PAPERS PRESENTED AT THE SALTSJÖBADEN CONFERENCE OCTOBER 2007

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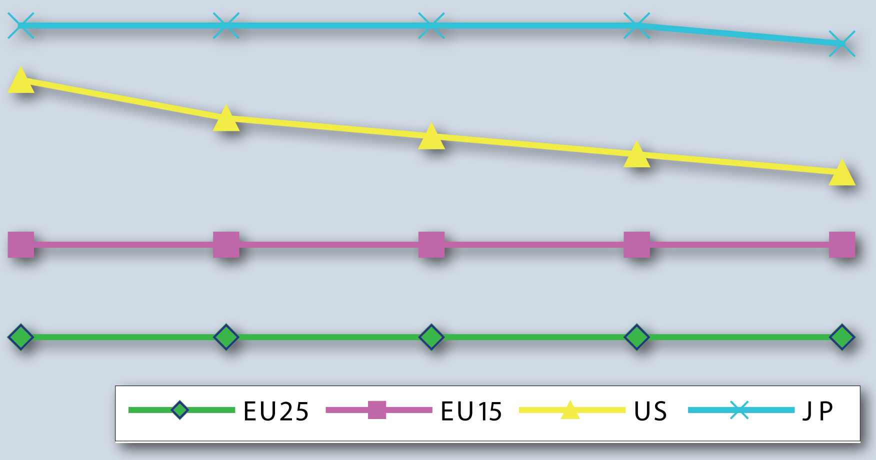

Yearbook on Productivity 2007

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2008

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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.

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 third one and was presented at our yearly conference in Saltsjöbaden as the coming yearbook. We want to especially thank Funda Celikel Esser and Ph.D. Ernesto Villalba at the Institute for Protection and Security of the Citizen (IPSC) European Commission- Joint Research Centre, Tarek M. Harchaoui, Catherine Michaud and Joanne Moreau at Statistics Canada, Dominique Guellec and Maria Pluvia Zuniga at the OECD, Bart van Ark at the University of Groningen and Charles Hulten University of Maryland and Emma Nilsson and Adrian Adermon at the University of Uppsala for their contributions. We also are in debt to Hans Lööf at the Royal Institute for Technology for Mariagrazia Squicciarini, VTT Technical Research Centre of Finland and KUL Leuven and Pierre Mohnen from Merit at the Maastricht University for many important comments and suggestions on our preliminary article on innovation. Those involved at Statistics Sweden include Martin Daniels, Tomas Skytesvall, Caroline Ahlstrand and Hans-Olof Hagén, Project Manager.

Kjell Jansson	Hans-Olof Hagén
Director General	Project Manager

Contents

The Lisbon strategy and development of metrics to measure innovation in Europe

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Abstract

The Lisbon Strategy, launched in 2000, gives major importance to innovation in order to achieve the strategic goal the European Union set: being the most competitive knowledge society by 2010. In addition, the Lisbon agenda set up the Open Method of Coordination (OMC) as a policy tool to promote exchange of best practices and policy learning among Member States. The OMC relies heavily on the creation and use of indicators and benchmarks. This paper presents a short overview of the European policy approach towards innovation from 2000. Special emphasis is placed upon the measurements of innovation and on the innovation performance of the EU vis-à-vis its main competitors based on the innovation indicators created within the framework of the Lisbon strategy.

1 *Funda Celikel Esser is with the research group Indicators and Benchmarks for Education Innovation and Knowledge Economy. Dr. Ernesto Villalba works for the Center for Research on Life Long Learning. The authors wish to thank Stefano Tarantola, who contributed to the final draft of this paper.*

Introduction

It has become a widespread view in research and policy making that success in innovation is closely linked to better economic performance, increased productivity, and growth[2]. Innovation policy today is a complex "toolbox" aiming to improve the innovation performance on the national and European level. The main aim of this paper is to analyze this "toolbox" at the European level and give a substantial overview of the innovation policy in Europe and the tools to exercise it. The paper starts with giving a general idea of the European policy of innovation that has started with the launch of the Lisbon agenda in 2000. It continues with an overview of measurement actions that the European Commission has taken in the area of innovation. It especially focuses on the European Innovation Scoreboard (EIS) and its developments. While in the second part we give brief chronological information about the various steps that were taken to develop the scoreboard since 2000, in the third section, we use the EIS dataset to portray an indication of the innovation performance of the Member States and the EU in comparison with their main competitors.

Policy Background: *The Lisbon strategy and the Open Method of Coordination (OMC)*

In the year 2000, the Heads of Government and State of the European Union agreed on the so-called, Lisbon Strategy. The Lisbon Strategy set up "a new strategic goal […] : to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion"[3]. The Lisbon Summit introduced the Open Method of Coordination (OMC) in order to achieve this strategic goal. The OMC is a policy instrument based on three main pillars: (1) Common definition of objectives, (2) common definition of instruments and monitoring measures, and (3) exchange of best practices, peer review and mutual learning[4]. There are no sanctions associated with the no fulfillment of the objectives, and thus it is considered as a "soft law" approach. The OMC was originally adopted for different policy areas such as employment or education, but not for Research and Innovation.

In reality, however, the Lisbon Strategy, set three years earlier, already aimed to "encourage the development of an OMC for benchmarking national research and development policies"[2]. The Council specifically asked for the introduction of the

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2 *See for instance Aghion, 2007, Botazzi, 2004, Sapir, 2004 .*

3 *Presidency Conclusions, Lisbon European Council, March 2000.*

4 *See, for example: http://europa.eu/scadplus/glossary/open_method_coordination_en.htm*

European Innovation Scoreboard (EIS). Previously, in 1998, the Commission had introduced the European Trend Chart to monitor changes in innovation policies in Member States[5]. This meant that before the formal decision of applying the OMC to innovation policies, there was a clear policy agreement on instruments for monitoring innovation. In 2002, the Barcelona Council set up the goal of increasing the investment on R&D to 3 % of the GDP by 2010. The Barcelona Council also placed the goal of increasing the business funding on R&D from 56 % to two-thirds of total R&D investment[6]. Later in that year, the Commission published the communication "More Research for Europe: Towards 3 % GDP"[7]. The communication presents the deficit in R&D investment in Europe in comparison with the US and proposed ten different areas for action. These goals and the existence of a measurement tool as the EIS on innovation permitted an easy adoption of the OMC in 2003. In other words, only in 2003 the March European Council agreed to apply the OMC for policies related to investment in research and innovation[8].

Just before this adoption, the Commission produced another Communication on "innovation policy: updating the Union's approach in the context of the Lisbon strategy"[9]. This Communication set up an important preliminary step of what would be the innovation policy later on. The communication on "innovation policy", together with a green paper on entrepreneurship[10], proposes a more broad approach to innovation policies. It refers to the Innovation Scoreboard and the Innobarometer to illustrate the performance gap with the US and Japan. It advocates for a multi-dimensional nature of innovation phenomenon and its implications for policy, among them the coordination of innovation policies with other policy areas to create innovative framework conditions.

It was in 2005, however, after the re-launch of the Lisbon Strategy when innovation becomes even more prominent on European Policy. At this point, "knowledge and innovation" was singled out as one of the three main areas to "help the Union and its Member States drive up productivity and create more and better jobs"[11]. The President of the Commission, Jose Manuel Barroso, put it this way in a Communication to the Spring European Council: "Knowledge and innovation are

5 *European Commission (1998). Implementation of the first Action Plan on Innovation in Europe.*

6 *Presidency Conclusions, Barcelona European Council, March 2002.*

7 *COM (2002) 499.*

8 *Presidency Conclusions, Brussels European Council, March 2003, p. 14*

9 *COM (2003) 112.*

10 *COM (2003) 27*

11 *COM(2005) 24, p. 15*

the beating heart of European growth"[12]. Later in that year, the Communication "More Research and Innovation – Investment for growth and employment"[13] specifies the actions to be taken in this area. It builds on the Community Lisbon Programme (CLP) and the Integrated Guidelines[14] (IG) for the preparation of the National Reform Programmes[15]. This communication indicates four set of actions related to: (1) EU Policies, (2) EU funding, (3) Business innovation and (4) National reform Programmes. In total, the Commission identified 19 actions that would shape innovation policy in Europe for the next few years. Most of the different initiatives set up in the following years, such as Europe INNOVA or PRO INNO find their origin in this Communication. There is also a clear connection established between the European Research Area and innovation polices at the business sector. In addition, in this Communication there is the intention of using the Structural Funds and the European Investment Bank as well as the Seventh Framework Programme to invest in innovation. In this Communication on"More research and Innovation", one can find the origin of setting up the European Institute of Technology to strength the connection between University research and business implementation.

At the end of 2005 within the FP6 priority of"Structuring the European Research Area" the Commission set up the Europe INNOVA initiative. This consists of a sectoral approach for innovation to"inform, assist, mobilize and network the key stakeholders in the field of entrepreneurial innovation"[16]. In October 2005 The Commission launched a call for proposals for creating PRO INNO. PRO INNO is meant to foster trans-national cooperation among innovation agencies and programmes.

PRO INNO was officially started in December 2006; it brings together different initiatives already in place to develop more coherent innovation policies throughout Europe. Reinhard Büscher, Head of the European's Commission's Innovation Policy Development Unit, stated: "We want to shape a European innovation Space… with PRO-INNO our aim is to stimulate co-operation, networking and concrete actions. But this should be on the basis of sound analysis"[17]. PRO INNO has three main strands: (1) Policy Analysis, (2) Policy Learning and (3) Policy Development. Policy analysis includes four pillars:

12 *Ibid, p. 4.*

13 *COM (2005) 488.*

14 *Council recommendation 2005/601/EC of July 2005 on the brad guidelines for economic policies of the Member States.*

15 *http://ec.europa.eu/growthandjobs/key/nrp2005-2008_en.htm.*

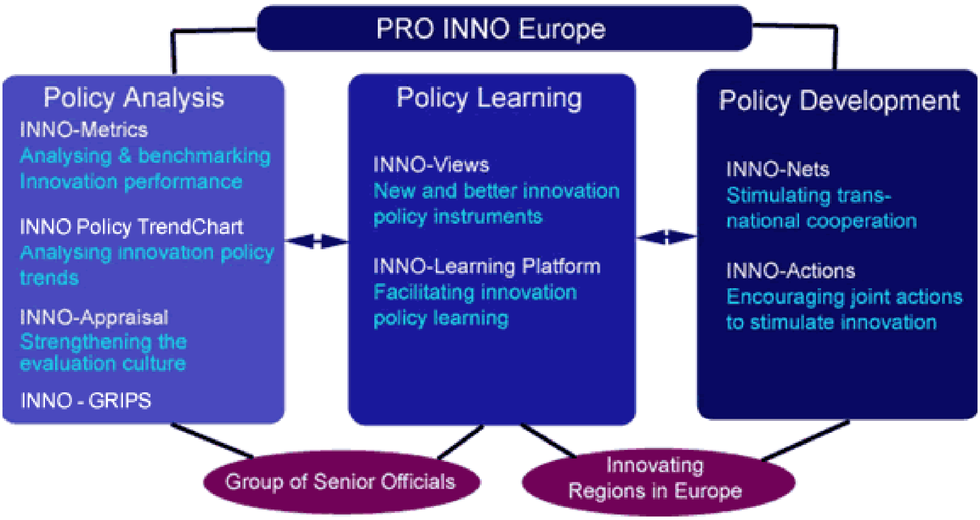
16 *http://www.europe-innova.org*

17 *European Innovation, May, 2007, p. 3.*

- INNO-Metrics
- INNO- Policy Trend Chart
- INNO-Appraisal
- INNO-GRIPS

They all aim at provide evidence to establish what policies might be working better for innovation. Policy Learning is organized in"Inno-views"and"INNO-Learning platforms". They both focus on bringing together all the possible stakeholders on innovation to learn from each other. Finally, Policy Development includes INNO-Nets and INNO-Actions that aim at implement adequate policies[18].

Figure 1 PRO INNO Europe structure



PRO-INNO, arguably, is showing the European Intention of setting up a broad-based innovation strategy initiated in the 2003 Communication on"innovation policy"[19]. In September 2006, the Communication "putting knowledge into practice"put forward this broad-based innovation strategy[20]. The communication set up a road map of 10 actions with"high political priority" (see table 1). These 10 actions summarize policy positions related to innovation that the Commission is taking in different communications presented in 2006 and 2007. In February 2006, the Communication"fostering entrepreneurial mindsets through education and learning"[21] set up the importance of entrepreneurial skills for innovation; the

18 More information on PRO INNO can be found at: http://www.proinno-europe.eu/

19 COM (2003) 112 final.

20 COM (2006) 502 final.

21 COM (2006) 33 final.

year before a Communication on key competences included entrepreneurship as one of the key skills that young people have to possess in order to function in the knowledge society[22]. In September 2007, a Communication on e-skills for the 21st century also shows the importance of e-skills for innovation purposes[23]. In March 2006,"Improving knowledge transfer between research institutions and industry across Europe: embracing open innovation"[24] stressed the importance of knowledge transfer between research institutions and private business. In May, the Communication"Delivering on modernization agenda for universities"[25] stressed the importance of innovation and connection between education, research and innovation. In November 2006, a Communication calls for the establishment of a European Institute of Technology mainly to promote the connection between research and innovation[26]. In the same month the Commission launched a Communication on tax incentives for R&D[27], and Early in 2007, a strategy on Intellectual Property Rights[28].

To sum up, to certain extent, European Policies are now more coherent than ever in terms of research and innovation, and there is a clear political interest in the promotion of innovation in a broad-sense. Links between innovation, research and education are more and more common in policy documents. Education, Research and innovation are now seen as the vertices of the knowledge-triangle upon which the success of the Lisbon strategy depends[29]. The OMC relies heavily on indicators and benchmarks. European Member States are encouraged to learn from each other through the use of this accepted measures and benchmarks. Indicators are seen as tools for Member States to determine their level at one point in time, and to monitor their progress towards the common objectives. The use of indicators and benchmarks encourage in this way mutual learning, and exchange of best practices. Countries that at one point in time might have similar levels can evaluate differences among them at other point in time. It is because of this major importance of indicators that the rest of the paper, identifies those indicators in the area of innovation as used by the European Union.

