France IndAtB Ind15t16 Ind17t19 Ind20 Ind21t22 Ind24 Ind25
Ind26 Ind27t28 Ind29 Ind30t33 Ind34t35 Ind36t37 IndE IndF IndG IndH Ind60t63 Ind64 IndJ IndK

. xtdpd RandDintensity L(3).(PriceMFPVA PriceMFPVA2), noconstant dgmmiv(RandDintensity PriceMFPVA PriceMFPVA2) liv(Year- France IndAtB- IndLtQ) artests(2)
note: UK dropped from liv() because of collinearity
note: IndH dropped from liv() because of collinearity

Dynamic panel-data estimation Number of obs = 1299
Group variable: Observation Number of groups = 165
Time variable: Year
Obs per group: min = 4
avg = 7.872727
max = 8

Number of instruments = 148 Wald chi2(2) = 10740.86
Prob > chi2 = 0.0000
One-step results

RandDinten~y	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
PriceMFPVA						
L3.	.1787256	.005751	31.08	0.000	.1674538	.1899973
PriceMFPVA2						
L3.	-.1296943	.0057199	-22.67	0.000	-.1409051	-.1184834

Instruments for differenced equation
GMM-type: L(2/.).RandDintensity L(2/.).PriceMFPVA L(2/.).PriceMFPVA2
Instruments for level equation
Standard: Year Australia Germany Netherlands Sweden_ US Japan France IndAtB Ind15t16 Ind17t19 Ind20 Ind21t22 Ind24 Ind25 Ind26 Ind27t28 Ind29
Ind30t33 Ind34t35 Ind36t37 IndE IndF IndG Ind60t63 Ind64 IndJ IndK IndLtQ

Estimation without extreme observations

. xtdpd RandDintensity L(**1**).(PriceMFPVA PriceMFPVA2), noconstant dgmmiv(RandDintensity PriceMFPVA PriceMFPVA2) liv(Year- **France IndAtB**-IndLtQ) artests(2)
note: Japan dropped from liv() because of collinearity
note: IndJ dropped from liv() because of collinearity

Dynamic panel-data estimation   Number of obs = 1492
Group variable: Observation   Number of groups = 165
Time variable: Year
Obs per group: min = 2
avg = 9.042424
max = 10

Number of instruments = 155   Wald chi2(2) = 12477.97
Prob > chi2 = 0.0000

One-step results

RandDinten~y	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
PriceMFPVA						
L1.	.2391793	.0067895	35.23	0.000	.2258722	.2524864
PriceMFPVA2						
L1.	-.1930294	.0068341	-28.25	0.000	-.206424	-.1796348

Instruments for differenced equation
GMM-type: L(2/.).RandDintensity L(2/.).PriceMFPVA L(2/.).PriceMFPVA2
Instruments for level equation
Standard: Year Australia Germany Netherlands Sweden_ US UK France IndAtB Ind15t16 Ind17t19 Ind20 Ind21t22 Ind24 Ind25 Ind26
Ind27t28 Ind29
Ind30t33 Ind34t35 Ind36t37 IndE IndF IndG IndH Ind60t63 Ind64 IndK IndLtQ

. xtdpd RandDintensity L(**2**).(PriceMFPVA PriceMFPVA2), noconstant dgmmiv(RandDintensity PriceMFPVA PriceMFPVA2) liv(Year- France **IndAtB-IndLtQ) artests(2**)
note: Australia dropped from liv() because of collinearity
note: IndH dropped from liv() because of collinearity

Dynamic panel-data estimation   Number of obs = 1358
Group variable: Observation   Number of groups = 165
Time variable: Year
Obs per group: min = 2
avg = 8.230303
max = 9

Number of instruments = 153   Wald chi2(2) = 15948.91
Prob > chi2 = 0.0000
One-step results

```
------------------------------------------------------------------------------
RandDinten~y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------

PriceMFPVA |
        L2. |   .2215567   .0059785    37.06   0.000     .2098391    .2332743
 PriceMFPVA2 |
        L2. |  -.1747768   .0059984   -29.14   0.000    -.1865334   -.1630201
------------------------------------------------------------------------------
Instruments for differenced equation
        GMM-type: L(2/.).RandDintensity L(2/.).PriceMFPVA L(2/.).PriceMFPVA2
Instruments for level equation
        Standard: Year Germany Netherlands Sweden_ US Japan UK France IndAtB Ind15t16 Ind17t19
Ind20 Ind21t22 Ind24 Ind25 Ind26 Ind27t28 Ind29 Ind30t33
              Ind34t35 Ind36t37 IndE IndF IndG Ind60t63 Ind64 IndJ IndK IndLtQ
```

Alternative GMM-model

. xtdpd RandDintensity L(1).(PriceMFPVA PriceMFPVA2), noconstant dgmmiv(RandDintensity PriceMFPVA PriceMFPVA2) liv(Year- **France IndAtB- IndLtQ) vce(robust) twostep**

```
note: Japan dropped from liv() because of collinearity
note: IndJ dropped from liv() because of collinearity
Dynamic panel-data estimation              Number of obs        =     1464
Group variable: Observation                Number of groups     =      164
Time variable: Year
                                   Obs per group:    min =         2
                                                     avg =  8.926829
                                                     max =        10


Number of instruments =     155            Wald chi2(2)         =    70.36
                                   Prob > chi2          =    0.0000
Two-step results
------------------------------------------------------------------------------
             |              WC-Robust
RandDinten~y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  PriceMFPVA |
        L1. |   .2408882    .035197     6.84   0.000     .1719034     .309873
 PriceMFPVA2 |
        L1. |  -.1946205   .0326196    -5.97   0.000    -.2585538   -.1306873
------------------------------------------------------------------------------
Instruments for differenced equation
GMM-type: L(2/.).RandDintensity L(2/.).PriceMFPVA L(2/.).PriceMFPVA2
Instruments for level equation
Standard: Year Australia Germany Netherlands Sweden_ US UK France IndAtB Ind15t16 Ind17t19
Ind20 Ind21t22 Ind24 Ind25 Ind26 Ind27t28 Ind29
              Ind30t33 Ind34t35 Ind36t37 IndE IndF IndG IndH Ind60t63 Ind64 IndK IndLtQ
```

. xtdpd RandDintensity L(1).(PriceMFPVA PriceMFPVA2), noconstant dgmmiv(RandDintensity PriceMFPVA PriceMFPVA2) liv(Year- FranceIndA tB- IndLtQ) vce(robust) twostep

```
note: Japan dropped from liv() because of collinearity
note: IndH dropped from liv() because of collinearity

Dynamic panel-data estimation              Number of obs        =     1471
Group variable: Observation                Number of groups     =      161
Time variable: Year
```

Obs per group: min = 2
avg = 9.136646
max = 10

Number of instruments = 155 Wald chi2(2) = 72.41
Prob > chi2 = 0.0000
Two-step results

WC-Robust
RandDinten~y Coef. Std. Err. z P>z [95% Conf. Interval]

PriceMFPVA
L1. .3353447 .0838951 4.00 0.000 .1709133 .4997761
PriceMFPVA2
L1. -.2942181 .0819326 -3.59 0.000 -.4548031 -.1336332

Instruments for differenced equation
GMM-type: L(2/.).RandDintensity L(2/.).PriceMFPVA L(2/.).PriceMFPVA2
Instruments for level equation
Standard: Year Australia Germany Netherlands Sweden_ US UK France IndAtB Ind15t16 Ind17t19
Ind20 Ind21t22 Ind24 Ind25
Ind26 Ind27t28 Ind29 Ind30t33 Ind34t35 Ind36t37 IndE IndF IndG Ind60t63 Ind64 IndJ IndK IndLtQ

The improvements of the National Accounts system in Sweden

– An overview of the program

Kajsa Ben Daher, Statistics Sweden

1. The study of the review of the economic statistics

On 14 September 2000, the Swedish government decided to set up a committee to analyse and chart the changing needs in society for economic statistics. As a starting point, the aim was to make a thorough study of the situation for statistics in general, and the national accounts in particular.

This assignment from the government was initiated because it was clear that economic statistics, in particular the national accounts, had grown in significance in recent years.

- The directives for economic policy goals were increasingly given in quantitative terms, such as the government's goal for a ceiling on costs, savings in the public sector, goals for inflation, employment and unemployment.
- The growing need of the EU for comparable statistics was important to calculate membership fees, structural funds and quality requirements for the EMU.
- Financial markets can be vulnerable when economic statistics sometimes cause sharp reactions in interest rates and exchange rates
- The conditions to meet the economic development have changed, due to globalisation, technical developments, and a difficulty to distinguish between price and quality changes.
- Enterprises sometimes have difficulties in submitting information according to the definitions of Statistics Sweden. This results in non-response and a need to make the response process easier.

Directives

According to the directives, this study will provide proposals for changes in the economic statistics, and inform the needs for continued development measures.

The study will provide a comprehensive examination of the national accounts and the requirements for primary statistics. The study will describe how calculations and revisions are made, how productivity is measured and explain the concept of income. Comparisons will be made with other countries. The task will be done in close cooperation with the National Institute of Economic Research and the Riksbank.

Persons involved with this study

The assignment was very comprehensive. It took two years to complete, and involved many statisticians and experts within and outside Statistics Sweden as well as from other areas.

The Director General at Statistics Sweden at the time, Mr Svante Öberg was appointed by the government as the head of the study. Ms Lena Hagman was employed as Head Secretary and Ms Cecilia Westström was Secretary. The fourth person was Mr Sigvard Ahlzen, consultant from the Riksbank.