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22 COM (2005) Key skills

23 COM (2007) 496 final

24 COM (2007) 182 final

25 COM (2006) 208 final.

26 COM (2006) 604 final/2.

27 COM (2006) 728 final.

28 COM (2007) 165 final.

29 COM (2007) 703 final

Table 1 A road map for a more innovative Europe* (to be redone)

Action 1: Member States are invited to significantly increase the share of public expenditure devoted to education and to identify and to tackle obstacles in their education systems to promoting an innovation friendly society. In particular, they should implement the recommendations included in the Communication "Delivering on the Modernization Agenda for Universities"19 for better education and innovation skills.

COM (2006) 208 "Delivering on the modernization agenda for universities: Education, research and innovation"

COM (2006) 33. "Fostering entrepreneurial mindsets through education and learning"

E-skills for the 21st Century: Fostering Competitiveness, Growth and Jobs (COM(2007) 496)

Action 2: A European Institute of Technology should be established to help improve Europe's innovation capacity and performance. The Commission intends to put forward a proposal in October 2006 and the EIT should be operational by 2009.

Proposal from the Commission to establish a European Institute of Technology (COM(2006)604)

Action 3: The Community and Member States should continue to develop and implement a strategy to create an open, single and competitive European labor market for researchers, with attractive career prospects, including possible incentives for mobility..

Green paper on 'The European Research Area: New Perspectives' (COM(2007)161).

Action 4: In order to address the poor up-take of research results in Europe, the Commission will adopt a Communication in 2006 - including voluntary guidelines and actions of Member States and concerned stakeholders - to promote knowledge transfer between universities and other public research organizations and industry.

Communication from the Commission on 'Improving knowledge transfer between research institutions and industry across Europe: embracing open innovation' (COM(2007)182)

Action 5: The EU's cohesion policy for the period 2007-2013 will be mobilized in support of regional innovation. All Member States should seek to earmark an ambitious proportion of the 308 billion € available for investing in knowledge and innovation.

The Council Decision of 06.10.2006 on Community Strategic Guidelines on Cohesion.

Action 6: A new framework for State aid to research, development and innovation will be adopted by the Commission before the end of 2006, to help Member States better target State aid on market failures preventing research and innovation activities. Member States should reorient their State aid budgets to target these objectives, in full respect of their overall commitment to "less and better targeted aid". The Commission will also present a communication later in 2006 with detailed guidance for the design and evaluation of generally applicable tax incentives for R&D..

Towards a more effective use of tax incentives in favour of R & D' (COM(2006)728).

Action 7: Drawing on the recent public consultation, the Commission will present a new patent strategy before the end of 2006 and prepare a more comprehensive IPR strategy in 2007, facilitating inter alia the circulation of innovative ideas.

Enhancing the patent system in Europe' (COM(2007)165

The table continues on the next page

Table 1 A road map for a more innovative Europe*

The table continues from the previous page

Action 8: Building on its review of the copyright acquis, the Commission will continue its work to ensure that the legal framework and its application are conducive to the development of new digital products, services and business models. In particular, it will bring forward an initiative on "copyright levies" before the end of 2006

e-Business W@tch

Action 9: The Commission will test in 2007 a strategy to facilitate the emergence of innovation friendly lead-markets. In this context, it will conduct, after a public consultation including in particular the Technology Platforms and the Europe INNOVA innovation panels, a detailed analysis of potential barriers to the take-up of new technologies in a limited number of areas. In parallel, using this experience, the Commission will prepare a comprehensive lead-markets strategy.

European Technology Platforms and the Europe INNOVA Innovation Panels

Action 10: The Commission will publish and distribute a Handbook on how pre-commercial and commercial procurement can stimulate innovation by end 2006 to support Member States in availing themselves of the opportunities offered by the new procurement Directives.

**Adapted from COM (2006) 502*

The Development of Innovation Metrics:

The European Innovation Scoreboard (EIS)

The main benchmarking and indicator tools of the European policy makers to assess various dimensions of the innovation in Europe and to actively exercise the OMC are listed as follows[30]:

European Trend Chart[31]

The "Trend Chart on Innovation in Europe" is a practical tool for innovation policy makers and scheme managers in Europe. It was set up in 1998, as a tool to monitor the innovation Policies in Europe. In 2006 it was included within the PRO INNO metrics. It takes up the collection, updating and analysis of information on innovation policies at national and Community level. The Trend Chart supports policy makers in Europe with summarized information and statistics

30 *taken from European innovation policy portal visited on 01/10/2007 http://cordis.europa.eu/innovation/en/policy/home.html*

31 *For more information, please visit http://trendchart.cordis.europa.eu/index.cfm*

on innovation policies, performances and trends in the European Union. It is also a European forum for benchmarking and the exchange of"good practices". It comprises of various measuring, benchmarking and dissemination activities like annual country reports, European progress report, European Innovation Scoreboard, Trend chart workshops etc.

Community Innovation Survey (CIS) [32]

The Community Innovation Survey provides the statistical basis on which the European innovation policies have been built and answers the policy makers' questions about innovation, even when they are related to intangibles. It has been done so far four times, from 1992 onwards, by the Member States and has been coordinated by the statistical office of the European Commission, EuroStat. The methodological basis of the CIS is provided by the"Oslo manual", a joint publication of EuroStat and the OECD. Data collection is done by the statistical offices or competent research institutes in the Member States. The results of the surveys are treated at national level using a common methodology and further processed by EuroStat to increase cross country comparability.

Inno-barometer [33]

The Innobarometer is an opinion poll done by the European Commission since 2001 under the Euro barometer poll system. The main objective of the survey is to explore the opinions of European managers on their companies' needs and investments in innovation as well as the output achieved. The main theme of Inno-barometer has been different each year. Some examples of the topics that have been analyzed so far are"the main factors that push innovation (2002)","the role of European integration in access to advanced technologies, mobilization of human resources, protecting and sharing knowledge, access to funding and customer acceptance of innovations (2003)" and" public support to innovation (2004)". For each theme addressed, the reports present the results obtained in relation to:

- the European Union as a whole and each of its 15 Member States,
- the various types of companies in terms of workforce size,
- the company's sector of activity,
- the share of turnover accounted for by exports,
- the age of the company.

32 *For more information on CIS, please visit http://cordis.europa.eu/innovation/en/policy/cis.htm*

33 *For more information on Innobarometer, please visit http://cordis.europa.eu/innovation/en/policy/innobarometer.htm*

European Innovation Scoreboard (EIS)

In a recent work, Arundel and Hollanders define in general terms innovation scoreboards as consisting of a collection of national and regional indicators of relevance to innovation[34]. The authors signify that the main purpose of an innovation scoreboard is to assist policy by summarizing a range of innovation indicators at the national, regional or sector level [35]. Being a good illustration to those, European Innovation Scoreboard is the range of measures produced to benchmark the EU countries' innovation performance. As already mentioned, in the context of Lisbon agenda, The European Council explicitly requested the introduction of a European Innovation scoreboard (EIS), as one of the benchmarking tools. This paper will emphasize more on the EIS as the metric to evaluate innovation in the EU for two simple reasons; first of all, EIS uses the other metrics like CIS and Inno-barometer as inputs to come up with robust composite indicators. Secondly and more importantly, it provides a good and almost complete trend data set for the EU innovation performance since the launch of the Lisbon agenda.

The first EIS was tentative and it was published in September 2000, which set out a basic plan for the innovative action, built on the four objectives: protection of intellectual property, financing innovation, the regulatory framework and administrative simplification, education and training gearing research towards innovation and above all strengthened overall coordination, all of which have been drafted in "First Action Plan for Innovation"[36]. It did not also include a composite indicator for overall innovation performance.

The EIS in 2001 followed the general scheme of the 2000 outline. It provided an overview of Europe's innovation performance by presenting data on 17 indicators for 17 countries. The indicators were grouped into categories of Human resources, Creation of new knowledge, Transmission and application of new knowledge, innovation finance, output and markets.

Table 2 European Innovation Scoreboard (EIS), 2001

1.1	S&E graduates / 20-29 years
1.2	Population with tertiary education
1.3	Participation in life-long learning
1.4	Employed in med/high tech manufacturing
1.5	Employed in med/high tech services

34 Arundel, A., H.Hollanders, 2008, P.1

35 Ibid., P.2

36 COM (1998) 589 final.

2.1	Public R&D / GDP
2.2	Business R&D / GDP
2.3	High tech EPO patents / population
2.4	High Tech USPTO patents / population
3.1	SMEs innovating in-house
3.2	SMEs innoation cooperation
3.3	Innovation expenditures/total sales
4.1	High Tech venture Capital / GDP
4.2	New capital raised / GDP
4.3	Sales of new-to-market products
4.4	Home internet access
4.5	ICT Markets/GDP
4.6	High tech valued added in manufacturing

Compared to the tentative scoreboard of 2000, there have been some improvements like updated data, improved definitions of several indicators, better coverage of the competitors (US and Japan), availability of the trend data for 10 indicators, integration of new indicator on lifelong learning, improvement of the indicator on patents. The EIS 2001 also included analysis of the trends for the indicators where the data were available, variations, correlations and recommendations on how the scoreboard could be used as a tool for exercising open method of coordination.

In the 2001 version of the EIS, the overall EU average has been computed as a sum of the numerator and the denominator across all EU countries of that time for each indicator. A tentative Summary Innovation Index (SII) has also been introduced, that was calculated as the number of indicators that are more than 20 % above the EU overall mean, minus the number that are more than 20 % below. The index varied between +10 to -10. The choice of equal weighting, as well as the scale of +10 to -10 and the boundary of the 20 % was chosen arbitrarily and the resulting index was relative to the EU average, showing how much a Member country was different from the EU average. The data have been extracted from EUROSTAT and OECD and selected among education statistics, labor force survey, R&D Statistics, European patent office statistics, 2nd Community Innovation Survey (CIS-2 hereby on), Euro barometer and European Structural Indicators.

After its creation in 2001, the EIS has gone through various upgrading as regards to its content, data and methodology. There have been considerable attempts to also extend the geographic coverage of the scoreboard from 2002. The following year, the scoreboard incorporated data for all the associated countries and candidate countries as of that year[37], as well as US, Japan and some other countries in or outside Europe. The 2003 scoreboard also introduced the innovation performance at different classes of manufacturing sectors. This was an introduction to identify, at the European level, the role of high-tech levels of manufacturing on innovation diffusion. In addition, new indicators were introduced to improve the coverage in service sector. As a continuation, the 2004 EIS examined for the first time the differences between various sectors. The most innovative sector in the EU was found to be electrical and optical equipment, while textiles and textile products were brought up the rear. The EIS 2004 explored also as a novelty the non-technological innovation and differences between types of innovators and innovation modes.

Since its launch, the EIS became a substantial tool for benchmarking and evaluating the EU performance, as is necessary to exercise the OMC. However, it has also received criticisms in terms of the insufficiency of the indicators to cover all the dimensions of the innovation performance in a country and the robustness of the methodology of building the composite indicator of SII [38]. For that reason in 2005 the methodology was completely reviewed by a group of experts from MERIT and JRC. A Group of Senior Officials (GSO), composed of the representatives from the Member States, has been actively involved as well. The first revision took place concerning the selection of indicators. Five blocs of indicators, identifying inputs and outputs of innovation were selected. This also gave an indication of efficiency with which European countries transform their innovation inputs into innovation outputs for the first time. Accordingly, innovation drivers, knowledge creation and innovation and entrepreneurship were defined to depict the inputs for innovation while application and intellectual property describe the output. Under these five categories, 52 indicators were identified according to policy relevance. Then the indicators were halved, in accordance with their policy relevance and impact, as well as the data availability and results of statistical test techniques like principal component analysis and first corner privilege[39]. The GSO approved the final list and EIS came up with those selected 26 indicators as seen in table 3.

37 Included EU-15, Bulgaria, Romania, Cyprus, Czech Republic, Hungary, Estonia, Iceland, Israe, Latvia, Liechtenstein, Lithuania, Norway, Poland, Slovak Republic and Slovenia.

38 see for instance Grupp and Mogee 2004, mentioned in Arundhel and Hollanders, 2008

39 Sajeva, Tarantola, Gatelli, Hollanders, Methodology Report on European Innovation Scoreboard 2005, 2005.

Table 3 European Innovation Scoreboard (EIS) and sources, 2006

INPUT – INNOVATION DRIVERS (inidrv)		
1.1	S&E graduates per 1000 population aged 20-29	Eurostat
1.2	Population with tertiary education per 100 population aged 25-64	Eurostat, OECD
1.3	Broadband penetration rate (number of broadband lines per 100 population)	Eurostat
1.4	Participation in life-long learning per 100 population aged 25-64	Eurostat
1.5	Youth education attainment level (% of population aged 20-24 having completed at least upper secondary education)	Eurostat
INPUT – KNOWLEDGE CREATION (iniKC)		
2.1	Public R&D expenditures (% of GDP)	Eurostat, OECD
2.2	Business R&D expenditures (% of GDP)	Eurostat, OECD
2.3	Share of medium-high-tech and high-tech R&D (% of manufacturing R&D expenditures)	Eurostat, OECD
2.4	Share of enterprises receiving public funding for innovation	Eurostat (CIS4)
INPUT – INNOVATION & ENTREPRENEURSHIP (inientrep)		
3.1	SMEs innovating in-house (% of all SMEs)	Eurostat (CIS3)[30]
3.2	Innovative SMEs co-operating with others (% of all SMEs)	Eurostat (CIS4)
3.3	Innovation expenditures (% of total turnover)	Eurostat (CIS4)
3.4	Early-stage venture capital (% of GDP)	Eurostat
3.5	ICT expenditures (% of GDP)	Eurostat
3.6	SMEs using organisational innovation (% of all SMEs)	Eurostat (CIS4)
OUTPUT – APPLICATIONS (inoapp)		
4.1	Employment in high-tech services (% of total workforce)	Eurostat
4.2	Exports of high technology products as a share of total exports	Eurostat
4.3	Sales of new-to-market products (% of total turnover)	Eurostat (CIS4)
4.4	Sales of new-to-firm products (% of total turnover)	Eurostat (CIS4)
4.5	Employment in medium-high and high-tech manufacturing (% of total workforce)	Eurostat
OUTPUT – INTELLECTUAL PROPERTY (inoip)		
5.1	EPO patents per million population	Eurostat
5.2	USPTO patents per million population	Eurostat, OECD
5.3	Triadic patent families per million population	Eurostat, OECD
5.4	New community trademarks per million population	OHIM[31]
5.5	New community designs per million population	OHIM

Secondly, the the JRC and MERIT revised the methodology on how the composite indicator was built, by using statistical and participatory methods[40] to set up weights for normalization and for imputation of missing values. In the end, the results of the work have proved that the methodology currently used to compose the SSI, where equal weighting, rescaling the values between (0,1) and not imputing the missing values but taking the indicator for the first previous year

40 *See Sajeva, Tarantola, Gatelli, Hollanders, Methodology Report on European Innovation Scoreboard 2005, 2005.*

available, is robust and very minimal differences have been observed between different techniques of indicator building. As a last adjustment, the measurement of innovation in various sectors was extended to a total of 25 sectors for 15 countries where data was available.