A number of experts were also appointed:

- Ann-Marie Bråthen, Unit Head at Statistics Sweden's National Accounts Unit
- Monica Helander, Deputy Director
- Cecilia Hermansson, Economist
- Thorbjörn Isaksson, Deputy Director
- Anders Klevmarken, Professor
- Hans Lindberg, Head of Forecasting
- Alexander Nilson, Consultant

Other international experts included:

- Svein Longva, Director General of Statistics Norway
- Tim Holt, Professor and previously Director for Office of National Statistics in Great Britain
- Steven Landefeld, Director of the Bureau of Economic Analysis, United States

Working methods

The study included a large number of interviews with various government ministries, organisations, financial enterprises, the academic world and unit heads at Statistics Sweden. Important users of statistics such as the Ministry of Finance, the National Institute of Economic Research and the Riksbank together with Statistics Sweden's National Accounts Unit submitted written viewpoints. Requirements of EU were studied, as well as the requirements of the programme councils. A number of seminars were arranged which dealt with productivity calculations and the new economy. Study visits were also made to some ten countries such as the Nordic countries, the Netherlands, the UK, the US, Canada, Australia and New Zealand.

Results

The study provides proposals for improved economic statistics and improved working methods together with an organisational change. The emphasis is on an improvement in the national accounts.

The study maintains that those resources set aside for official statistics in Sweden are from an international perspective relatively small in relation to the size of the country.

Concerning improvements of the economic statistics, proposals were made to study price statistics, input/output calculations, IT statistics, capital stock calculations, speeding up the production of statistics, statistics on service industries and the public sector, productivity calculations, the hidden economy etc. Long time series would also be produced.

Concerning working methods and the organisation, it was proposed that

- Analysis capacity and competency in the national accounts should be strengthened
- Cooperation between the national accounts and primary statistics on the one hand, and between the national accounts and the users on the other should be developed
- Service Level Agreements should be formed between the primary statistics products and the national accounts
- Documentation of the national accounts and information on revisions should be improved
- A council for the national accounts should be formed

Costs to carry out these proposals were estimated by the committee to amount to about SEK 64 million.

2. Action plan for improving the economic statistics – the Emma Project

An action plan for the economic statistics was formed in the beginning of 2004 with the aim that most of the proposals from the study on the review of the economic statistics would be conducted over the five-year period 2004-2008.

The improvement work began slowly in 2004 and 2005, largely within the frame of appropriations. From 2006 until the end of 2008, Statistics Sweden and the economic statistics received an increase in appropriations to work with the improvements according to the action plan. During the years 2006-2008, the Riksbank also contributed temporary funds to improve the economic statistics.

The Emma project, a large umbrella project, began with the task to run and follow up all of the approximately 40 sub-projects within the Emma umbrella. The project work within Emma went on since 2006 and is basically completed now.

The table in appendix 1 presents the follow up of the proposals of the committee, divided into two parts

1. Action plan
2. Other proposals from the committee

The table illustrates that most of the proposals have been conducted and that a number have been partly conducted. There are also some proposals that have not yet begun, usually due to a lack of interest from the users, which has led to re-prioritising or sometimes a lack of resources within certain areas. These may also be proposals that would be difficult to carry out.

Later in 2006 the action plan of the Emma project was expanded to also include some other important improvements such as

- More accurate quarterly estimations and fewer revisions in the quarterly statistics. This included projects in the national accounts as well as improvements of the data submitted to the national accounts
- Coordination between the national accounts, financial accounts and the balance of payments
- Purchase by non-residents in Sweden Process mapping of the national accounts and later on to become the IT development project Navet

Results from the development project

The activities in the action plan are mainly directed to either develop new statistics or to improve the quality of the existing economic statistics.

New statistics

Concerning new statistics, the following products were developed and introduced into the running production.

1. Monthly construction production statistics
2. Quarterly sector accounts
3. IT investments for enterprises
4. Non-profit institutions serving households
5. Volume measures for the public sector
6. Quarterly TPI for different industries
7. Monthly service production index
8. Intermediate consumption for the service sektor
9. Trade margins

10 Health accounts

11. Public finances – yearbook
12. IT use – individuals and enterprises

A large amount of the new statistics have EU requirements and are published on Statistics Sweden's website. There are some parts that mainly comprise data to the national accounts, such as Non-profit institutions serving households, volume measures for the public sector, consumption of service enterprises and trade margins.

Some of the new statistics can be taken into the national accounts directly, while other parts need to be evaluated and perhaps further developed, such as annual statistics for Non-profit institutions serving households and trade margins.

Improved quality
The following are some of the quality improvements that have been conducted:

- Review of estimations of the hidden economy
- Improvements of the sample in the Producer Price Index
- Improvements of the Consumer Price Index according to the proposals of the Consumer Price investigation
- Speeding up the quarterly GDP to 60 days
- More explanations and analyses when publishing GDP
- New system for balancing the quarterly accounts
- Capital stock calculations.

Remaining work 2009/2010
In some areas of the action plan, development work has only been partly conducted and needs to be continued. This mainly applies to the areas of long time series for the national accounts, better consistency between the national accounts, the financial accounts and the balance of payments, as well as seasonal adjustment.

One particular issue concerns the newly developed primary statistics as a basis for the national accounts. Even though these statistics are now in regular production, it may take some years until the new statistics can be integrated into the regular calculations of National Accounts. This means that the final utilisation of the development work for the national accounts can take longer to achieve than those time points presented in each sub-project.

Right now, a so-called major revision of the national accounts is being done and will be published in May 2010. A number of projects included in major revision that intend to implement the results from the various Emma projects are now being done. Evidently, the implementation of the new statistics in the national accounts is much more complicated, expensive and time consuming than expected. The implementation work was never planned for in the action plan or in the Emma project, and therefore resources are lacking to carry out the implementation at the rate that would be desirable.

Reports on the Emma project concerning the users will be made in connection with the Saltsjöbaden Conference in October 2009. At about the same time, a web version of a final report from the Emma project will be published on Statistics Sweden's website. The report consists of a summary of about one page for each sub-project and a link to the final report from each sub-project.

3. What follows the Emma project – A strategic plan for economic statistics

At present, work is going on at Statistics Sweden to produce a strategic plan for the economic statistics.

Concerning the national accounts, continued development work will be needed in the areas for long time series and seasonal adjustment, where it has been particularly difficult to reach the desired results and fulfil the requirements and wishes from the users.

Several areas of development in the economic statistics were of low priority due to lack of funds in the Emma project. The following areas should be discussed for future development:

- Globalisation
- Volume indicators, quality adjustments
- Productivity database
- Monthly wealth indicators
- Capital stock reports
- Import structure
- GDP flash

Additional proposals for development made by the review:

- Productivity development in the public sector
- More types of services in the foreign trade statistics
- Satellite accounts for household production
- Price statistics on real estate market
- National wealth statistics

Coordination work between the national accounts and the financial accounts must continue to reduce discrepancies in financial savings. This is especially important since the EU has criticised Sweden concerning the quality of EDP reporting (Excessive Deficit Procedure), where the public sector's savings and net debt is presented according to the EU convergence criteria.

The revision of the Swedish Standard Industrial Classification (NACE) requires considerable funds. The work began this year and will continue until 2011-2012. The national accounts according to the new NACE will be published for the first time in September 2011.

The revision of the System of National Accounts will be implemented in the national accounts in 2014. This is a tremendous challenge and is already requiring funds for preparatory work. The scope of this work will increase in the next coming years.

Future development areas being taken up by the ESS and the OECD include

- Financial accounts
- Sectors parallel with national accounts, higher grade of detail (30-60-90)
- Expanded public sector
- Economic trend analysis, story telling
- GDP flash
- Asset prices and balance sheets
- Households' income and wealth
- Globalisation indicators

Appendix 1

Follow-up of proposals based on the study of the review of the economic statistics

Proposal number	Product	Work completed	Work partly completed	work not begun
	Action plan			
	Ministry of Finance, economic policy			
17	Construction production statistics	X		
	National accounts			
32	Public sector finances	X		
22	Annual reports Productivity development	X		
57	Strengthening of the national accounts incl. primary statistics	X		
17	Quarterly sector accounts	X		
37	Longer time series in national accounts		X	
21	Volume measures for the public sector	X		
43	Non-profit institutions serving households	X		
15	Basis for capital stocks calculations	X		
16	Reports on capital stocks			X
12	IT investments for enterprises	X		
36	Untaxed work in the national accounts/hidden economy	X		
18	Flash indicators regarding GDP		X	
22	Productivity development in government agencies			X
24	Database on productivity development in public sector			X
	Input/output statistics			
7	Information on import structure		X	
8	Intermediate consumption for private services	X		
6	Information on trade margins	X		
	Price statistics			
3	Adapt various indices (PPI,PPP, HIKP) to EU regulations	X		
5	Prices for foreign trade in services	X		
2	Sample in Producer Price Index(PPI)	X		
4	Development of producer price index for services	X		
1	Proposals made by CPI investigation	X		
10	Price index for IT products	X		

	Speeding up EU statistics			
17	Speeding up national accounts	X		
17	Speeding up Industrial Production Index	X		
17	Speeding up of vacancies	X		
25	Short-term indicators for service sector	X		
	Other improvements of other economic statistics			
39	Time series analysis, seasonal adjustment		X	
65	New organisational unit for data provision from enterprises	X		
38	Long time series in other economic statistics		X	
47	Monthly/quarterly statistics for household wealth		X	
20	Speeding up of VAT statistics	X		
50	Currency conversion	X		
	Ministry of Finance			
19	Speeding up municipalities accounts		X	
	Ministry of Industry, Employment and Communications, regional policy			
28	Quicker Gross Regional Product (GDRP)			X
	Ministry of Industry, Employment and Communications, IT issues			
13	IT use by enterprises	X		
13	Individuals' use of IT	X		
14	Satellite accounts in the IT sector		X	
	Ministry of Health and Social Affairs			
33	Health accounts	X		
34	Public financed activities in private sector	X		
	Other proposals from the study			
9	Definition IT products/IT services		X	
11	Capital stocks for IT			X
26	Increase number of service industries in national accounts		X	
27	Increase number of service industries in foreign trade statistics			X
29	Develop/speed up register-based regional statistics	X		
30	Statistics at municipality level available free of charge			X
31	Improve the data for calculating central government consumption in national accounts	X		
35	Annual report about the development of public sector	X		