The recent 2006 EIS has adopted almost fully the indicators selected and the methodology followed from the previous year, with minor enhancements in definitions of some indicators. The main contribution of the last year however, was the creation of a Global Innovation Scoreboard (GIS), which aims to compare the innovation performance of the EU-25 to that of main and emerging economies. GIS could include only 12 of the 25 indicators that EIS was built on due to the inadequacy of data. However this has created the opportunity to make analysis with a sample of 48 countries and aggregate of the EU-25.

The attempts to improve the Regional Innovation Scoreboard that have started in EIS 2002 have continued in this latest edition as well with more regional coverage and improved methodology. However, the current state of the research has remained at a quite preliminary stage and left a large room for improvement for the 2007 work[41].

Last but not least, in the last two years, the political agenda has put increasing importance in measuring innovation in services and in developing a service sector innovation index (SSII). In 2006, there was a first attempt to develop an innovation index for the European business services sector covering 27 EU Member States, Iceland and Norway. The index was computed based on 24 indicators assigned to seven themes: Human resources; innovation demand; technological knowledge; non technological changes; sources of knowledge; commercialization and intellectual property. Compared to the EIS of that year, there were only 4 indicators identical, 9 similar and 11 were new. The data mostly came from CIS-3. The SSII for the services sector did not include all business services, but only wholesale trade, transport, storage and communication, financial intermediation and computer, R&D and other business services due to the unavailability of data for all services sectors[42]. The 2007 SSII continued the work of the previous year by reviewing the selection of indicators by statistical tests and policy relevance and updating the data by using CIS-4. After the choice of the 23 indicators listed in table 4, the SSII was calculated for the manufacturing, services, knowledge intensive business services (KIBS) and services excluding KIBS. As for the methodology, min-max approach was used to rescale values and only those indicators that provide data above certain threshold limits were included in the final calculation[43].

41 *See EIS 2006 Report, pp. 28-30, 2007*

42 *See Kanerva, Hollanders and Arundel, 2006 for further details.*

43 *See Arundel, Kanerva, van Cruysen, Hollanders, 2007 for further details.*

Table 4 European Service Sector Innovation Scoreboard (SSIS) indicators, 2007

HUMAN RESOURCES		
1.1	Share of firms engaged in training for innovation purposes	Same as SSII 2006
1.2	Share of firms reporting lack of qualified personnel as an important issue	Same as SSII 2006
INNOVATION DEMAND		
2.1	Share of firms reporting uncertain demand for innovative goods/ services as an important issue	Similar to SSII 2006
2.2	Share of firms reporting no need to innovate because no demand for innovation	Not used in SSII 2006
PUBLIC AND PRIVATE SUPPORT		
3.1	Share of firms that received any public funding for innovations	Not used in SSII 2006
PRODUCT AND PROCESS INNOVATION		
4.1	Share of firms engaged in intramural R&D	Not used in SSII 2006
4.2	Expenditures in intramural R&D (% of total innovation expenditure)	Similar to SSII 2006
4.4	Share of firms engaged in acquisition of machinery, equipment, hardware or software	Not used in SSII 2006
PRODUCT AND PROCESS OUTPUTS		
5.1	Share of firms with highly important effects in reduced materials and energy per unit output	Not used in SSII 2006
5.2	Share of firms with highly important effects in improved flexibility of production or service provisions	Not used in SSII 2006
5.3	Share of firms with highly important effects in improved quality in goods or services	Not used in SSII 2006
5.4	Share of firms with highly important effects in reduced labor costs per unit output	
	Not used in SSII 2006	
NON TECHNOLOGICAL INNOVATION		
6.1	Share of firms that introduced organisational and/or marketing innovations	Similar to SSII 2006
6.2	Share of firms that introduced organisational innovations	Same as SSII 2006
6.3	Share of firms that introduced marketing innovations	Same as SSII 2006

NON TECHNOLOGICAL INNOVATION OUTPUTS		
7.1	Share of firms with highly important effects in reduced time to respond to customer or supplier needs	Not used in SSII 2006
7.2	Share of firms with highly important effects in improved quality of goods/services	Not used in SSII 2006
7.3	Share of firms with highly important effects in reducing costs	Not used in SSII 2006
COMMERCIALISATION		
8.1	Turnover of new and significantly improved products only new to firm (% of total turnover)	
	Same as SSII 2006	
8.2	Share of firms that have new or significantly improved products new to market	
	Not used in SSII 2006	
INTELLECTUAL PROPERTY		
7.1	Share of firms that applied for a patent	
	Same as SSII 2006	
7.2	Share of firms that registered an industrial design	
	Same as SSII 2006	
7.3	Share of firms that registered a trademark	Same as SSII 2006

Table 5 Evaluation of EIS since its launch

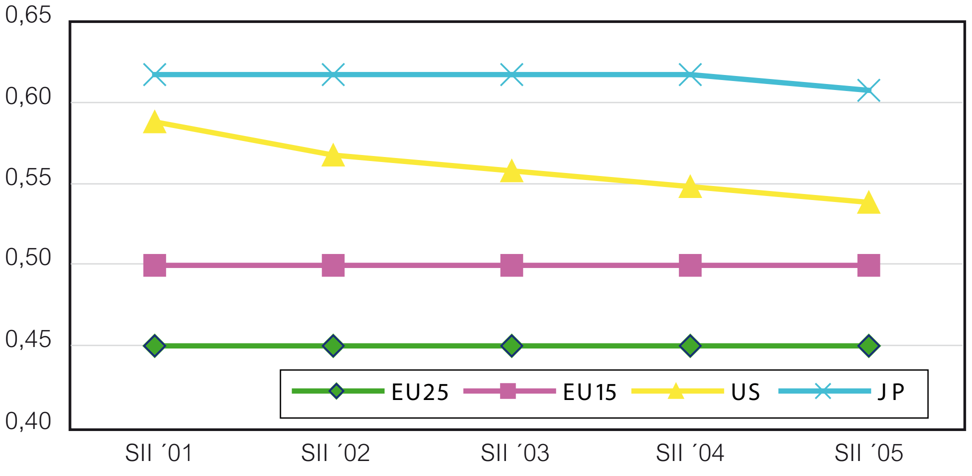
EVALUATION of EUROPEAN INNOVATION SCOREBOARD

Year	Changes/Improvements
2001	17 indicators, Only EU-15; US and JP, No sectors, simple methodology, value range between (-10,10)
2002	Same number of indicators, EU-10 added, trials to improve methodology
2003	3 more indicators, coverage of 32 countries including CH, NO,IS; different classes of manufacturing sectors, regional breakdown within the EU
2004	Attempts to measure sectoral innovation, non-tech. Innovation and differences between types of innovators and innovation modes
2005	New 26 indicators were selected, New methodologies were tested
2006	Input/output ratio, GIS, Service sector innovation scoreboard, regions
2007	(planned) Measuring innovation efficiency, non-tech. Innovation, identifying regional clusters.

European Position on Innovation: *Some results from the European Innovation Scoreboard (EIS)*

As mentioned various times so far, the main goal of the EU for the first decade of 21st century was set to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion. To detect whether there has been any improvement since the initiation of this goal in the field of innovation, we have to first of all see the place of the EU concerning innovation vis-à-vis main economies in the world. Figure 2 summarizes the trend of the SII for the EU together with the main competitors USA and Japan.

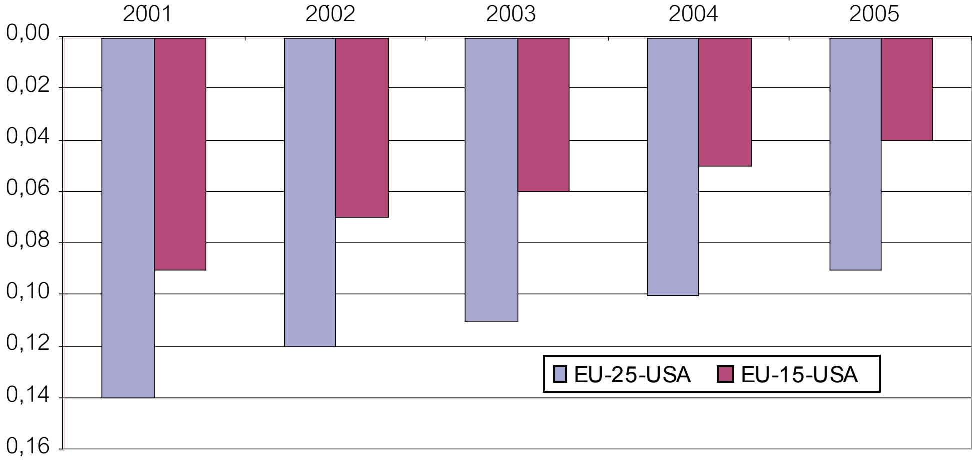
Figure 2 **What has changed since Lisbon- International Comparison?**



Source: European Innovation Scoreboard Report 2006

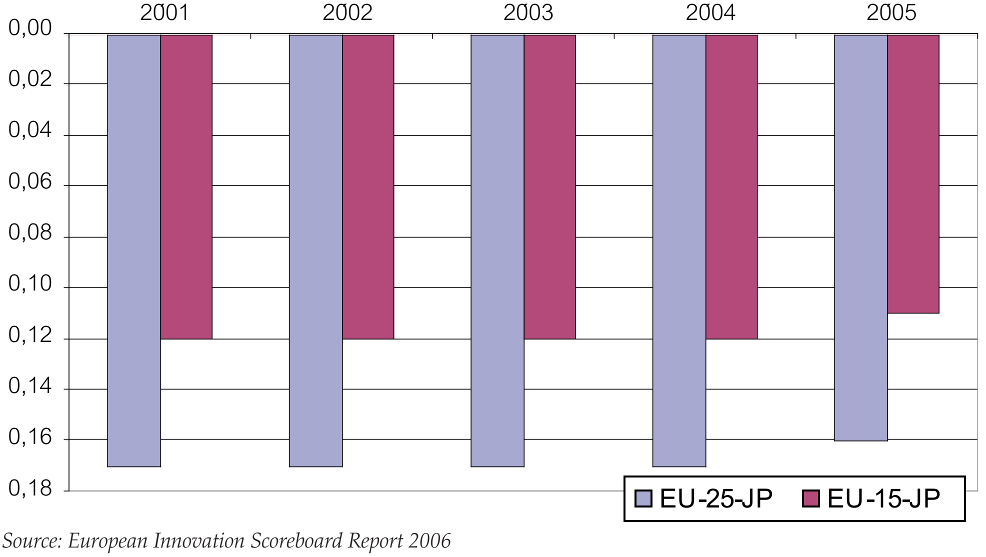
Two remarkable points can be derived from the figure. First of all, the EU-25 as an aggregate could not improve its position in terms of innovation and still lags behind the main competitors, US and Japan. One might think that the stagnant behavior of the EU might be due to the enlargement that has taken place in 2004 and beginning of 2007, which has resulted in the accession of transition economies of Central and Eastern Countries to the EU those of which are naturally doing worse on innovation account as compared to the old European Member States. However, we observe the same sluggish line for the EU-15, though on a higher scale. Although the EU has not shown an active performance, the performance gaps toward the US and Japan have decreased since the beginning of 21st century, as can be observed from figures 2 and 3, mainly due to the deteriorating performances of the competitors.

Figure 3a EU innovation gap towards USA



Source: European Innovation Scoreboard Report 2006

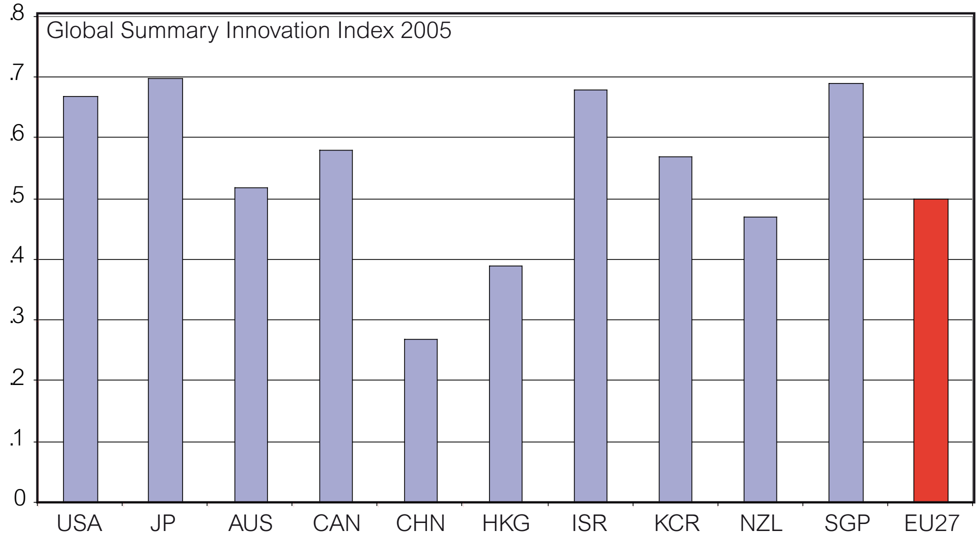
Figure 3b EU innovation gap towards Japan



Source: European Innovation Scoreboard Report 2006

Figure 4 below summarizes the GIS scores for some selected OECD and catching up countries. The picture clearly depicts that the EU is far from being the "most competitive economy" at least in terms of innovation as of 2005. Of the non-EIS countries, Singapore, Israel, Republic of Korea, Australia and Canada outperform the average innovation performance of the EU.