40	Two new income concepts, develop measurements of return on capital and present long time series		X	
41	Household dwellings, review relevant MIS reports	X		
42	New consumption unit scale	X		
44	Integrated gender equality perspective should be introduced in all statistics		X	
45	Increased possibilities to work from a gender equality perspective in all statistics		X	
46	Satellite accounts for household production			X
48	Short-term statistics on prices on real estate market			X
49	Increase short-term salary statistics		X	
51	Strengthen analysis competency	X		
52	Strengthen competency in national economics	X		
53	Develop cooperation between Statistics Sweden and universities	X		
54	Develop testing, explanations, presentation of inconsistencies	X		
55	Efficient and modern competitive intelligence	X		
56	Develop contacts with users (press conferences, seminars)	X		
58	Update documentation of calculations of national accounts annually			X
59	Improve documentation of other economic statistics	X		
60	Revisions of national accounts should be analysed and presented regularly	X		
61	Improve press releases and other publications	X		
62	Method reports easier to access	X		
63	Microdata and other data easier to access	X		
64	Analyse risks of publishing too early	X		
66	Review organisation of national accounts	X		
67	Council for national accounts	X		
68	Service Level Agreements with important users		X	
69	Statistics responsibility for financial accounts from Swedish Financial Supervisory Authority to Statistics Sweden			X
70	Develop strategic plan for improvement of economic statistics based on proposals from the study	X		
71	Annual follow-up of the implementation of the proposals of the study	X		

Recent Productivity Growth in the OECD: Sectoral Patterns and Effect of Innovation

Julien Dupont, Dominique Guellec and Joaquim Oliveira Martins (OECD)

Abstract

This paper reviewed the main productivity trends over the past decade, comparing US, European countries and Japan. The slowdown of productivity appeared to be due to a significant decceleration in ICT investment followed by a decrease in Multi-Factor productivity. The decline of productivity was particularly marked in some sectors, such as construction, and market services. Looking for possible explanations of the decline, a marked slowdown in innovation emerged as the most likely cause. It concludes that, if no new wave of innovation, comparable in size to the one of the late 1990s, happens again, there is little reason why trend productivity growth would recover its level of the late 1990s. Only a recovery in innovation itself will trigger a sustainable recovery in productivity in the major OECD countries.

1. Introduction

Labour productivity growth declined significantly since 2004. The post 2004 slowdown in OECD was driven first by the US, but it is also marked in Japan while productivity is nearly stable in the EU (slowing down in the United Kingdom and Sweden, about stable in other countries). In certain EU countries the productivity slowdown started in fact after 2001 already: in Germany notably, but also in France; that is also the case in Canada and Australia. At the opposite, productivity had accelerated markedly in the US and slightly in the UK between 2002 and 2004: but the 2005-2007 productivity growth is significantly lower than the 1995-2001 performance.

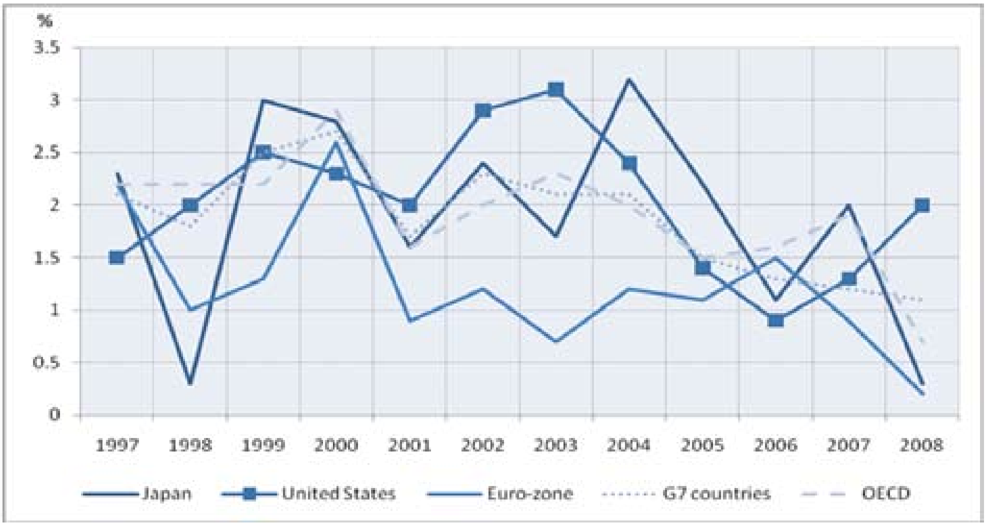
It is key to investigate the reasons of this decline and underlying real sector trends, especially in the major OECD member countries. The emergence of significant productivity gaps during the late 1990s within the OECD had triggered a lively debate on their causes, in particular the role of structural policies. The recent productivity trends in the US put this debate into a different perspective. In this context, the aim of this paper is to examine productivity growth patterns across main OECD countries by enlightening the role of some specific factors, such as innovation and the construction sector. These have played a significant role in the building of expectations about the real economy and influenced the dynamics of the crisis, as well as will impact possible exit strategies.

The paper first describes the decreasing productivity gap among major OECD countries at the level of the total economy. It uses the decomposition of labour productivity growth into the contribution of capital deepening and the growth in Multi-Factor Productivity (MFP), as well as the decomposition of GDP growth. Then it provides information at the industry level. The third section focuses on the links between innovation and productivity cycle. This empirical analysis raises issues about productivity measurement and the need of timely and disaggregated productivity estimates.

2. US vs. Europe: convergence and divergence of productivity

Discussion about why the US historically maintained higher productivity growth rates than Europe usually focuses on a structural policy gap: labour conditions (hiring and firing), product market regulations, and the uptake of technology. Figure 1 provides labour productivity (per hour worked) trends across the US, the Euro-zone and Japan. After the emerging gap on the late 1990s, a striking feature is a convergence "to the bottom" after 2003. By 2007, all major OECD areas were running at approximately the same productivity growth rate, at around 1-1.5%. Actually, a productivity gap appear again in 2008 with a turnaround of productivity in the US at around 2%, while in the Euro-zone productivity growth slowed down significantly in the aftermath of the crisis to less than 0.5%. The connexion between these productivity trends, expectations and the crisis is still a subject for research (see Mulligan, 2009)

Figure 1. Labour productivity growth at the total economy level (annual growth rates)



Source: OECD Productivity database, August 2009

2.1 A decomposition of labour productivity

Assuming a standard Cobb-Douglas function and constant returns to scale, the growth in labour productivity can be decomposed into the MFP growth and the contribution of capital deepening defined as the weighted capital input relative to the weighted labour input:

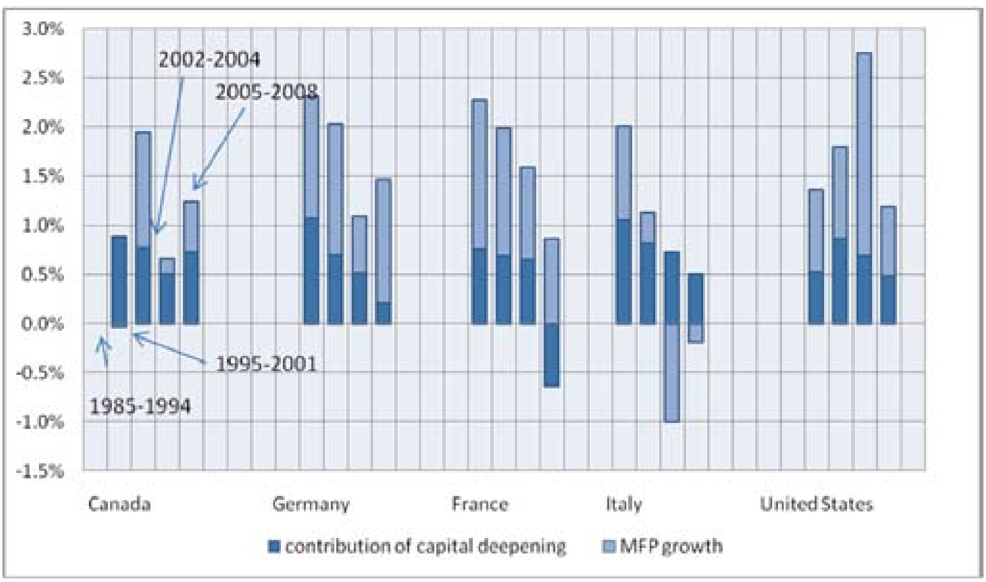
$$\ln\left(\frac{L_t}{L_{t-1}}\right) = \ln\left(\frac{MFP_t}{MFP_{t-1}}\right) + s^K * \ln\left(\frac{\left(\frac{K_t}{H_t}\right)}{\left(\frac{K_{t-1}}{H_{t-1}}\right)}\right)$$

Where L represents labour productivity, MFP represents multi-factor productivity, s^K represents the share of capital income in total income, K represents the capital input, and H represents the total hours actually worked[1] in a specific industry. Growth in capital deepening refers to the growth in the aggregate flow of capital services minus the growth in aggregate hours worked. Growth in capital deepening has a positive effect on labour productivity because a larger amount of capital per worker should increase the output per worker.

[1] *The measure of total hours worked is an incomplete measure of labour input because it does not account for changes in the skill composition of workers over time, such as educational attainment, and work experience. Adjustment for such attributes would provide a more accurate indication of the contribution of labour to production. In the absence of these adjustments, as is the case in the series shown here, more rapid output growth due to a rise in skills of the labour force are captured by the MFP residual, and not attributed to labour. This should be kept in mind when interpreting rates of MFP growth.*

Using this decomposition, Figure 2 shows the two main drivers of labour productivity during the period 1985-2008. The contribution of capital deepening to labour productivity growth slowed over the last decade in all the large countries analysed here, except Canada. However, trends in MFP growth differ markedly across countries. From 1985 to 2004, MFP growth supported labour productivity in the Germany, in France and in the US. Canada experienced a sharp decline in MFP growth during in the recent years while growth in MFP in Italy was negative. An acceleration of MFP is noticeable in the US for the years 2002-2004, but since then it has growing at a much slower pace. Overall, the slowdown of labour productivity growth over the whole period 1985-2008 was driven more on the deceleration in MFP growth than on the contribution of capital deepening in most OECD countries. This stresses the usual fact about the importance of technology for aggregate productivity.

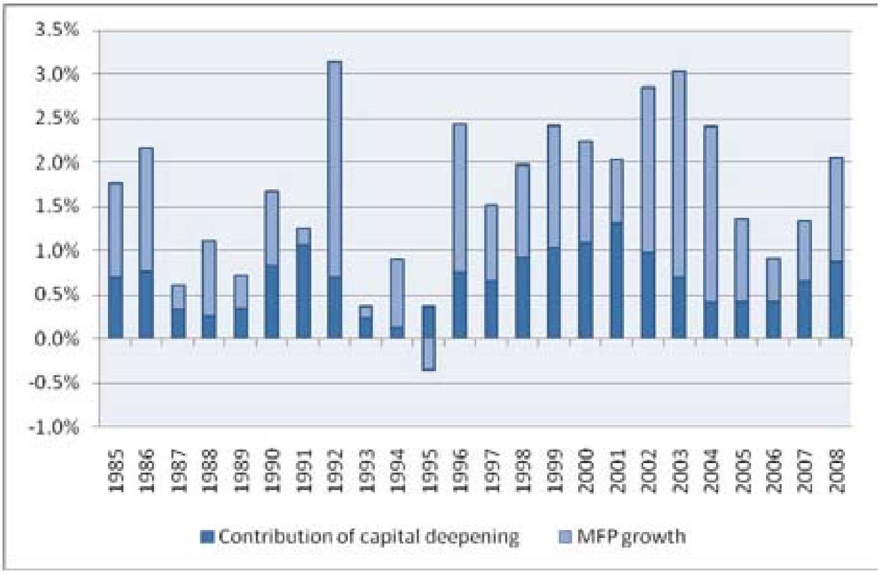
Figure 2. The decomposition of labour productivity growth in MFP growth and capital deepening, 1985-1994, 1995-2001, 2002-2004, and 2005-2008 (average annual growth rates)



Source: OECD Productivity database, September 2009

Figure 3 enables to look with more detail, year by year, on the evolution of this decomposition of labour productivity for the US. An interesting feature is an apparent revival of MFP and capital deepening since 2006.

Figure 3. The decomposition of labour productivity growth in MFP growth and capital deepening in the US, (annual growth rates)



Source: OECD Productivity database, September 2009

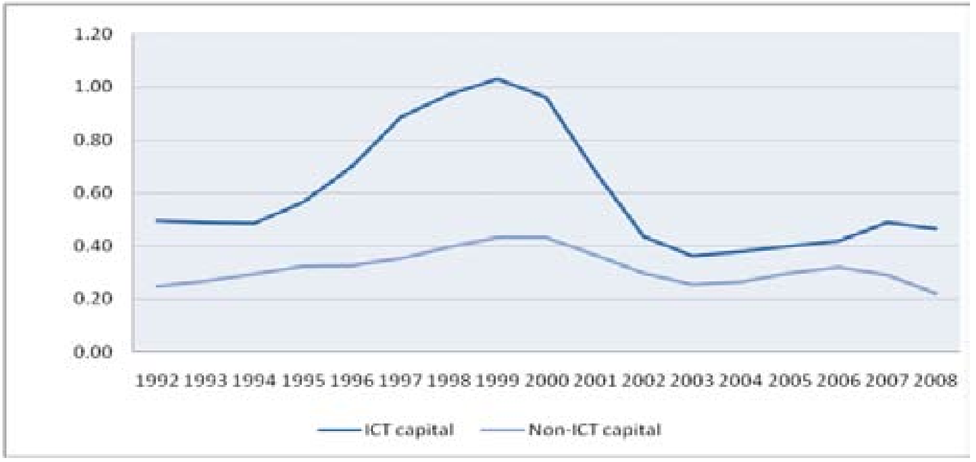
2.2 The role of technology for labour productivity

The impact of technological changes on productivity growth has already been assessed in several studies (e.g. OECD 2003b, Colecchia and Schreyer 2001). The contribution of ICT capital in GDP growth is measured using capital services by type of assets using the OECD productivity database, measured as variations of productive capital stocks. The contribution of ICT capital reflects two effects, the growth rate of the input and its relative importance in production.

In the US, investment in Information and Communication Technologies (ICT) explains the bulk of capital's contribution to GDP growth. However, the contribution of ICT capital to GDP growth fell in most OECD countries between the periods 1985-2006 and 2001-2006. Figure 4, shows some evidence for a significant effect of deceleration in the contribution of ICT capital to GDP growth in the period 2000-2003 in the US. Over the same period, the contribution of non-ICT capital only decreased slightly. Then, the contribution of ICT capital to GDP growth remained stable over the years after 2004. The average service life of ICT equipment being shorter than the one of non-ICT capital, the influence of the fluctuations in real investment is more important for ICT capital services than non-ICT, and the ICT capital services are more sensitive to the business cycle (see OECD 2003 and Colecchia and Schreyer 2001). The 2004 break in the rising contribution of ICT confirms the hypothesis of a break in ICT investment after the bust of the Internet bubble.

In contrast, MFP growth accelerated from 2001 to 2003, reacting with some lag to the accumulation of ICT investments of late 1990s. After 2003, MFP growth has declined probably also reflecting with a lag the slowdown in ICT investment.

Figure 4. Contribution of ICT and Non-ICT capital in GDP growth in the US (annual growth rates)



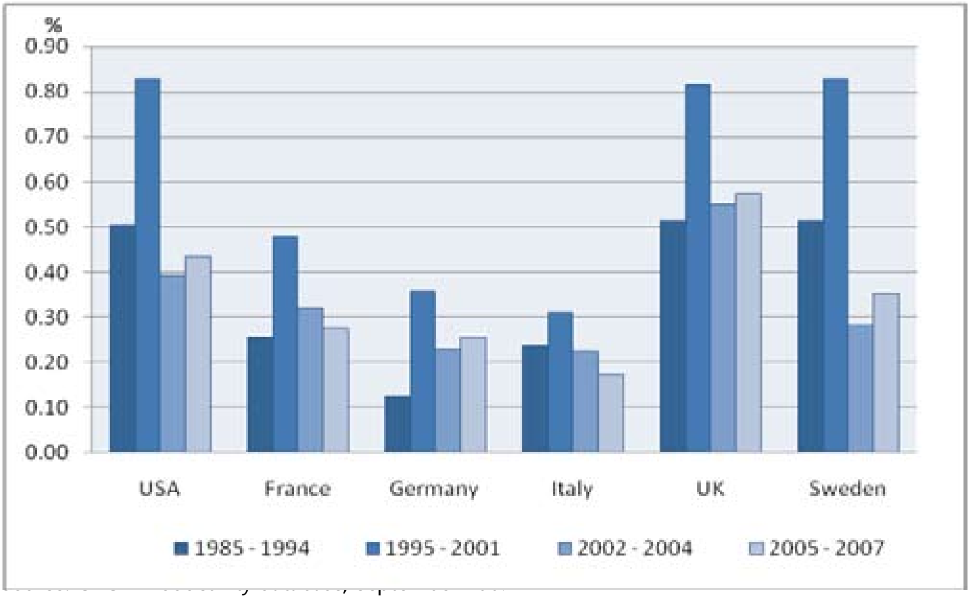
Source: OECD Productivity database, September 2009

Figure 5. Growth in MFP in the US (annual growth rates)

Source: OECD Productivity database, September 2009

The Figure 6 shows the evolution of ICT investment in France, Germany, Italy and Sweden and in the United Kingdom compared with the US. The sharp decrease in the contribution of ICT capital is noticeable in all countries comparing periods 1995-2001 and 2002-2004. However, it is noticeable that the contribution of ICT capital was less significant in France, Germany and Italy than in Sweden, in the United Kingdom or in the United States in the years 1995-2001.

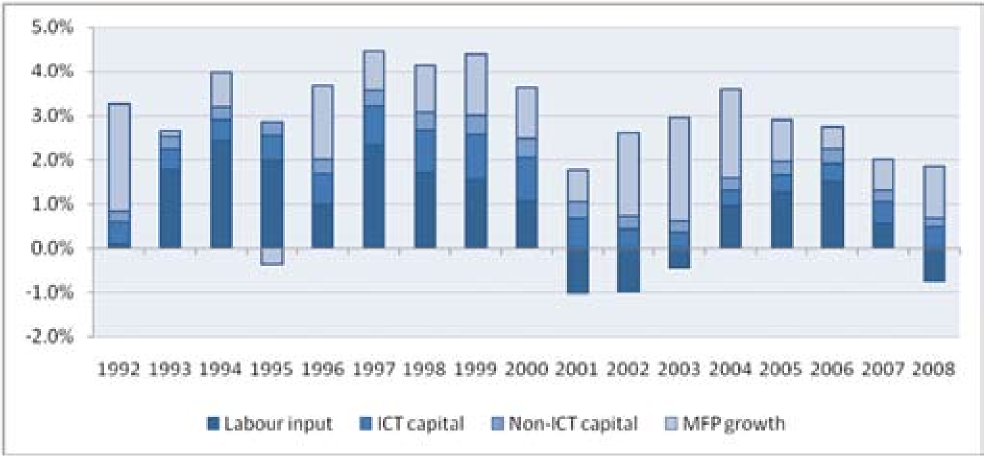
Figure 6. The contribution of ICT capital to the growth in GDP (average annual growth rates)



2.3 Growth accounts

Having analysed the components of labour productivity growth, a growth accounting approach can be presented. At the total economy level, the growth accounting is a weighted average of labour and capital inputs (weighs are respective share in total costs). For example, the contribution of labour to the growth in value added is measured as the speed with which labour input grows, multiplied by the relative importance of labour captured by its share in total costs. The growth contribution of capital is measured in a similar way so that the growth contribution reflects two effects, the growth rate of inputs and their relative importance in production.