Figure 4: International Comparison of Innovation Performance based on the Global Innovation Scoreboard



Source: Global Innovation Scoreboard Report, 2006

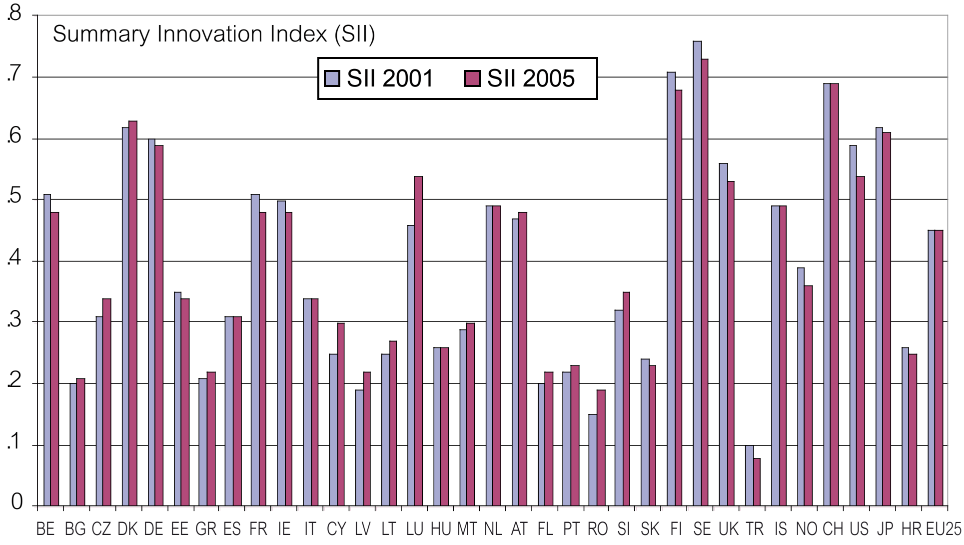
Another targeted achievement of the Lisbon agenda was to enhance cohesion within the EU on a series of key policy areas that in turn induces sustainable economic growth, including innovation. Figure 5 portrays the innovation performances of the EU member and candidate countries, as well as the USA, Japan, Switzerland, Norway and Iceland. Accordingly, since the beginning of the EIS up to day, there has been variation between the innovation performances of the different EU member countries. While some countries are performing as innovation leaders, like Sweden, Germany, Finland, Denmark, some tend to behave as catching up countries like most of the Central and Eastern European Countries. Moreover, the innovation performance trend of countries since the launch of Lisbon has been different, while some has made some progress in terms of innovation performance like some of the new member states (Czech Republic, Cyprus, Lithuania, Latvia, Poland etc.); some have deteriorated the actual performance, like Germany and France. However, given the fact that the New Member States are transition economies going through the catching up process, it is not abnormal that they do improve their performances more radically and rapidly compared to the core EU member states. If we consider the decrease of the value in 'between country variance" in SII scores of the member states, though minimally, we can conclude that there has been a convergence in the innovation performance of the EU member states since the launch of the Lisbon agenda in 2000.

Table 6: Convergence of Innovation Performance within the EU-25

	SII `01	SII `02	SII `03	SII `04	SII `05
Between country variance	0.0307	0.0300	0.0297	0.0284	0.0273
Standard deviation	0.1753	0.1733	0.1723	0.1684	0.1651
% change in standard deviation		-1.16	-0.53	-2.28	-1.94

Source: Own calculations based on EIS 2006 data

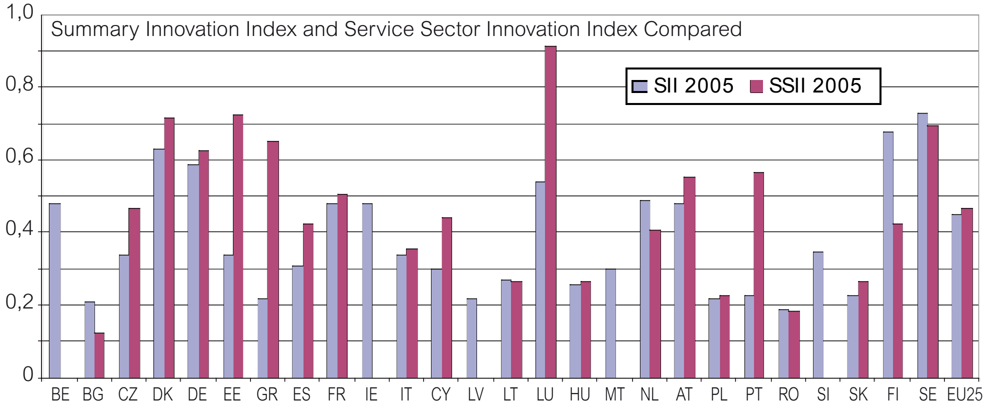
Figure 5: What has changed since Lisbon- Within the EU Comparison?



Source: European Innovation Scoreboard Report 2006

As an overall conclusion, the figures presented show that, the European Union is facing a relatively poor performance concerning its research achievements, the production of innovative ideas and translating these ideas into productivity and economic growth. There has been an exhaustive line of research on the deficient innovation performance of the EU, the reasons behind it and suggestions to improve the performance. These discussions are out of the scope of this paper. What should be important to underline for us is, however, the need for further indicators to detect precisely and appropriately the possible culprits for the sluggish performance. As shown in table 4 in the previous chapter, the EIS has always been developed to include more and robust indicators to serve this aim.

Figure 6: European Summary Innovation Index & Services Innovation Index compared

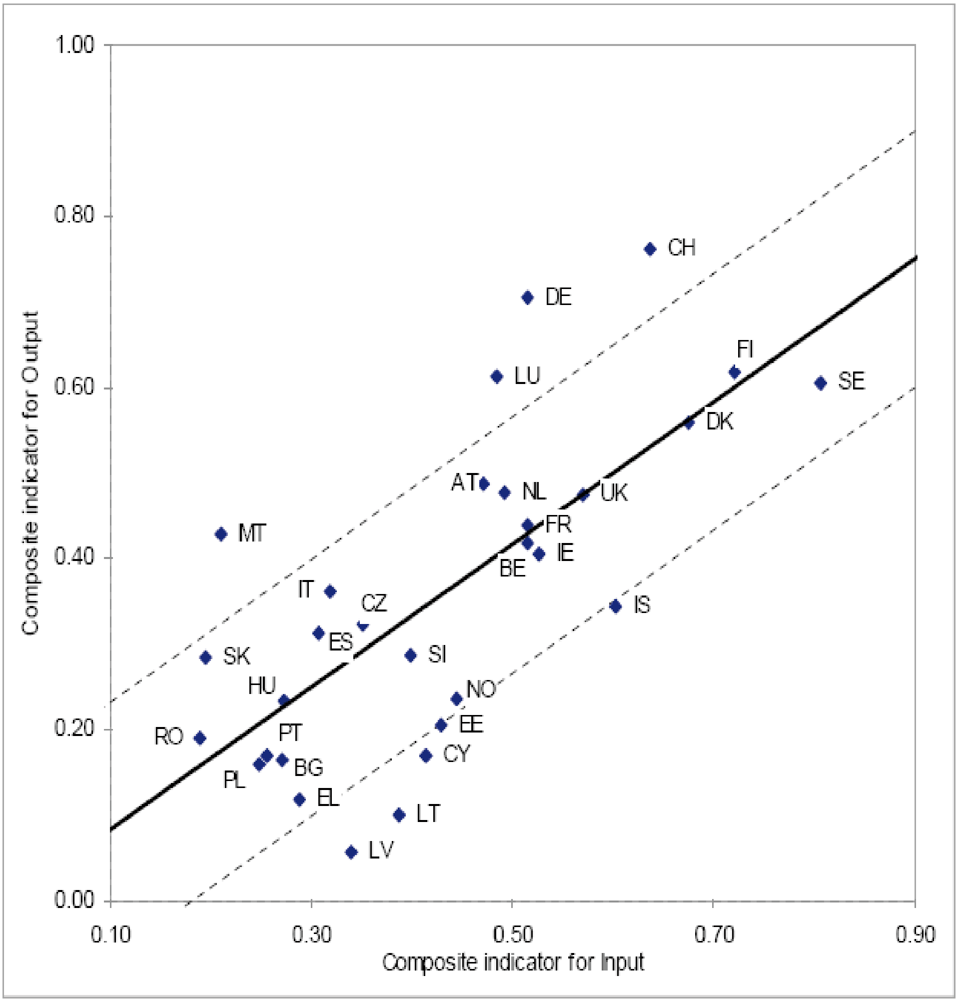


Source: Innovation Statistics for European Service Sector Report, 2007

One of the possible reasons for the low score of the EU measured by the existing innovation indicators is referred to be the over-emphasis on the manufacturing and industries with a low intensity of research (see for instance Botazzi, 2004 for a well structured pro and cons argument for this statement). For that reason, last two EISs aimed to focus more on establishing sectoral metrics, and more importantly developing a sound overall assessment of innovation in European services sector. Figure 6 presents a snapshot of comparison of European Innovation Index and European Service Sector Innovation Index. One can recognize the national differences in performance on the SII for service innovation and the EIS index for technical innovation. This suggests that some countries that have relatively lower scores in EIS perform better in services like Luxembourg, Portugal, Spain, Greece, Estonia and Czech Republic. This can be explained by the role of organizational innovation that is captured in Service Innovation index. However, the data availability does not lead to a broad set of countries and does not allow us at this stage to make direct conclusions.

Similarly, a common argument in the literature concerning the lagging behind innovation performance of the EU is said to be the innovation inefficiency, in other words, the weakness of the EU in transforming the innovation inputs into innovation outputs (see for instance Botazzi, 2004, Hughes, Cosh and Fu, 2006 etc.). These resulted in attempts to measure innovation efficiency based on the inputs and outputs identified in the EIS. However, this work is still at a preliminary stage and the results presented in the latest EIS do not have a solid theoretical background, as confirmed by the authors (EIS 2006 Report, P.14). Yet, figure 7 gives an indication about efficiency on the country level. Accordingly, the countries above the diagonal line perform better on transforming inputs into outputs than the countries below the diagonal .

Figure 7 **Innovation inputs and outputs**



Source: Taken from "European Innovation Scoreboard 2006

Summary and conclusions

Throughout this paper, we gave an overview of the innovation policy at the European Level that was initiated with the Lisbon Agenda. The major part of the paper was devoted to the metrics developed to measure innovation in order to fulfill the benchmarking and monitoring exercise that the Lisbon Strategy encourages through the adoption of the Open Method of Coordination. The main focus was on the European Innovation Scoreboard and how the innovation performance is positioned accordingly in comparison with its main competitors.

As our main conclusion, we find it noteworthy to underline that EIS presents an overview of the innovation performance within the European Union. We are encountered with the usual problem of using composite indicators to explain complex, multi-dimensional phenomena, in this particular case: dimensions of innovation. The 26 indicators used to measure this complex phenomenon provide an overall picture, incorporating various dimensions of the concept; however, they constitute a simplification of the reality[44].

There is also still room for improving the already existing composite indicator in order to better capture the important aspects of innovation performance within the EU. Forthcoming work on the metrics needs to focus on measuring regional innovation clusters in order to better understand the linkages of innovation to regional institutions and markets. We need indicators and analysis which can identify non-technological innovation, innovation in services and innovation efficiency more precisely and with a broader coverage. Moreover, further analysis with micro-data might be performed in order to explore the relationship between innovation performance and its connection to financial information of the enterprises, macro economic performance of the countries and how effective and transparent they are governed.

With the data available from the EIS, the immediate conclusion one could derive from the analysis presented is that the European Union is lagging behind its main competitors in terms of innovation performance. The data show that the Lisbon strategy has not been successful so far in improving European innovation performance.

44 *See for instance* http://composite-indicators.jrc.ec.europa.eu/ *for a complete assessment of pros and cons of using the composite indicators. Further information is available in Nardo, M., M. Saisana, A. Saltelli, S. Tarantola (JRC) & Hoffman, A. and E. Giovannini (OECD), 2005, "Handbook On Constructing Composite Indicators: Methodology And User Guide"*

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1 *CIS4 data for the indicator on the share of SMEs innovating in-house were not available.*
2 *Office for Harmonization in the Internal Market (Trade Marks and Designs): http://oami.eu.int/*

Innovation matters

An empirical analysis of innovation 2002–2004 and its impact on productivity

Hans-Olof Hagén, Caroline Ahlstrand, Martin Daniels, Emma Nilsson and Adrian Adermon

Conclusions

In this study we have found that the choice for a firm to be innovative is very dependant on its markets. If a firm's primary market is local the probability that it has chosen to be innovative is very small, or the other way round, the probability for the firm to be successful outside the local market if it do not innovative is limited. For those firms which operate on the world market outside Europe it is even more important to be innovative, especially the large and medium sized firms. Size and being part of a group also helps. We have also found that a high proportion of the staff with at least three years university education is essential. For the medium sized and larger firms it seems like their ICT use also matters (there are very few observation on both ICT and innovation for the small firms)

For the innovative firms their market orientation is influenced not only if they invest in new products and services, but also by how much they invest per employee. Even more important is their innovation cooperation. Of this cooperation; those with customers, competitors and consultants seem to be of most value. Generally the cooperation stimulates the innovation even more for larger firms. However innovation investments per employee decrease with size. This could be due to an existence of return to scale in the innovation process, in other words it could be necessary to reach certain critical levels for the smaller companies. Knowledge is of course also essential, both university educated staff and the level of the firm's ICT use made significant contributions to the innovation intensity.

The innovation output, the proportion of new products and services in sales, is not only explained by product innovation activities but is also dependant on process innovation. The latter is even more important for the medium sized and large companies. For those companies the output that a firm produces, given the innovation input, is also significantly increased for the firms who had access to fast broadband in the beginning of the period. For all firms the efficiency of the innovation process, more output for a given input, increased with scale.

Finally the productivity of the innovative firms was dependent on the innovation output irrespectively the size of the firm. The quality of staff, as the market values it, was also an important factor for the productivity of the firm. Both these factors were major contributors to the productivity growth.

Introduction

This paper is partly based on a bachelor thesis[1] made by Adrian Adermon and Emma Nilsson at Uppsala University in cooperation with Hans-Olof Hagén and Martin Daniels at Statistics Sweden. These analyses have been further developed by Caroline Ahlstrand, Martin Daniels and Hans-Olof Hagén, the project manager. This work has been done in contact with an ongoing innovation project run by the Organisation for Economic Co-operation and Development (OECD) which Statistics Sweden is participating in. We want to thank Hans Lööf at the Royal Institute for Technology for being our inspiration for this work and also for his valuable comments. We also want to thank Mariagrazia Squicciarini, VTT Technical Research Centre of Finland and KUL Leuven *and Pierre Mohnen from Merit at the Maastricht University for many important comments and suggestions.*

Innovation is a strategy to improve the firm's performance

There are several reasons why a firm chooses to innovate, but primarily a firm is innovative because it can potentially improve its performance. This can for example be by increasing demand or reducing costs. As a result of innovation activity; new products or processes can evolve that will enhance the competitive advantage of the innovative firm creating higher prices, increased market share and thus increased profits. Innovation also has the potential of improving a firm's performance due to the fact that it increases the ability to innovate. By process innovation the production creates a higher capability for the development of new products, organisational skills and knowledge that can be used to innovate even further. Innovation can thus be seen as an aspect of business strategy or part of an

1 *"Innovation and Productivity amongst Swedish Firms 2002-2004, An Empirical Analysis" by Authors:Adrian Adermon and Emma Nilsson http://www.dis.uu.se/Statistik/essays/c/Innovation_and_Productivity_rev%5B1%5D.pdf*

investment decision undertaken to create competence for product development or improved efficiency. (Oslo Manual 2005, p.29f)

Surveys and models

Innovation as an engine for growth in output and productivity has been widely acknowledged in the last decades and several studies have been conducted in the field trying to achieve a better understanding of the economic impact of innovation activities. In 1979 Griliches introduced a framework for the analysis of innovation and productivity illustrating how investments in research generate knowledge, innovation output and finally growth in production. Using a production function, Griliches estimated the partial contribution of R&D to growth and found significant problems concerning simultaneity, the measurement of output in R&D intensive industries, and the stock of R&D capital (Griliches 1979 p.2). With the Crepón, Duguet & Mairesse (CDM) paper in 1998, three important contributions were made in order to further understand the proposed link between innovation and productivity.

Firstly the CDM-paper introduced a structural model which explained productivity by innovation output[2], and innovation output by research investment and by doing so the authors brought together important parts of the empirical research conducted after Griliches (1979).

Secondly the CDM-paper made use of new data provided by the European Community Innovation Survey (CIS) which included important information on patents and innovative sales as well as qualitative indicators on demand pull and technological push indicators.

Thirdly the paper presented a significant contribution to the econometric method of innovation research by developing a modelling framework that accounted for sample selectivity (which originates from the firms' choice of undertaking R&D), simultaneity biases (productivity, innovation and research are determined endogenously), and the different statistical features of the data. (Crepón et al 1998 p.2).

Models similar to the CDM have become widely used amongst innovation researchers[3] and so also in Sweden. In Lööf & Heshmati (2006) a version of the CDM model was applied to Swedish CIS-data examining the sensitivity between innovation and firm performance amongst both manufacturing and service firms. Using the same framework for both groups of firms the authors examined the

2 *Previous research had concentrated on innovation input (R&D) and its effects on productivity.*

3 *See for example Klomp & van Leeuwen (2001), Criscuolo & Haskell (2003), Janz et al (2004) Benavente (2006), Jefferson, Huamao & Xiaojing (2006), Van Leeuwen & Klomp (2006), Mohen, Mairesse & Dagenais (2006)*

effect of innovation investment on innovation output as well as the effects of innovation output on firm performance. Matching the information from the CIS survey with business register data allowed the authors to widen the analysis and explore the sensitivity of their results even further. Whilst the understanding of the economic effects of innovation has grown it is still considered to be incomplete. Globalization and changes in the world economy have continuously changed the process of innovation as well as widened markets and access to information for firms. It is therefore important to continue to examine and improve the measures of innovation in order to develop efficient tools for analysis and design better policies for further economic growth. (Oslo Manual 2005, p.10) The CIS surveys have shown us that it is possible to collect information on the complex and differentiated process of innovation. With new Swedish data on innovation activities, we are presented with an excellent opportunity for further research on innovation amongst Swedish enterprises.

Our model

We have used a model developed by Lööf & Heshmati (2006) which allowed us to compare our results with theirs. While Lööf & Heshmati used data for their analysis from an enlarged survey we are presented with a much more narrow range of information by the CIS4. An exact comparison with the Lööf & Heshmati study will therefore not be possible since the CIS4 lacks information on variables included in their analysis.

However, in addition to using labour productivity to measure productivity as Lööf & Heshmati did, we also used multifactor productivity and the increase in multifactor productivity between 2002 and 2004. The multifactor productivity is generally a better measure of productivity since it takes account of more production factors. This is also true for innovation research purposes. Furthermore, it is an advantage to study the effect of innovation on the development in productivity for the same period and be able to use variables from different years.

Our data

The innovation data that was used is from the most recent Community Innovation Survey (CIS4), covering innovation activities in Swedish enterprises from 2002 to 2004, and as in Lööf & Heshmati this was complemented with business register data on the firms in CIS4. Some data on individuals was also taken from the LISA database to get some information on the quality of the staff of the individual firms. Finally a small proportion of the CIS4 firms, around 450, had also answered the questions in the E-business surveys for 2003 and 2004. These surveys actually cover the activities under 2002 and 2004 respectively, and the firms that have answered all the questions mainly have over 250 employees.

Definitions

Due to the complexity of innovation and the innovation process it is important to develop a basic definition of innovation and the innovative firm before we continue. According to the Oslo Manual (2005) which stakes out the guidelines for collecting and interpreting innovation data, innovation can occur in four main areas: product (good or service)[4], process[5], organisational[6] and marketing[7]. While the first two areas of innovation have been focused in previous manuals, organisational and marketing innovations are quite new and still not fully developed. The data in CIS4 contains information solely on product and process innovations our analysis will therefore be narrowed down to examining these two areas only.

When using the definition provided in the Oslo Manual it is not required that the firm implementing the product or process is the first firm on the market to do so (the definition allows imitators).[8] Instead the minimum requirement of innovation is that the product or process implemented needs to be new or significantly improved to the firm.

Our definition of innovation therefore becomes: *"a product (goods or service) or process new or significantly improved to the market or to the firm"*.

We use this definition when categorizing our sample into innovative and non-innovative firms. A firm is defined as innovative if it reports positive innovation investment (input) and has positive innovative sales (output). Non-innovative firms hence became those that during the same time period show; neither positive innovation investment nor positive innovative sales, firms with positive innovation input but no positive innovation output, and finally firms with positive innovation output but no innovation input.

4 *A product innovation is in the Oslo Manual (2005) defined as: ìthe introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.î (Oslo Manual (2005) p.48)*

5 *A process innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.î (Oslo manual 2005 p.49)*

6 *An organisational innovation is the implementation of a new organisational method in the firmís business practices, workplace organisation or external relations.î (Oslo Manual 2005, p.51)*

7 *A marketing innovation is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricingî (Oslo Manual 2005, p.49)*

8 *This originates from the fact that imitators often become innovators when they unintentionally or by design do things differently in the imitation process and therefore become innovators themselves.*

Like Lööf & Heshmati (2006) we define innovative sales (innovation output) as the sales revenue of a firm that originates from products introduced on the commercial market in the three most recent years (here 2002-2004). Innovation input is defined as the total sum of expenditures in four different areas of innovation involvement including: (i) R&D based products, services or process innovations within the firm, (ii) purchase of R&D undertaken by other firms, public or private research organisations (external R&D), (iii) acquisition of machinery and equipment related to products, services and process innovations, (iv) the acquisition or licensing of patents or non-patented inventions, know-how, or other knowledge from firms or organisations outside the firm (external knowledge). In Lööf & Heshmati the definition of innovation input is extended to eight innovation expenditures, covering areas such as education, industrial design and introduction of innovations to the market. Unfortunately the CIS-data covering our period of interest do not provide us with information on these expenditures.

Treatment of extreme values

Very few restrictions were imposed on the data in order to make it more suitable for analysis. All observations were removed for which the number of employees was missing or less than 10. Firms which according to questions in CIS4 had an ongoing or an abandoned innovation activity had to have spent money on innovation or else they were deleted from the dataset. Firms which produce innovation need to have a market to sell it on. The markets must be either local, national, European or in any other non-European country or else the firms were excluded. One question in the CIS4 innovation survey all firms hade to answer whether they innovated or not: had they introduced new or significantly improved methods of production, logistic, delivery or distribution system or introduced new improved supporting activity to the market? Otherwise they were dropped.

Theoretical framework

Previous research has shown that estimation of innovation models requires special care in choosing methods that correctly take into account the characteristics of the relationships and data material. Crépon et al (1998) have constructed a model (the CDM model) that takes account of both selectivity and simultaneity problems, which are known to arise when studying innovation and productivity. Failure to account for selectivity and simultaneity will cause biased results. A modified version of this model, presented by Lööf & Heshmati (2006), will be used in this thesis. But we are more true to the CDM model in the sense that we use lagged variables.

Hall & Mairesse (2006) pointed out that different researchers have tended to use slightly different specifications and methods when studying innovation, which makes comparisons between different studies harder. Therefore we will stay fairly close to the model used by Lööf & Heshmati (2006).

Model

In the Lööf & Heshmati (L & H) model as well as in ours only the sub-sample of innovative firms is used in the second half of the model. The sub-sample of innovative firms consists of those firms that have had both positive innovation input and positive innovation output during the period.

The model consists of three relationships, represented by four equations. The first is the determination of innovation input modelled as two equations:

(1) $$g^* = \hat{a}_{10} + \sum \hat{a}_{1i} x_{1i} + \mathring{a}_1$$

(2) $$k^* = \hat{a}_{20} + \sum \hat{a}_{2i} x_{2i} + \mathring{a}_2$$

Equation (1) is a selection equation that models the decision of individual firms whether to innovate or not. The dependent variable g^* is a latent (unobservable) variable representing the decision to innovate or not, and has an observable counterpart g = 1 when $g^* > c$, and g = 0 otherwise. The explanatory variables x_{1i} are the determinants of whether a firm innovates or not. In this study we have followed L & H and set c = 0, and thus assume that firms that report no innovation input actually do not innovate at all.

Equation (2) models the amount of innovation effort done by firms, where k^* is a latent variable representing innovation input. Its observable counterpart $k = k^*$ when g = 1 and k = 0 when g = 0. The explanatory variables x_{2i} are the determinants of the amount of innovation effort done by innovating firms.

Equations (1) and (2) are estimated for the full sample of firms, using a Heckman sample selection model[9].

The second relationship in the model is the one between innovation input and innovation output, which is estimated on the sub-sample of innovative firms:

(3) $$t = \hat{a}_{30} + \hat{a}_{31} k + \hat{a}_{32} \ddot{e} + \sum \hat{a}_{3i} x_{3i} + \mathring{a}_3$$

where t represents innovation output (or knowledge production), k is predicted innovation input, x_{4i} is the inverted Mill's ratio estimated from Equation (1), which is used to correct for sample selection bias, and the remaining

9 *This model is also sometimes called generalized tobit, or heckit.*

explanatory variables x_{3i} are other determinants of innovation output. We use innovation sales as a proxy for innovation output.

The fourth relationship is a production function, relating the firm's production to its innovation output and other determinants:

$$(4)\quad q = \hat{a}_{40} + \hat{a}_{41}t + \sum \hat{a}_{4i}x_{4i} + \mathring{a}_4$$

where q is productivity, t is innovation output, and the remaining explanatory variables x_{4i} are other determinants of productivity. In the L&H model, equations (3) and (4) are estimated as a system using three-stage least squares, to correct for simultaneity bias, using sub-sample of innovating firms only. This last equation in the system is based on an augmented Cobb-Douglas production function (Crépon et al 1998).

Model specification

In Lööf & Heshmati (2006), the model was estimated separately for manufacturing and service firms. We have mainly limited us to work with the total sample, for which the results will be presented. However in addition we have also estimated the equations separating manufacturing and service firms, but we will only comment on some of these results.

In the selection equation (1), the dependent variable is a dummy variable (g*) set to 1 if the firm has reported innovation input, and 0 otherwise. The continuous explanatory variable, the indicator of size is the logarithm of employment while the other continuous variable is the percentage of the staff which has at least a three-year university education. In addition, we have used a dummy variable specifying if the firm is part of a business group and four dummies for which geographic market(s) the firm sells to. The possible nine dummy variables representing strongly important obstacles to innovation, three dummies for cancelled or delayed innovation activities, have been tried and skipped. They all seem to have been answered to a much larger extent by the firms which actually do innovate, and are thus meaningless to use in this context. The two dummies representing strongly important reasons why the firm is not innovative are instead only answered by those who do not innovate and are equally meaningless.

In the innovation input equation (2), the dependent variable (k*) is the natural logarithm of innovation input per employee. The explanatory variables are the same as in equation (1), with the addition of seven dummies representing the firm's most valuable cooperation partner for innovation and less the group variable.

For the innovation output equation (3), the dependent variable (t) is innovation output per employee, measured as log innovation sales per employee. The continuous explanatory variables are again the size variable and the proportion with a university degree. Parallel to equation (1) we have a dummy for the firms belonging to a business group. Equation (3) also has the estimated inverted Mill's ratio from equation (1) as an explanatory variable to correct for selection bias, as well as a variable measuring productivity, used to catch any feedback effects from Equation (4). The productivity measurement which is used is the logarithm of the multifactor productivity year 2002, since this could give an indication of the economic opportunities for innovation activities during the period 2002-2004.