Figure 7. The components of GDP growth in the United States

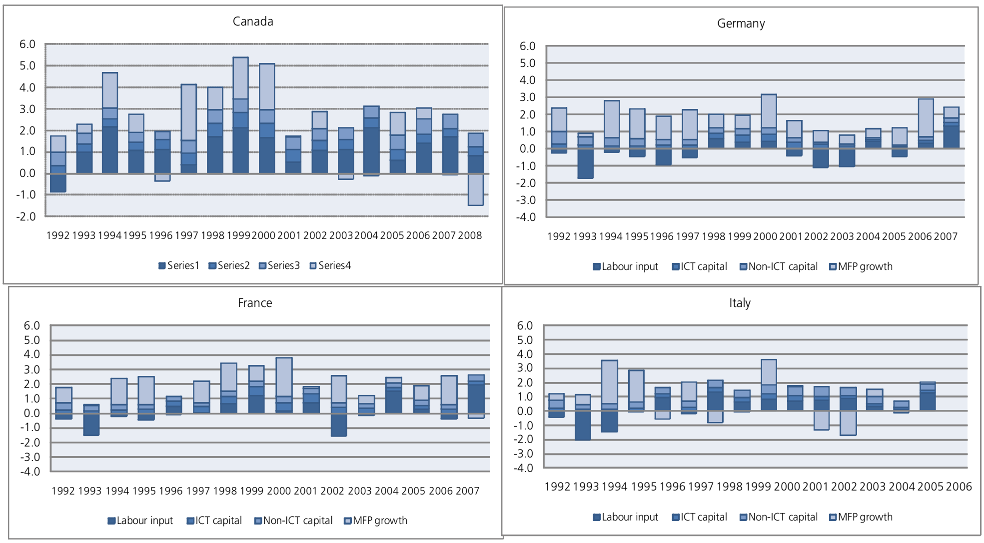


Source: OECD Productivity database, October 2009

At the aggregate level, from 1992 to 2008, GDP growth in the US was for a large part driven by growth in capital and MFP. Growth in capital accounted for around 0.9 percentage point of GDP growth from 1992 to 2008. Over the same period, ICT capital services represented between 0.6 percentage points of the growth in GDP. Growth in labour input was also significant. However, looking at the most recent years allows understanding the changes in productivity in the US. From 2001 to 2003, the contribution of labour input is negative in the US while the growth in MFP increases significantly. An opposite evolution can be observed during the following years, i.e. a slowdown in MFP growth and an increase in the contribution of labour input. But again, in 2008 the contribution of labour input is negative while the growth in MFP is rising, the contribution of capital remaining stable.

Figure 8, comparing the components of GDP growth of Canada, France, Germany and Italy, suggest that GDP growth was for a large part driven by growth in capital and MFP. Growth in labour input was less important than in the US. The contribution of growth in MFP was very small in Canada.

Figure 8. The components of GDP growth in Canada, Germany, France and Italy



Source: OECD Productivity database, October 2009

3. Which sectors are responsible for the slowdown of the labour productivity growth in the US?

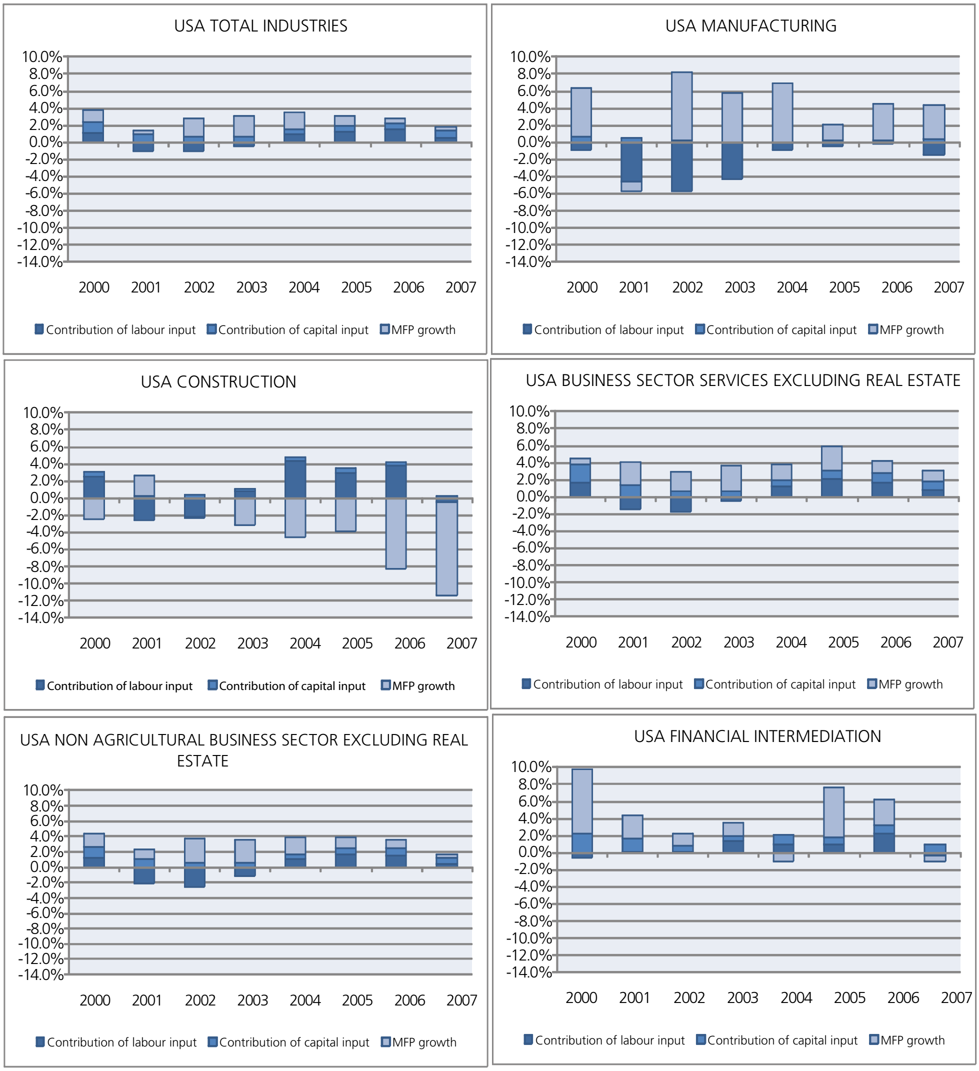
More disaggregated data can help to understand which sectors are responsible for the slowdown of the labour productivity growth in the US (measurement issues are discussed in Annex). To identify which sectors are responsible for the productivity slowdown in the US, Figure 9 breaks US productivity growths into six sectors: total industry, manufacturing, construction, business sector services excluding real estate, non agricultural business sector excluding real estate and financial intermediation.

While the picture for some industries (financial intermediation) is somewhat volatile, growth rates in MFP are significantly lower since 2004 than in the previous years. However, an important driver in the decline of MFP is the construction sector, which account for 6% of the total value added (see table 1 below) but due to the poor productivity performance has been a significant drag on aggregate productivity. MFP growth in the US construction sector is negative from 2000, while the contribution of labour input accounts positively on the growth in GDP.

By contrast, for the business services, the growth in MFP accounts positively in GDP growth in the years from 2000 while the contribution of labour productivity declined noticeably over the same period.

The picture in the sector of financial intermediation differs as the growth in MFP contributes significantly more to the growth in GDP in 2005 and 2006 compared with the previous years. Hence, Figure 9 suggests a positive effect of the direct and indirect use of ICT related financial intermediation on productivity growth. The development of new financial instruments related to increased use of ICT instruments might explain this trend in productivity in this sector. Moreover, the contribution of labour productivity rose over this period. However, both growth in MFP and contribution of labour productivity to the growth in GDP growth were negative in 2007.

Figure 9. Growth accounts by industry in the United States (contributions in %)



OECD Productivity database by industry, September 2009

Table 1. Value added and employment shares by industry, average 2004-2007

	USA		France		Italy		Germany		Canada		Spain	
	Value Added	Employm.	Value Added	Employm.	Value Added	Employm.	Value Added	Employm.	Value Added	Employm.	Value Added	Employm.
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Agriculture, hunting, forestry and fishing	1.58	1.25	3.54	2.61	4.17	2.55	2.20	1.06	2.48	2.25	5.00	3.45
Industry including energy	11.09	19.06	14.17	17.12	21.18	24.05	20.46	29.06	14.68	29.62	16.68	19.76
Non-agriculture business sector excl. real estate	62.66	71.87	61.85	68.53	67.23	73.48	67.24	73.26	69.83	75.76	67.73	73.62
Manufacturing	10.32	14.72	13.49	15.18	20.49	21.28	19.49	26.23	12.72	17.94	15.98	17.25
Construction	6.31	5.32	6.61	6.91	7.60	6.98	5.71	4.53	6.68	6.46	12.76	12.80
Business sector excl. real estate	45.26	47.49	41.19	44.51	38.46	42.45	40.96	39.99	48.47	39.68	38.30	41.06
Financial intermediation	4.29	8.95	3.12	5.67	2.51	5.59	3.18	5.40	5.52	8.27	1.99	5.29

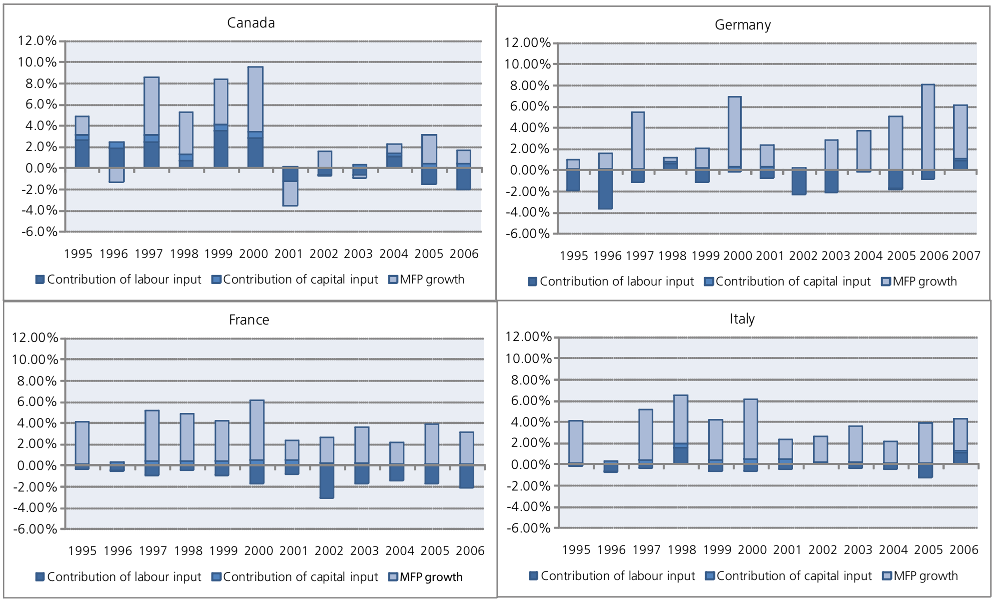
Source: OECD STAN database for Industry Analysis

4. Productivity trends by industry in Canada, France, Germany and Italy

The growth accounts by sector in the main OECD countries (namely Canada, France, Germany, and Italy) as illustrated next. Figures 11 to 12 compare MFP growth and input contributions to the growth in value added in the manufacturing, construction, and financial intermediation sectors. The components of growth follow similar patterns in European countries but diverge from those observed in the US and in Canada, especially from 2004.

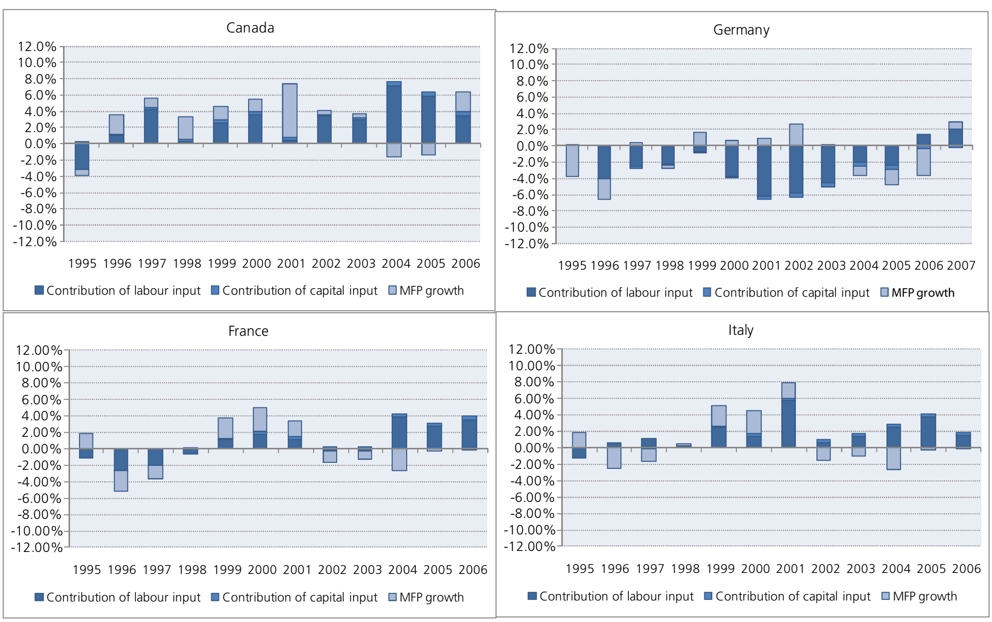
GDP growth in the manufacturing sector was for a large part driven by growth in MFP in most of the main OECD countries in Figure 10. However, the growth in MFP for construction was negative and declined markedly in the US over the period 2003-2007. MFP growth was also negative in Canada, France, Germany and Italy during this period. A noticeable increase in MFP growth also occurs during the years 2005-2007 in most of these countries, confirming the potential role of the development of new financial services.

Figure 10. Growth accounts in Manufacturing



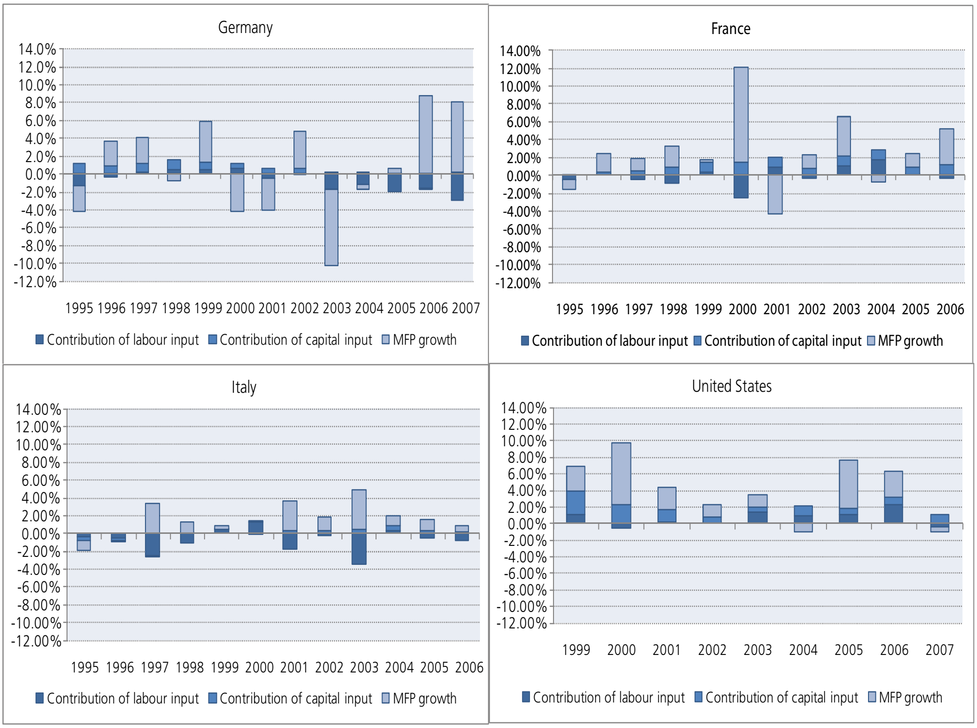
Source: OECD Productivity database by industry (estimates), October 2009

Figure 11. Growth accounts in Construction



Source: OECD Productivity database by industry (estimates), October 2009

Figure 12. Growth accounts in Financial intermediation



Source: OECD Productivity database by industry (estimates), September 2009

This analysis underlines the need for timely productivity estimates both at sectoral and total economy level. In this context, the first set of productivity by industry estimates computed by the OECD provides useful information for productivity analysis and can be linked to the measurement of innovation effects. A further development would require a decomposition of the capital input by type of asset in order to illustrate the role of ICT in the changes in productivity over the recent years. This type of approach has been developed in the context of the EU-KLEMS Project (Timmer et al., 2007), but currently estimates for the most recent years are not yet available.

5. Innovation and the productivity cycle

The analysis above has shown that a slowdown in productivity started long before the current crisis: in fact trend productivity slowed down after the Internet bubble burst of 2001, after having accelerated in the late 2000s in some countries. Looking at the components of productivity growth, we have seen that: i) the contribution of ICT capital dropped after the 2001 crisis (although the contribution of non-ICT capital did not decline significantly); and ii) MFP dropped in 2004-2005, depending on countries. What could explain this change in trend productivity? Economic analysis points to three major potential culprits:

The business cycle: according to certain studies, the change in economic activity has a positive, although lagged impact on productivity growth, due notably to the intensity of labour and lags in lay-offs in case of downturn. This explanation does not seem to correspond to the current cycle. As showed above, productivity slowed down when economic growth was still positive, and it picked up in the US just a few months after the crisis started in the course of 2007. Hence no visible pattern designates the business cycle as an explanation here.

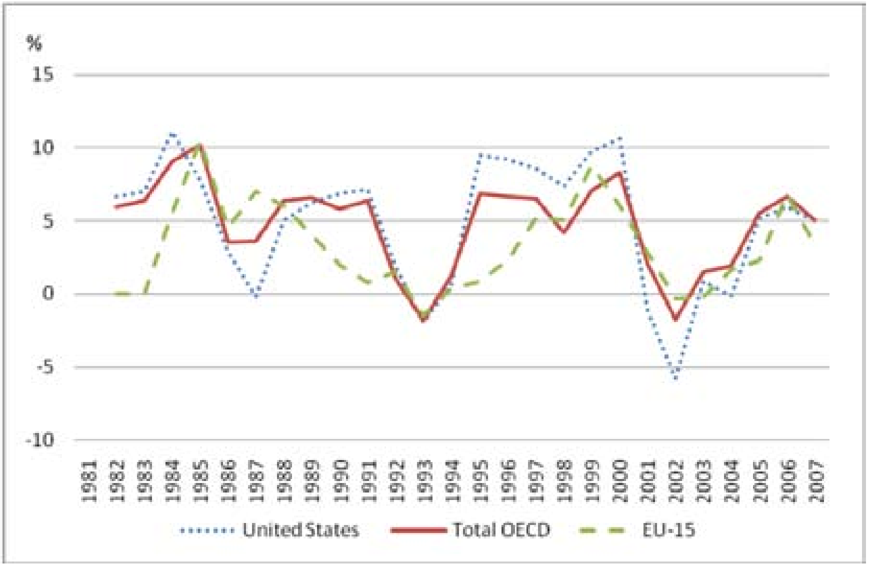
- **Human capital:** education and skills are major factors of productivity growth in the long term. It explains much of cross-country differences in productivity. However, one would expect that human capital, as a quite slow moving variable, would not trigger rapid changes in the pace of productivity, like those which occurred in the recent years.
- **Innovation:** the impact of innovation on productivity is shown by many studies both theoretical and empirical, at the enterprise, sectoral or national level. New products and new processes allow increases in the quality and variety of products and of the efficiency of productive activities, all components of productivity growth. Many quantitative studies have related productivity to indicators of innovation, usually expenditure in research and development (R&D), which is the most widely available indicator of innovation at international level. There is a convergence of the literature towards a highly positive impact: for instance Guellec and van Pottelsberghe (2004) find that an increase of business R&D expenditure by 1% can increase MFP by 0.1 to 0.2% at the national level. Thus, innovation is a candidate for explaining the slowdown in productivity growth of the early century. For this link to be valid there should be a slowdown or a decline in indicators of innovation at a similar time (the literature sees a rather short lag, of 1 to 2 years for the bulk of the impact of innovation on productivity). Accordingly, three indicators of innovation are examined below: business funded R&D, Patents applications and trademarks registrations. None of them is perfect, and have their limits; however, these are the only indicators available as time series for innovation. Their drawbacks are somewhat different from each other, so that it can be expected that if they point into the same direction it should give a rather robust message.