The productivity equation (4) is specified with three alternative measures of productivity (q) as the dependent variable. The alternative specifications are: log value added per employee (labour productivity), the log of gross production multifactor productivity and the difference between the log for the multifactor productivity years 2002 and 2004. The continuous explanatory variables, all as logs, are innovation output, employment, physical capital per employee and average human capital per employee. In the L&H model, simultaneity is taken care of by the 3SLS method. Several dummy variables are included in the analysis, one controlling for whether or not the firm belongs to a business group, and three dummies representing new or markedly improved process innovations for the firm. We have also tested with the Mills ratio in equation (4) but this did not change the result very much. The differences were not on the positive side, since it did not improve the estimation result for the other variables so we decided to only use it in equation (3).

Additionally, all equations contain 8 dummy variables controlling for differences between the industries. Since we have dummies for all industries, the intercept term in each equation would be a linear combination of the industry dummies, making estimation impossible. Thus the intercept term has been dropped.

Results

Using the L&H model we estimated a four equation model measuring three main relationships: determining innovation input using our full sample and a Heckman sample selection model (equations 1 & 2, the first relationship), the relationship between innovation input and innovation output (Equation 3), and the relationship between innovation output and productivity (Equation 4). The last two equations were estimated simultaneously with 3SLS, using a sub-sample of only innovative firms.

After removing or correcting observations with missing values, we have 2 728 firms in our full sample, of which 1695 are manufacturing firms and 1033 service firms. The innovative sample used consists of 1374 firms, but due to missing variables around 960 observations were used in the last two equations, of which roughly 670 were manufacturing firms and 290 service firms.

Equation 1 – selection equation

The first equation is a selection equation, constructed as a dependent dummy variable, and models the probability to engage in innovation activities with an outcome of 1 if the firm has reported innovation input, and 0 otherwise. Because this equation is modelled with a so-called probit method we cannot interpret the coefficients directly as marginal effects, but rather we use the estimate's relative size and statistical significance. Table 1 presents the most important coefficients for equation (1).

Variable definitions

Size = Number of employee 2004

University degree = Share of employment with a post-secondary education 3 years or more 2002

Group = Enterprise is part of a group, 0/1 dummy

Market Local = Enterprise has sold goods or services on the local market during 2002-2004, 0/1 dummy

Market National = Enterprise has sold goods or services on the national market during 2002-2004, 0/1 dummy

Market EU = Enterprise has sold goods or services on the European market during 2002-2004, 0/1 dummy

Market other (foreign) = Enterprise has sold goods or services on other foreign markets 2002-2004, 0/1 dummy

Industry 1 = Capital intensive manufacturing, 0/1 dummy

Industry 2 = Labour intensive manufacturing, 0/1 dummy

Industry 3 = High tech intensive, 0/1 dummy

Industry 4 = Utilities, 0/1 dummy

Industry 5 = Trade, 0/1 dummy

Industry 6 = Transport, 0/1 dummy

Industry 7 = Communication, 0/1 dummy

Industry 8 = Knowledge intensive services, 0/1 dummy

The result from the first equation in table 1 gives a significant estimate for all included variables on a one percent level. The size of the company measured as the number of employees has together with the employee level of qualification (university degree) a great positive effect on the probability (or choice) to become innovative. But also the indicator that measures if the enterprise belongs to a group has a positive, significant effect. This is in consensus with economic theory.

Table 1 Sample selection equation (1)

Parameter	Estimate: Full sample
Size	0.102a
University degree	0.967a
Group	0.102a
Market Local	-0.222a
Market National	0.277a
Market EU	0.194a
Market other foreign	0.323a
a significant at the 1 percent level	
b significant at the 5 percent level	
c significant at the 10 percent level	

The geographical market the firm is operating on affects the choice of whether or not to conduct innovation activities. Firms operating on the local market are less likely to innovate than firms operating on the national or the European market. Most likely to innovate are firms operating on foreign markets outside Europe.

The industry dummies are only for strengthening the model and are not interpreted.

If the innovation selection equation is estimated separately for manufacturing services one finds that the differences are rather small, but being a part of a group does not matter for service firms. Furthermore, size and the percent of the staff that have a university degree is a little less important for the decision to become innovative.

Equation 2 – Innovation input

The first and the second equation in the model is a simultaneous determination of innovation input into the firm. The first equation was a Heckman selection equation that models the decision of individual firms on whether to innovate or not. The second is the outcome equation of Heckman called innovation input equation that models the amount of innovation input done by innovating firms. Table 2 presents the most important coefficients for equation (2).

Variable definitions

Own group = Cooperation with other enterprises within enterprise group, 0/1 dummy

Suppliers = Cooperation with suppliers of equipment, materials, components, or software, 0/1 dummy

Clients = Cooperation with clients or customers, 0/1 dummy

Competitors = Cooperation with competitors or other enterprises in your sector, 0/1 dummy

Consultants = Cooperation with consultants, commercial labs, or private R&D institutes, 0/1 dummy

Universities = Cooperation with universities or other higher education institutions, 0/1 dummy

Government = Cooperation with government or public research institutes, 0/1 dummy

Table 2 Innovation input equation (2)

Variable	Estimate: Full sample
Size (employment)	-0.104a
University degree	3.721a
Own group	0,254c
Suppliers	0.411a
Customers	0.888a
Competitors	0.921a
Consultants	0.931a
Universities	0.537b
Government	0.391
Market Local	-0.297b
Market National	0.199
Market EU	0.558a
Market other foreign	0.574a
a significant at the 1 percent level	
b significant at the 5 percent level	
c significant at the 10 percent level	
In all equations industry is controlled for	

The result from the second equation in table 2 gives a negative significant relationship between employment and the amount of innovation input per employee. Notice that this means that large firms innovate less per employee, not less in total amount of money spent on innovation input.

The human capital variable has a large significant positive effect on the amount of innovation input. A significant positive effect on the amount of innovation input is also the case for enterprises being part of a group.

Cooperation with other partners had a positive effect on innovation input. In other words, those firms spend on average more on innovation input. A significant positive effect on innovation input is the case for cooperation with suppliers, clients, competitors, consultants and universities. Competitors, clients and consultants are most important cooperation partners as can be seen from the size of the coefficients. One kind of cooperation partner did not have a significant effect on the innovation activity: government or public research institutes, probably due to too few observations. These kinds of organisations have a very small role in the Swedish context since almost all government money goes to the universities.

The estimates for the geographic market show that firms selling to local markets do less innovation than firms selling to national or global markets.

A separate estimation of the innovation input equation for manufacturing and service firms give quite similar results but the diminishing investment per head does not appear for the manufacturing firms. One the other hand staff education and innovation cooperation is even more important for these than for the service firms.

Equation 3 – Innovation output

The purpose of Equation 3 is to explain what affects firm's innovation output. Equation 3 contains only one model, but different results are achieved as the model is simultaneously estimated with the productivity Equation (Equation 4) presented in table 4. Equation 4 is estimated with three different models. The dependent variables differ between the models. The dependent variables used in Equation 4 are: Value added labour productivity 2004, gross production multifactor productivity 2004, and gross production multifactor productivity 2002-2004. Innovation output is used both as an endogenous variable (table 3) as well as an exogenous variable in the productivity model (table 4).

Variable definitions:

Innovation output = Log innovation output per employee

Improved production methods = Dummy variable where 1 = Introduced onto the market a new or significantly improved methods of production, 0 otherwise

Improved distribution methods = Dummy variable where 1 = Introduced onto the market a new or significantly improved logistic, delivery or distribution system, 0 otherwise

Improved support methods = Dummy variable where 1 = Introduced onto the market a new or significantly improved supporting activities, 0 otherwise

To explain innovation output, variable size and business-group is included, as in model 1 and model 2. Three improved methods within the business, namely for production, distribution and support, as well as gross production multifactor productivity for 2002 (not presented in table 3) are also used in order to explain innovation output. How much the companies spend on innovation input is predicted in equation 2 and included to this model. Finally the inverted Mill's ratio is included to correct for selection bias as only innovating firm is used in equation 3 and equation 4. Human capital and cooperation with others was tested for in this model but did not give any effect and is not included in equation 3. But they are indirectly included since they are major explanatory variables for the innovation input so the predicted value of innovation input might provide the equation with that information.

Table 3. Results of the different specifications of the innovation output

	Innovation output measurement:		
Variable	Value added labour productivity 2004	Gross production multifactor productivity 2004	Gross production multifactor productivity 2002-2004
Size	0.654a	0.637a	0.591a
Group	0.279a	0.278a	0.279a
Improved production methods	0.191b	0.210b	0.185c
Improved distribution methods	0.267b	0.241b	0.241b
Improved support methods	0.138	0.129	0.141
Predicted value of innovation input	0.225a	0.233a	0.262a
Inverted Mill's ratio	-0.130	-0.139	-0.024
a significant at the 1 percent level			
b significant at the 5 percent level			
c significant at the 10 percent level			
In all equations industry and gross production multifactor productivity is controlled for			

The number of people employed, (size) has a huge positive effect on innovation output in all models in table 3. According to the results large companies produce more innovation output per employee, controlled for other factors in the model, then small firms. If the innovation output equation is estimated separately for manufacturing services one finds that being a part of a group is important for service firms. Otherwise the results are almost identical.

Companies who improved both production and distribution methods during 2002-2004 generated more innovation output in 2004. The improvements for distribution are generally more effective to innovation output for service firms and the production for the manufacturing firms. Improved support methods had on the contrary no significant effect on innovation output.

More money spent per employee on innovation input results in more innovation output. According to the coefficient in the value added labour productivity model a 50 percent increase in innovation input raises innovation output by 10 percent points.

Equation 4 – Productivity

The productivity equations are an attempt to explain the productivity differences, respectively the changes in productivity, with the estimated innovation output and other relevant factors. In the first equation the productivity measurement is the value added labour productivity. This productivity measurement is the natural logarithm of value added in constant prices divided by the number employed persons in the respective firm. In the second equation gross production multifactor productivity is used instead as productivity measurement and in the third it is the change in the multifactor productivity. The multifactor concept means that both the input of intermediates, labour and capital is taken into account.

Variable definitions:

Gross production = total production sold to other firms or consumers in fixed prices

Intermediate inputs = the input of goods and services bought from other firms

Value added = gross production – intermediate inputs in fixed terms

Labour= number of people working in the firm

Capital=Book value of physical capital

Share of intermediate inputs in gross production = value of intermediate inputs/ gross production in current prices

Share of labour inputs in gross production = value of labour inputs/gross production in current prices

Share of capital inputs in gross production = value of capital inputs/gross production in current prices

Value added labour productivity = value added/ employment

Gross production multifactor productivity=gross production – industry median of value share of intermediates * Intermediates input –industry median of labour value share* Labour inputs – industry median of capital value share* Capital inputs

In this equation we will use some of the factors that are included in all the first three equations with just one exception, namely the size variable and an indication of the firm is part of a group. Beside the innovation output the new variables are the capital intensity (=logarithm for (physical capital per employed year 2004)) and the human capital variable. When it comes to explaining the productivity, it is not only the percentage of staff with an academic degree which is of relevance, as in the innovation process; it is the quality of the whole staff that matters. Therefore such an indicator that measures the quality of the whole staff has been used in the production function. It is also the level from the same year (2004) as the productivity measurement that is relevant since it is the people working that year that had created the productivity level which is to be explained.

Human capital

The method to calculate the human capital indicator that has been used is very much a market oriented one. The working population has been split into many subgroups according to four different characteristics. For each of the subgroups we calculated the average incomes from both the employed and the self-employed.

If the labour market functions well, the average income for each subgroup is the market's valuation of the different categories as labour inputs. This is in accordance with a long tradition represented by Jorgensen (1987) and Bureau of Labour Statistics (1993) both of which have somewhat different approaches for the US labour market. This has been further developed in US and Canadian data by Gu and Maynard (2001). The income means are then treated as the market valuation of different categories of labour in respective workplaces. In most workplaces there are of course only a small number of these categories represented. But with the help of the average income or prices on the labour input for each group it is possible to calculate a synthetic labour cost, or labour composition indicator for the whole workplace. This is a measurement that gives the labour quality as the market values it for each firm.

The characteristics that have been used are the traditional ones: age, education and ethnicity. However, gender is not included. The choice of the different categories for each variable is based on how they are valued on the market. The education variable is split into two dimensions: orientation, and levels. There are five different levels but only two fields: 1) the technical and natural science orientation and 2) all other orientations together. The levels starts with primary (level 1 and 2) and lower secondary, and ends with post graduate education (level 6). Concerning age, the workforce is split in as many as six categories, but of these the first and the sixth are very infrequent on the Swedish labour market. These categories are namely those who are 16-20 years of age, and those who have reached the age of 67. The ethnicity variable is based on the countries where they were born. Those with an origin outside of Sweden are divided in four groups.[10]

In the third specification of productivity which is used is the change in multifactor productivity between 2002 and 2004. In consequence with this choice the change in human capital between the same years are used instead of their 2004 levels. In all these specification it is controlled for industry.

Value added labour productivity

The hypothesis behind the specification of the productivity equation is that the innovation activity 2002-2004 that has created new products and services in 2004 should increase the firm's productivity level. The first alternative measurement of productivity is value added labour productivity. As can be seen from table 5 the coefficient is very high and significant, actually as high as 0.4. The capital intensity is as expected to be positive and significant. More machinery per worker should of course increase the value added per worker. However the coefficient is only 0.12 which is rather low compared with standard results. This could be because the size and group variable captures some of its effect.

There seems to be an increasing return to scale since the size coefficient comes out significant and positive. The advantage in the innovation process of being part of a group gives an additional boost to the firm's labour productivity with as much as 10 percent, given the innovation output and other factors. But more interesting is the very high coefficient for the human capital variable. A 10 percent higher level of this measurement leads to 7 percent higher value added labour productivity. But perhaps it is not so surprising since the cost of hiring more qualified staff increases the wage bill in proportion to value added just as much.

10 The reason why the gender variable is excluded is because the human capital indicator that is used in this context was constructed for growth accounting purposes. Most of the differences of yearly earnings between men and women are more of an indicator of the differences of working hours than of anything else. In Sweden there are many more women than men who are working shorter hours. Since the quantitative labour input is measured in hours, the sector difference is already incorporated in that variable, and if the gender is included it is measured twice. The rest of the differences between the two sexes are considered to be a reflection of discrimination and not a difference in labour quality. Regional differences in wage levels also exist on the Swedish labour market, but these differences are not mainly due to differences in competence but rather to the size and character of the local labour market. The same is true for industries. In general there could be a tendency for an expanding sector to pay more for the same skill since it needs to attract more people. Sector differences can also be a reflection of regional differences. However, this is not only due to chance but also to conscious choices. Industries that are maturing are driven out from growth areas due to high wages and high rents. These factors are the reason for not including regions and sectors among our variables.