5.1 Business funded R&D

R&D (research and development) expenditure is an investment which results in new knowledge, new products or processes (see the Frascati Manual, OECD 2002). R&D can be funded by government or by businesses. Government funded R&D aims mainly at producing new fundamental knowledge or satisfying social needs like health or defence. Business funded R&D results rather in increasing productivity, when it is successful. Business funded R&D is pro-cyclical, as it is subject to financing constraints (available cash puts a limit on R&D expenditures).

As showed in Figure 13, businesses increased significantly their R&D expenditure in the late 1990s, notably in the US (an average growth rate of about 9% a year in 1995-2000) but also, to a lesser extent, in the EU. After a through in 2001-2002, particularly deep in the US, business funded R&D recovered on progressively after 2003 and did not achieve then growth rates as high as in the late 1990s in the US and in the EU (around 3% a year only). As the cost of capital was not significantly higher in the latter period than in the former one, this slowdown could be explained by a decline in technological opportunities as perceived by businesses.

Figure 13. Business funded R&D (annual growth rates)



Source: OECD, Research & Development Statistics (RDS) Database, October 2009.

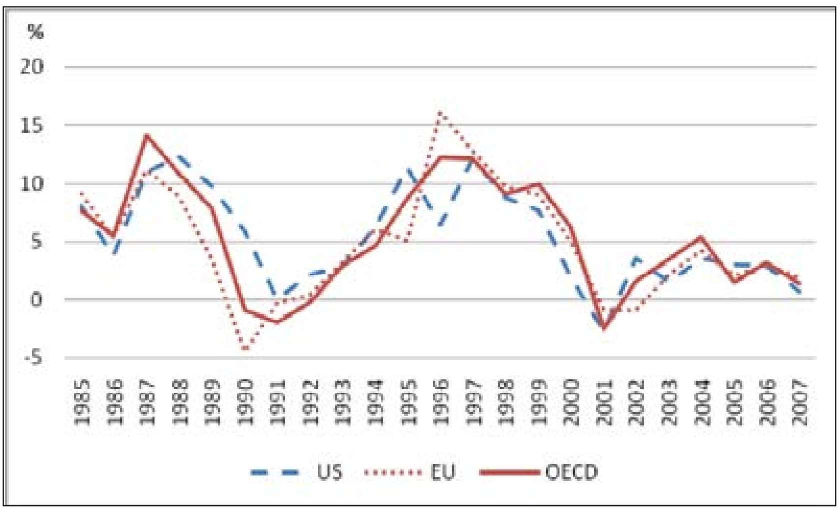
5.2 Patents

Patent are legal titles which provide their holder an exclusive right for exploiting (implementing, selling) an invention. Patent counts are used as an indicator of the pace of invention (Patent statistics Manual, OECD 2009): although it has drawbacks and must be interpreted with care, it also carries unique information, and in the past accelerations in patent fiolings have usually been associated with acceleration in inventions (e.g. around the years 1880s, when electrical technology and modern chemistry were invented). Patents are applied to and granted by national or regional offices, like the European Patent Office (EPO), to applicants coming from any country and seeking protection on the concerned market for their invention. Figure 16 reports patent applications to the EPO, classified by "priority year" (the year of first filing world-wide, which is the closest to the actual invention date).

Patent applications accelerated sharply in the mid to late 1990s all over OECD countries (Figure 14). After a significant drop in the crisis of the early 2000s, patent applications recovered after 2002. However, the growth rate then was on average 3% a year in OECD, against almost 10% in the late 1990s.

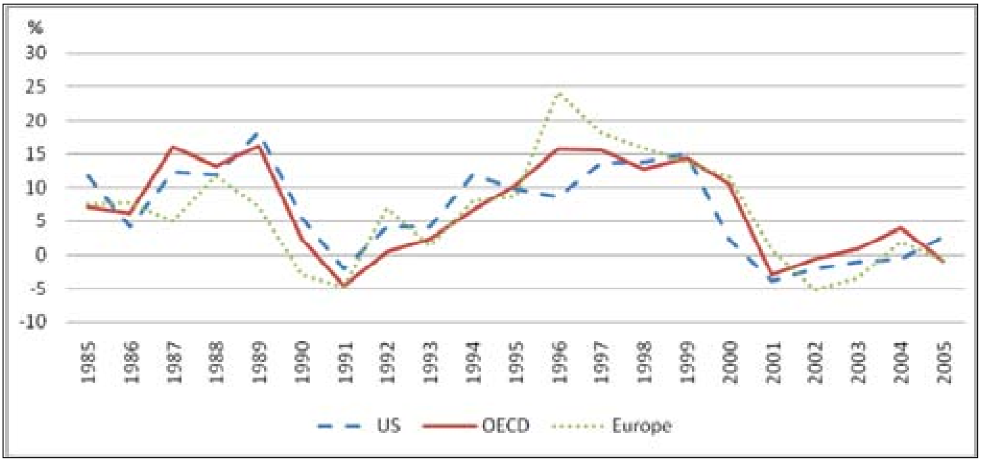
When looking at the technology field composition, it turns out that ICT played a key role in this dynamics (see Figure 15). Patent applications in ICT fields are more than one third of all applications, hence contributing significantly to aggregate changes. These applications increased by around 15% a year in the second half of the 1990s, and they were down to about 0 to 5% in the years 2000.

Figure 14. Patent applications at the EPO (annual growth rate)



Source: OECD, PATSTAT Database, October 2009

Figure 15. Patent applications to the EPO in ICT fields (annual growth rate)

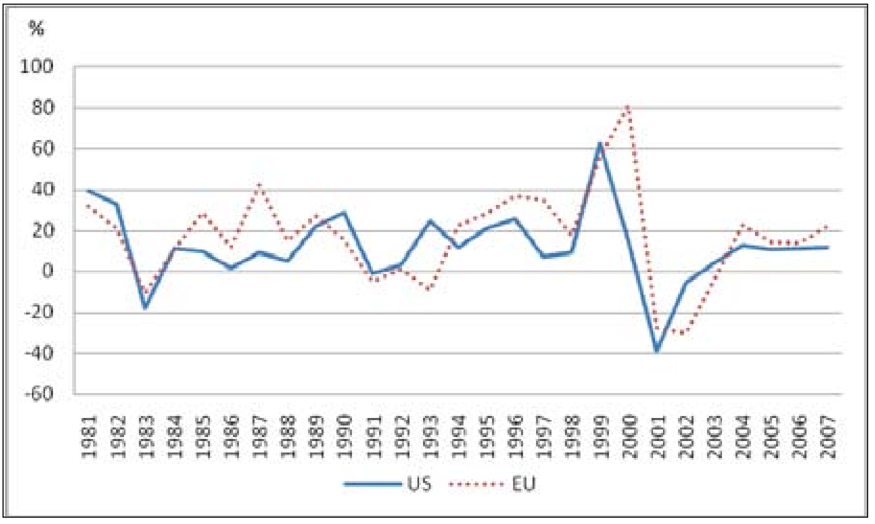


5.3 Trademarks

Trademarks are legal protections for distinctive signs of products, such as names or logos. Trademark activity reflects the introduction of new goods or services on the market, or changes in marketing strategies for existing products. It is therefore related to innovation, including non technological innovation. More than R&D, which is an investment, and patents, which reflect inventions, trademarks are really a downstream indicator, reflecting commercialized products. Trademarks are filed at the country level, to the national office in charge, by applicants from any country. Trademarks are filed at the USPTO for new products and marketing targeting the US market.

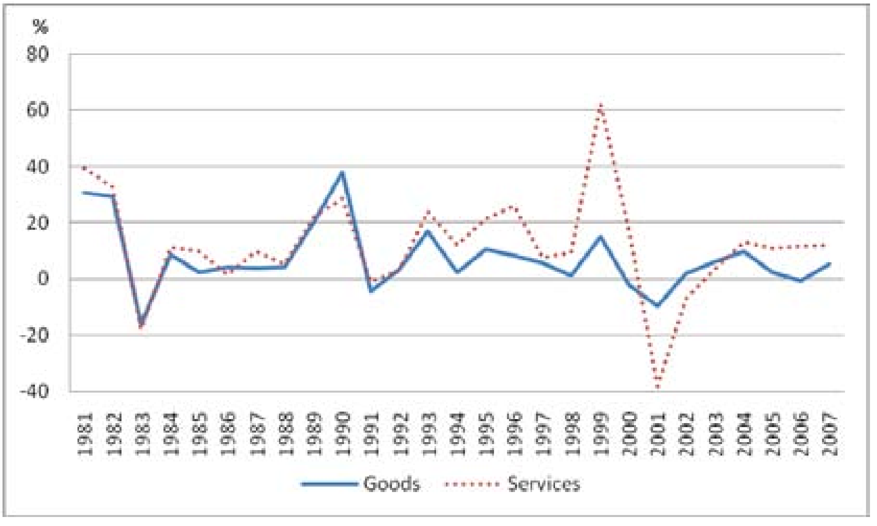
Trademark filings are pro-cyclical (Figure 16) as they are driven by the size of the market. They surged in the period 1995-2000, growing on average by 18.0% a year for EU holders and 12.8% for US holders. The growth was led by service related marks, and it culminated in 1999 and 2000, in connection with the internet bubble: many internet related marks were filed these years, reflecting both actual new services and also the anticipation of possible future services for which companies and individuals where acquiring pre-emptive rights.