Table 4 Results of the different specifications of the productivity equation

Variable	Productivity measurement: Value added labour productivity 2004	Gross production multifactor productivity 2004	Gross production multifactor productivity 2002–2004
Group	0.099c	-0.024	-0.043
Size	0.425a	0.029	-0.137a
Capital intensity	0.115a	-0.106a	-0.04a
Human capital (2004 level respectively the change 2002–04)	0.734a	0.471a	Change variable 0.685a
Innovation output (estimated)	0.442a	0.075a	0.217a
a significant at the 1 percent level			
b significant at the 5 percent level			
c significant at the 10 percent level			
In all equations industry is controlled for			

There are also some other factors which have been tested for but found not significant, and thus are excluded from the final estimation. Among these variables is process innovation, but it should be remembered that this comes out significant in the estimation of the innovation output. That means that if process innovation is included in the productivity equation it is only to test if it gives some extra to the explanation of the labour productivity besides its effect on the innovation output. And since it is a measurement of process innovation input and not innovation output it is a very logic result. To get an similar output measure as for product innovation it is necessary to include a question like "What percentage of the production is made in a new or significantly improved process" and so on…in the CIS surveys. Furthermore, if the group indicator and the size variable become significant this is in addition to their effects on the innovation process.

Gross production multifactor productivity

A more interesting productivity measurement is the gross production multifactor productivity which measures how efficient the firm uses not only its labour input, but also its intermediates and its capital. All the coefficients should be smaller in this equation since their effect is measured on the gross production instead of value added which on average is more than twice as large. No indication of additional advantage of being part of a group is found here, nor any return to scale. On the contrary the large firms have improved their productivity to a lesser degree.

The significant and negative coefficient for the capital intensity must be interpreted as the capital intensive firms are less efficient in our data set. However it must be remembered that since industry is controlled for in the equations, capital intensive firms are those firms which are more capital intensive than the average firm in their industry. This result could perhaps been influenced by the fact that there is a high correlation between the increase in capital intensity between 2002 and 2004 and the level 2004.

Even in this equation the human capital indicator comes out very significant and with a very large coefficient. Here the effect should be higher than the increased cost of the wage bill. The overall competence, as valued by the market, is very important for the firm's productivity beyond the effect of the innovation output and thus not only via the innovation process. Finally the innovation process also seems to be very important, not only for value added labour productivity but also for the gross production multifactor productivity, now with a much smaller coefficient. Still it is very significant. This means that a 13 percent higher proportion of new services and products in the firm's sales give a one percent higher level of sales given all inputs. This is something when 5 percent is a rather normal figure for net profit rate on sales. The growth in the gross production multifactor productivity

The innovation process that has taken place between 2002 and 2004 should not only be able to explain the differences in gross production multifactor productivity between firms 2004, but even more interesting the development during these years. Generally the results are very similar to those in the previous equation. This means that the innovative activities during these years have had a large impact on the multifactor productivity growth. A 10 percent higher proportion of new products and services in sales of 2004 should increase sales between 2002 and 2004 by almost 2 percent. This is as always when all inputs in form of labour, capital and intermediates have been taken into account. There has not been any additional value of being a part of a group in this development process other than via the innovation process. But given the earlier results, it is not surprising than an increased quality in firm's staff has a very large impact on their increase in efficiency. This effect is also far beyond its effect on the cost side. Neither the capital intensive firms nor the large firms have been very successful in increasing their multifactor productivity during these years.

If the dataset is split into manufacturing and service firms, similar results are found for manufacturing while for service firms the innovation output does not give a significant effect in the multifactor level specification but in the change specification. It must be remembered that the service set is a rather small data set.

General observation for some variables

The size variable is included in all the equations and this gives some general results. Large firms are more inclined to innovate but they invest less per employee. However, in total they get out more of their investments in the form of new products and services given this investment and since they are more efficient in the innovation process. This effect is much larger, 0.7 compared with -0.1 which means that large firms have much more innovative sales per employee, especially since the -0.1 is scaled down by 0.2 which was effect of innovation input on output. Given their innovative sales their labour productivity is also higher, but this is explained by their higher capital input, since the sign is switched for the multifactor specification. But this can not offset the fact that the large firms get a higher productivity boost from their efficiency in the innovation process.

Another variable that is used in three of the four equations is the variable that indicates that a firm belongs to a group. This apparently increases the probability of the firm to decide to innovate. From a separate test we also know that these firms do not invest more per employed persons. However they got out much more in the form of innovative sales given the investments and their labour productivity are somewhat higher and the multifactor productivity is not significantly lower given the innovative output. This means that both size and group are major contributors to innovation and especially to the efficiency in the innovation process, and finally to the productivity.

Another import variable is human capital. In the first two equations it is the percent of the staff that have at least a 3 year university degree which is introduced as an explanatory variable, while in the production function it is a measurement of quality of the total labour input that is used. From this it is very evident that labour quality both increases the probability to innovate and also the invested amount. Finally it increases productivity via the innovation output as well as directly.

Equations with ICT variables

An important aspect of innovative firms and something that probably influences their performance is of course their ICT level and ICT use. This could make a difference in all the steps in the innovation process; the decision to become innovative, how much to spend on innovation, the efficiency in the innovation process and finally the productivity outcome.

The only possible source of information about the firm's ICT standard and use is the Eurostat E-business survey. Unfortunately the samples for the E-business survey and the CIS4 are drawn independently; this means that there is a very small probability for a small or medium sized firm to be selected for both surveys. But all larger firms get both questionnaires. Since the response rate is around

70 percent in both surveys there are even less firms that have answered the questionnaire for both surveys. Actually there are only 452 observations available, and the majority of these are innovative as could be expected, since larger firms are more innovative than smaller ones. But with the criteria for excluding some observations and missing values already mentioned there are finally just 209 innovative firms left to study. This means that the results will be rather uncertain and it will be quite hard to get significant results in the regressions for many variables. Still it is worthwhile to make a try, since the ICT and innovation should be rather interlinked.

ICT use is a complex process with many links between the different uses. If a single activity is picked out and put in a regression and found significant, the result will most likely be exaggerated. The firms that use ICT in this way are probably also using it in other ways, so the regression results reflect the effect of these combinations and not of just the single variable. The only alternative to avoid this is to realize that ICT use comes in bundles and create measurements that capture this phenomenon and use these instead. This is of course not easy and will be highly questioned, since there is no apparent way to make such bundles.

These kinds of composite indicators are created by adding activities that are measured in quite different ways. It is like composing fruit baskets with different fruits and trying to decide which fruit basket is most attractive. To one person who does not like oranges, it does not matter how many oranges you put into the baskets; it will not become more attractive to that person, but to many others it will make a difference. Weighing together different indicators of ICT use is even more challenging; the only comfort is that most broad composite indicators will rank firms in similar order.

The ICT level

In this context a broad composite indicator has been created based on the Eurostat E-business survey 2003, which actually measures the situation year 2002. The choice of the year 2002 is based on the perception that it is the ICT use in the beginning of the innovation period that influences the process during this period. The broad indicator is based on four different aspects of the firm's ICT use: internet use, business system integration, purchase and sales on electronic channels, mainly the Internet.

Variable definitions:

Internet use = Number of business activities

Business system integration level = types of activities integrated with orders and purchase systems

Online purchasing in percent of total purchase

Online sales in percent of total sales

ICT level = Internet use + business system integration level+0.1* (online purchasing in percent + online sales in percent)

Internet use. The different Internet activities are the following in 2003 E-business survey: general information, analysis of competitors, financial transactions, provide service and support, download digital content and finally staff education.

Business system integration level. The business system integration activities that are integrated with the firm's order and purchase system which are specified in 2003 E-business survey are: internal system for reordering, pay system, production, logistics, marketing, customers and suppliers.

Fast broadband

The importance of the Internet could not be exaggerated in today's business, but it was already critical five years ago which has been proven in some studies. This means that a high standard of Internet connection could also be of importance in itself or as an indication of the value the firm puts on the Internet. In 2002 an Internet connection with at least 2 MB was really a high speed connection. This variable, if the firm has access to an Internet connection of at least 2MB, has been used together with the ICT level composite indicator in the estimations, bearing in mind the problems with single variables.

The innovation selection

In table 5 the difference between the estimates for two samples on the selection equation is highlighted. As could be expected it is hard to get significant results in the small ICT sample. But probably the advantage of being part of a group and being rather big is not relevant for the choice of being innovative or not for these rather big firms.

Table 5 The Innovation selection equation, the full sample and ICT-sample compared

Variable	Estimate	
	Full sample	ICT sample
Group	0.10a	0.03
Size	0.10a	0.07
University degree	1.10a	0.54
Geographic markets		
Local	-0.22a	-0.58a
National	0.28a	0.33c
EU, EFTA	0.19a	-0.06
Other countries	0.32a	0.67a
ITC-level 2002	---	0.04c
a significant at the 1 percent level		
b significant at the 5 percent level		
c significant at the 10 percent level		
In all equations industry is controlled for		

What caused the education variable, the percent of the staff with at least a 3 year university education leading to a degree to become non significant is probably more the sample size than anything else, since the coefficient is not that much lower than in the equation with the full sample. However, the geographical markets the firm is working on do have a significant effect on the probability for firms to innovate, also for this sample. The firms which just are local seem to have low incentive to innovate irrespectively of their size. It is even more necessary for the larger firms to innovate if they are selling on the world market. The firm's ICT level becomes significant, but on a rather low level, and adding the broadband indicator did not give any result.

The innovation input

The difference in estimation results for the innovation input between the two groups is not that large for the firms which actually spend resources on innovation. The importance of being a part of a group regarding the amount the firm spends on innovation per employed has vanished for the ICT group with only larger firms. One the other hand the diminishing investment per employed is much stronger for the ICT sample. It is also much more important for these firms with all forms of cooperation; even cooperation within their group becomes significant.

Table 6 **The Innovation input equation, the full sample and ICT sample compared**

Variable	Estimate	
	Full sample	ICT sample
Size	-0.10a	-0.58a
Academies	3.72a	2.76a
Geographic markets		
Local	-0.30a	-0.14
National	0.20	0.58b
EU, EFTA	0.56a	1.05a
Other countries	0.57a	0.48c
Within the Group	0.25	0.56b
Suppliers	0.41a	1.16a
Customers	0.89a	1.66a
Competitors	0.92a	1.72a
Consultants	0.94a	1.49a
Universities	0.54a	1.26a
Government	0.39	1.29
IT-level 2002	---	0.16a
a significant at the 1 percent level		
b significant at the 5 percent level		
c significant at the 10 percent level		
In all equations industry is controlled for		

Finally, even if the ICT use had some effect on the probability of being innovative, the effect of how much the firms spends on innovation per employee is much higher. In this equation the broadband indicator has also been tested and found insignificant.

The innovation output

The estimation of the efficiency of the innovation process, how much output is produced given the innovation input, gives a rather similar picture even if there are some substantial differences for single coefficients. The coefficient that differs most is the process innovation which is of much more importance to the larger firms in the ICT sample. Innovation inputs and size on the other hand matter almost as much for both samples. For the firm to get something out of the innovation process, it seems to be an advantage to be a large company. And of course if a firm adds some innovation input it gets more innovation output. Fast broadband with a speed over 2 megabits per second seems to be of significant importance, but not the ICT level.

For the multifactor alternatives the similarities and differences are the same between the two samples. The third specification of the productivity variable, the change in gross production multifactor productivity, gives a mirror result of the level specification. The only difference is a tendency for the impact of the innovation input on the innovation output to be slightly higher. Looking at these results together the obvious reflection is on the similarities of the results. This means that the results are quite robust.

Table 7 The innovation output equation, the full sample and ICT sample compared

	Productivity measurement					
Sample	Labour		Multifactor		Change in Multifactor	
	Full sample	ICT sample	Full sample	ICT sample	Full sample	ICT sample
Size	0.65a	0.58a	0.63a	0.56a	0.69a	0.65a
Innovation input (estimated)	0.21a	0.17c	0.21a	0.16c	0.26a	0.23b
Improved production methods	0.21b	0.55a	0.22b	0.55a	0.15c	0.52c
Fast Broadband 2002	---	0.63a	---	0.65a	---	0.66a
Inverted Mill's ratio	-0.25	-1.54b	-0.25	1.65a	-0.07	1.75a
a significant at the 1 percent level						
b significant at the 5 percent level						
c significant at the 10 percent level						
In all equations industry is controlled for						

The productivity equation

In the production function all the different specifications of productivity seem to work almost as well as for the ICT sample as for the full sample; even the degree of significance is almost the same even if a somewhat lower level should have been expected as the number of observations has been reduced substantially.

Table 8. The Productivity equation, the full sample and ICT-sample compared

	Productivity measurement					
Sample	Labour		Multifactor		Change in Multifactor	
	Full sample	ICT sample	Full sample	ICT sample	Full sample	ICT sample
Size	0.43a	0.30a	0.04	0.06	-0.14a	-0.07b
Capital intensity	0.12a	0.22a	-0.11a	-0.12a	-0.05a	-0.07
Human capital (2004 level respectively the change 2002-04)	0.73a	0.75a	0.47a	0.37a	0.68a	1.96a
Innovation output (estimated)	0.44a	0.36a	0.08a	0.10b	0.22a	0.15a
a significant at the 1 percent level						
b significant at the 5 percent level						
c significant at the 10 percent level						
In all equations industry is controlled for						

Given the innovation output there is no extra advantage of being a part of a group or being big for the larger firms in the ICT sample. However, in the value added labour productivity specification the size is significant but the coefficient is just half of the full sample level. Actually it seems to be a disadvantage for the large firms when it comes to productivity growth between 2002 and 2004, as it was in the full sample. The same is true for the firms which were capital intensive relatively to their industry means. However, the human capital specification is very significant with large coefficients in all the specifications. A change in the relative human capital level with a given percent gave on average an increase in the production that was twice as large.