Figure 16. Trademarks filed to the USPTO (annual growth rate)



Source: Source: USPTO, Trademarks Database, 2008.

Figure 17. Trademarks filed to the USPTO by OECD entities (annual growth rate)



Source: USPTO, Trademarks Database, 2008.

Trademarks for goods did not experience a higher than usual growth rate in the late 1990s. The drop in 2001-2002 was sharp, and it was stronger for services than for goods. The recovery that followed has been significant, but the pace in 2003-2007 was 6.9% for US holders and 9.5% for EU holders on average, much lower than in the late 1990s. The difference between the two periods is higher for services than for goods, although services continue to outpace goods after 2004.

On the basis of these indicators, it makes sense to conclude that the pace of innovation has been slower since the crisis of the early 2000s than it was in the late 1990s. The latter experienced the "IT wave", or "internet wave", with a surge in innovation relating (and driven by) information technology and the internet. All indicators of innovation dropped during the internet bubble burst (Table 2), and when they recovered, after 2003, they did not reach back their levels of the late 1990s, but instead their average level of the previous period, before the pre-internet wave acceleration. It is trademarks relating to services and IT-related patents which explain the acceleration and subsequent slowdown.

Table 2. Comparison of 1995-2000 and 2003-2007 (average annual growth rates)

	Business funded R&D		EPO Patent applications		USPTO Trademarks	
	1995-2000	2003-2007	1995-2000	2003-2007	1995-2000	2003-2007
EU	4.7	2.8	9.6	2.7	18.0	9.5
US	9.2	3.4	8.1	2.4	12.8	6.9
Japan	3.7	4.9	12.0	2.1	13.7	2.1
OECD	6.6	4.1	9.7	3.0	13.0	7.0

This slowdown in IT innovation would explain why businesses reduced investment in IT equipment and software after 2003 (hence the drop in the contribution of IT capital to GDP growth): the efficiency gains to be expected from new capital relative to installed one were smaller than before. In turn, the slowdown in MFP occurred later, in 2005-2006. One explanation for this, in accordance with the economic literature on technical change, would be that the learning effects that come with new technology and allow users to make the best of them in terms of productivity progressively declined, as the installation of new equipment itself declined. It took a few years for that to happen, as there is normally a lag between implementation and learning.

6. Concluding remarks

This paper reviewed the main productivity trends over the past decade, comparing US, European countries and Japan. The slowdown of productivity appeared to be due to a significant decceleration in ICT investment followed by a decrease in Multi-Factor productivity. The decline of productivity was particularly marked in some sectors, such as construction, and market services. Looking for possible explanations of the decline, a marked slowdown in innovation emerged as the most likely cause.

Taking a forward-looking view, what are the prospects for a productivity recovery, when the current downturn will have passed? If no new wave of innovation, comparable in size to the one of the late 1990s, happens again, there is little reason why trend productivity growth would recover its level of the late 1990s. Instead, the type of regime of mid-1970s to mid-1990s could prevail again. The current acceleration in the US productivity is due to a massive reduction in the labour force and, therefore, is not sustainable of that basis. Only a recovery in innovation itself will trigger a sustainable recovery in productivity.

ANNEX: The measurement of MFP by industry

The estimates of MFP at the industry level have been computed in the framework of the OECD Productivity database by industry (hereafter, PDBi). The method used for PDBi is, as far as possible, consistent with the one used for the aggregate level released in the OECD Productivity database (hereafter PDB). The MFP measures are developed in the framework of the OECD STAN Database for Industry Analysis (STAN). The guiding principles in the construction of PDBi indicators are to consider industry aggregates as single units in the calculation process, to exclude the real estate activities, and to represent capital by a single type of asset.

Under the assumptions of perfect competition and constant returns to scale, growth in total factor productivity can be defined as the Solow residual, and then written as following:

$$\Delta \ln MFP = \Delta \ln(q) - \alpha \cdot \Delta \ln(l) - (1 - \alpha) \cdot \Delta \ln(k) \qquad (1)$$

Where α is the revenue share of labour (*wL/PQ*), *q* the volume value-added, *l* the labour input, and *k* the capital input computed as described below. For each industry, labour input is represented by the total hours worked of all persons engaged from STAN. When total hours worked are missing, the total hours worked of employees or the hours worked at the level of the total economy is split into the STAN industry breakdown using the structure of employment.[2]

The estimation of the industry-level multi-factor productivity requires the measurement of the labour input, the capital input and the growth rate in production. The capital input of a specific industry is represented by a single type of asset and computed applying geometric depreciation rates to the Perpetual Inventory Method (PIM), which estimates the constant prices values of capital stocks still in use by summing the original investment data for this asset over its lifetime. A standard approach with geometric rates of depreciation δ is applied to obtain harmonised net capital stocks by industry. Then, the capital stock at the beginning of period t, Kt, is as follows:

$$K^{t+1} = K^t + [I^{t+1} - \delta(I^t/2 + K^t)] \qquad (2)$$

then

$$K^{t+1} = K^t (1 - \delta) + I^t (1 - \delta/2) \qquad (3)$$

It is important to note that K_t is a measure of the capital stock and not of the capital services. This reflects absence of investment data cross-classified by asset and industry. Thus, unlike the PDB data, PDBi capital input is not a measure of capital services.

[2] *Full-time equivalent, full-time equivalent employees, total employment or employees (priority order) have been used as proxy.*

The initial net capital stocks K^0 is approximated for the year 1984 by the cumulative depreciated investment of previous years, using the long-run growth rate of investment volume:[3]

$$K^0 = \frac{GFCK_{1984}}{(\delta_{1984} + (\frac{GFCK_{1983}}{GFCK_{1960}})\hat{}(1/(1983-1960)) - 1)} \tag{4}$$

Depreciation rates by industry and by asset ($\delta_{i,k}$) are collected from the EUKLEMS database and adjusted establishing the equality between their average weighted by the ratio between investment in a particular industry and investment for the total industries (from STAN), and the asset specific depreciation rates (δ_k^{PDK}) at the level of the total economy from PDB, to take into account some country specific conditions:

$$\sum_i (\frac{GFCF_i}{GFCF_{Tot}})\delta_{i,k} = \delta_k^{PDB} \tag{5}$$

Then, country specific depreciation rates by industry (δ_i) are calculated as the weighted average of asset-specific depreciation rates ($\delta_{i,k}$) and using shares of net capital stocks of asset k (K^t_k) in the aggregate net capital stocks (K^t_{Tot}) at the level of the total economy from PDB[4] as weights:

$$\delta_i = \sum_k (\frac{K_k^t}{K_{Tot}^t})\delta_{i,k}^t \tag{6}$$

The consistency with PDB is also ensured by the use of an exogenous rate of return.[5] This way, an independent estimate for the remuneration of capital input is generated. The user cost of capital is:

$$R_i = P_i.((i - \frac{\Delta CPI^e}{CPI}) + \delta_i - (\frac{\Delta P_i^e}{P_i} - \frac{\Delta CPI^e}{CPI})) \tag{7}$$

Where *i* is the representative long-run nominal interest rate, and δ_i the depreciation rate of the representative asset in the industry *i* computed as above. Assuming that expectations about investment prices *Pi* follow approximately expectations about CPI, the user cost of capital is equal to the anticipated real interest rate plus

[3] *GFCK volume investment time-series available in STAN are backward extrapolated to 1960 using volume investment time-series from OECD Annual National Accounts database.*

[4] *When Kt is not available from PDB, estimates for the United States are used as benchmark.*

[5] *See Schreyer, Dupont and Bignon (2003) for a description of the method and the OECD Capital Manual (pp. 85-87) for an overall discussion on this issue.*

the anticipated depreciation times the beginning of the period stock price of the representative asset in the industry *i*:

$$R_i \equiv P_i.(RIR+ \delta_i) \quad (8)$$

Where the real interest rate RIR = $(1+r^*)(1-p_t)-1$

The expected real rate of return r* is assumed to be constant but country specific for the whole period. The constant real rate of return is computed by taking the long-run average of annual real rates of return. These are measured as observed nominal rates (un-weighted average of interest rate with different maturities) deflated by the consumer price index (CPI), pt representing the expected overall inflation rate.

Then R represents the user cost per unit of capital stock at constant dollars for an industry as:

$$R_i \equiv P_i. [((1+r)/(1+p)) - 1 + \delta_i] \quad (9)$$

The labour share of a specific industry is computed taking into account the mixed income effect:

$$\alpha_i = \frac{(WL_i.(\frac{EMPN_i}{EMPE_i}))}{(WL_i.(\frac{EMPN_i}{EMPE_i}) + RK_i)} \quad (10)$$

with WL the compensation of employees, EMPN the total employment, EMPE the number of employees, and RK computed as above description. MFP is estimated according to equation (1). As already mentioned, the main drawback of the simplified approach outlined above is that it neglects capital services and is therefore not the recommended measure for capital input and productivity calculations.[6]

6 *Net capital stock and capital services could differs unless the unrealistic case applies where the prices of all types of assets move at the same rate and each type of asset depreciates at the same rate.*

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