Overview of the estimation results

The elasticity between innovation input and innovation output for the labour productivity that was found in this study was lower than the estimates from Lööf & Heshmati. However Both Lööf & Heshmati and Crépon et al find elasticises for innovation output on productivity of around 0.1, while our results for the value added labour productivity are as shown much higher. This gives roughly the same relation between innovation investments and productivity. For the multifactor specification the results were little lower than the estimates found in the literature. Using multifactor productivity the effect of innovation output ranging from 0.15

to 0.17 which is twice as much as our findings. Van Leeuwen & Klomp (2006) find an elasticity of around 0.13, using a multi-factor productivity specification. Griffith et al (2006), using a different model, find elasticities of 0.13 for France, 0.11 for Germany and 0.06 for Spain and the UK, using CIS3 data. On the other hand our result for the change in multifactor productivity is high 0.2, which is higher than all these.

We had also access to a sub sample with ICT variables from E-business 2003 and E-business 2005 (actually describing the situation the years before: 2002 and 2004) where all firms had at least 250 employees.

The results obtained in this thesis support the links between innovations and firm performance, and the estimated strengths of these links are in line with previous innovation literature. The CDM model has proven to be robust across different data sets and specifications. Our main contribution to the innovation literature is that we test the model by Lööf & Heshmati by applying it to a new data set, as well as introducing multifactor productivity and change in multifactor productivity in addition to labour productivity to measure firm performance. We have also developed an advanced measurement of the labour quality which is used in the productivity equation. Finally, an introduction of the ICT variables in a small sub sample is also new.

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Appendix

Tables

Table 1 Summary statistics for the continuous variables, full sample

Variable	Mean	Maximum	Minimum	Std Dev
Innovations input	109 086	11 904 762	0	583 862
Innovations output	3 955	651 297	0	25 196
Gross Production	27	351	2.6	24
Multifactor productivity 2004				
Gross Production	1.2	148	0.1	3.0
Multifactor productivity 2002–2004				
Value added labour productivity	37 000	2 874 820	35	136 656
Value added in fixed prices	141 929	15 288 845	104	605 200
Capital in fixed prices	137 010	18 101 676	3.3	842 999
Employment	194	19213	10	677

Table 2 Summary statistics for the continuous variables, ICT sample

Variable	Mean	Maximum	Minimum	Std Dev
Innovations input	346 421	9 836 065	0	1 223 135
Innovations output	15 081	574 964	0	45 800
Gross Production	28	163	3.9	27
Multifactor productivity 2004				
Gross Production	1.2	9.9	0.1	0.8
Multifactor productivity 2002–2004				
Value added labour productivity	132 471	2 874 820	2 237	279 384
Value added in fixed prices	565 852	10 180 766	3 685	1 242 924
Capital in fixed prices	590 522	18 101 676	100	1 864 164
Employment	714	8754	11	1 071

Table 3 **Summary statistics for all variables**

Variable	Min	Max	Mean	N
Innovation dummy	0	1.00	0.50	2728
Innovation input	-5.1	12.7	1.91	2728
Innovation output	0	15.1	3.11	2681
Productivity	3.54	15.3	9.19	2654
Multifactor productivity	-2.2	6.40	3.01	2623
Gross production multi factor productivity 2002–2004	-4.3	5.00	0.05	2604
Employed persons	2.30	9.86	3.90	2728
Part of a group	0	1.00	0.64	2728
Physical capital intensity 2004	-1.8	12.5	4.86	2666
Humacd02	0	1.00	0.12	2728
Humcap04	6.73	7.92	7.37	2702
Improved production methods	0	1.00	0.25	2728
Improved distribution methods	0	1.00	0.14	2728
Improved support methods	0	1.00	0.24	2728
Capital intensive manufacturing industry	0	1.00	0.11	2728
Labour intensive manufacturing industry	0	1.00	0.23	2728
High tech intensive industry	0	1.00	0.24	2728
Utilities industry	0	1.00	0.03	2728
Trade industry	0	1.00	0.08	2728
Transport industry	0	1.00	0.11	2728
Communication industry	0	1.00	0.02	2728
Knowledge intensive services	0	1.00	0.17	2728
Local market	0	1.00	0.81	2728
National market	0	1.00	0.60	2728
European market	0	1.00	0.56	2728
All other countries	0	1.00	0.36	2728
It Level 2002	0	15.5	7.16	457
Fast Broadband	0	1.00	0.71	457
Within the group	0	1.00	0.06	2728
Suppliers	0	1.00	0.09	2728
Customers	0	1.00	0.09	2728
Competitors	0	1.00	0.01	2728
Consultants	0	1.00	0.03	2728
University	0	1.00	0.02	2728
Government	0	1.00	0.00	2728

Capitalising R&D

Martin Daniels, Statistics Sweden

Abstract

Treating R&D as an investment rather than an expense will effect the calculations of GDP (Gross Domestic Product) and increase it. The effects need to be further analysed and evaluated before this is implemented in the National Accounts. The greatest impact will be on figures for the business sector, but the government sector will also be affected to some extent.

Intangible assets, or knowledge based capital of the firm, are comparable in importance to physical capital such as factories and equipment. New ways to count all capital investments, not only tangibles, in the National Accounts will be good for productivity analyses of the economy, especially multifactor productivity.

A first draft calculation to link R&D statistics and the National Accounts for Sweden (2003) show a production value amounting to SEK 127 billion or 5 percent of GDP. However, this includes acquired R&D for own production, that is not the case in official R&D/GDP ratios. Furthermore, it includes all public R&D and hence R&D that may be counting as freely available R&D in the final bridge table, depending on recommendations in the ongoing revision on SNA (Systems of National Accounts).

As a small open economy, Sweden actively interacts with foreign markets. Internationalisation of Swedish R&D has been studied a bit closer in this paper with a case study of seven big multinational enterprise groups in Sweden and the results are striking. Swedish R&D is dominated by a few groups in some R&D intensive industries. All of these groups have very different R&D structures, but most of them work globally on R&D.

Current findings

The present manual for the National Accounts treat R&D as follows:

SNA definition (1993)[1]: *"The value of research and development (R&D) should be determined in terms of the economic benefits it is expected to provide in the future. This includes the provision of public services in the case of R&D acquired by government. In principle, R&D that does not provide an economic benefit to its owner does not constitute a fixed asset and should be treated as intermediate consumption. Unless the market value of the R&D is observed directly, it may, by convention be valued at the sum of costs, including the cost of unsuccessful R&D."*

…but this is not the case in the present National Accounts.

All the costs and investments a firm undertakes during a year are counted in the national accounts: some are costs such as gas bills, others are investments in form of plants and equipment. The problem is that only tangibles are treated as investments (and more recently also software investments), but intangible investments in knowledge, R&D and other human capital investments are still missing. To put capital spending on R&D in the same category as gas bills is not a useful way for qualified analyses of the economy, e.g. to measure multifactor productivity.

Conceptually it is not hard to argue for a capitalisation of R&D and other intangible assets.[2] But in practice it is associated with bridging and methodological problems that need to be managed. Statistics Sweden had studied two of those issues. Firstly, a draft bridge table was constructed for the year 2003. Secondly, a study was done of internationalisation of Swedish R&D and a case study of eight MNE (Multinational Enterprises) and their R&D and related activities. I will return to the Swedish contribution later in this paper.

Besides the measurement problem of R&D, the frequency of R&D surveys (every second year in Sweden) and the lack of long time series in the service industries, it is still important to measure intangible assets and investments in R&D. To leave them out will lead to a big underestimation of the total investments of the business enterprises. Both a British and an American study[3] show the importance of intangible investments. The researchers find that for every pound or dollar that businesses are investing in physical assets they are spending another building up intangible assets, i.e. the investments in intangible assets are as high as the investments in tangibles, but only tangible investments are included in the

1 *Aspden (2007)*

2 *Corrado (2005), Business Week (2006), The Economist (August 2007)*

3 *The Economist (August 2007), Fölster et al (2007)*

National Accounts. Moreover, the intangible investment has been increasing much faster than tangible assets and than the rest of business output. For example, the ten biggest companies in the US have increased their investments in R&D by 42 percent since 2000. At the same time, investments in tangibles only increased by two percent. The researchers show that when the US GDP was adjusted for knowledge investments the economy looks more powerful with faster growth rates, the high consumption figures decrease and the low saving rate will increase.

As a result, growth occurs in both output and productivity. As Mr Haskel says, "There's a ton more investment going on and lots more GDP."[4]

Bridge table for Sweden[5]

A first draft calculation to link R&D statistics and the National Accounts for Sweden (2003) show a production value amounting to SEK 127 billion or 5 percent of GDP. However, this includes acquired R&D for own production, that is not the case in official R&D/GDP ratios. Furthermore, it includes all public R&D and hence R&D that may be counting as freely available R&D in the final bridge table, depending on recommendations in the ongoing revision on SNA (Systems of National Accounts).

Calculations for the Swedish economy on aggregate level show R&D amounted to SEK 97 100 million. This is all R&D conducted on its own account (Intramural R&D). Then we add all acquired R&D to be used as input of R&D output (Extramural R&D or contract R&D). This is an important item amounting to SEK 25 658 million. Reductions for depreciations of capital goods owned by R&D producers and used in R&D production need to be done, amounting to SEK 7 552 million. At the same time we need to deduct for capital expenditure for tangibles already included as an investment in the National Accounts, amounting to SEK 5 630 million. Furthermore, to come to the R&D output measure we need to adjust for production taxes less subsidies, amounting to minus SEK 717 million, and add an operating surplus on R&D to the cost based R&D figures to arrive at an output measure. The way of calculating operating surplus on R&D can be discussed but not in this paper.

4 *Ibid*

5 *The draft bridge tables in table 1 below show an overview of total effects that the capitalisation will cause. A more detailed table for each sector has also been constructed but is not included in this paper.*

Table 1: Draft bridge table to compare FM[6] and SNA data on R&D, total for all sectors[7] in Sweden 2003, SEK millions

	FM	Bridging values	SNA	Data sources	Comments
I. OUTPUT					
A. FM's GERD MEASURE	97 100			R&D survey	
1. minus Increase of inventories of materials purchased during the period and intended to be used as inputs of R&D activities		0			N/A
2. plus Acquisition of R&D to be used as input of R&D output		25 658		R&D survey	Extramural R&D
3. plus Depreciation of capital goods owned by R&D producers and used in R&D production		7 552		National Accounts	We are working on PIM calculations. Here with a mark-up on GERD wages and intermediate cost for research, calculated for each industry.
4. plus Operating surplus contained in R&D output measured at basic prices		3 139		National Accounts	For 2003, the surplus was zero or negative for R&D industry (NACE 73). Here calculated with a surplus on wages and intermediate consumption.
5. plus Other taxes on production less other subsidies		-717		National Accounts	Taxes associated with compensation of employees are included in GERD. Other taxes are usually very small and difficult to attribute to R&D. Subsidies to R&D are included.
6. minus Capital expenditures		5 630		R&D survey	Land, buildings, instruments and equipment
7. Software R&D		16 425		R&D survey	Including all software related costs in BERD
B. R&D OUTPUT BY SNA93 DEFINITIONS Equal to GERD - (1) + (2) + (3) + (4) + (5) – (6) (Some additional differences have not been taken into account)			127 102		Production costs of R&D output (not use)

6 *Frascati Manual (2002) and System of National Accounts (1993)*

7 *Bridge tables on sector level have been released in a separate paper, but no calculation has been done on an industry level.*

One important issue is to avoid double counting of software R&D. Software that is already capitalised in the National Accounts. Due to the R&D survey 2003, all software related expenditure amounted to SEK 16 425 millions, including both own-account and acquisition of software. However, merely own-account R&D is a subject-matter of double counting in software and R&D capital.

Internationalisation of Swedish R&D

In general most corporate R&D is produced on the company's account for internal use. But a small open economy such as the Swedish economy has considerable interaction with foreign countries. These transactions are a significant part of total corporate R&D and will be a challenge to face in the capitalisation process.

About 75 percent of all R&D in Sweden is performed by companies[8] and a large amount is conducted by a few big multinational enterprises (MNEs). For example, 34 big MNEs account for 70 percent of total business enterprise R&D and more than 50 percent of total Swedish gross domestic R&D[9]. These MNEs' involvement in internationalisation of R&D is substantial compared to local firms and small groups. Furthermore, internationalisation of R&D in Sweden is highly concentrated to a few R&D intensive industries – pharmaceuticals, electronics and motor vehicles.

The MNEs play an important role regarding the capitalisation of R&D.

This part of the paper will give examples and explain how R&D is organised in Swedish companies by giving several examples of case studies of companies from the business world involved with R&D. We study the structure their FDI (Foreign Direct Investment) of R&D, foreign trade of R&D, contract R&D and R&D financed from abroad. A common characteristic of the case companies is that they are all very active in R&D in Sweden and in one of the following key industries: pharmaceuticals, electronics or motor vehicles. The case studies include both Swedish-owned and foreign owned MNEs.

Primarily, this paper is using the R&D survey for intramural (in-house) and extramural (contract) R&D, foreign trade of services for import and export of R&D and IPR (intellectual property rights), foreign direct investment survey for inward and outward R&D. It is also matched with the EU Industrial R&D Investment Scoreboard.

8 *BERD, business enterprise expenditure on R&D*

9 *GERD, gross domestic expenditure on R&D*

Internationalisation – an increasing phenomenon

Internationalisation, or globalisation, is an increasing phenomenon all over the world. This is not only true for production and selling of goods, but also for other functions such as marketing and R&D. Big MNEs have affiliates in most countries and their profits are increasingly worldwide and in a lesser sense linked to the home country. Consequently, it is harder to identify the origin of profits, even for those at the companies responding to the survey. The problem to identify the origin of a certain business activity to a specific country is also true for R&D.

Per definition profit-making companies will optimise profits for their shareholders.[10] Because tax levels and production costs differ among countries, companies are driven to fragment the value chain and do tax planning. One way to do tax planning is by inter-company transfer price, by letting the enterprises within the group trade, import cheaply and export expensively or vice versa, to distribute the profit to low-tax countries.

By trade liberalisation and new ways of using information technology to reduce distances, FDI and trade of R&D and other business functions in companies will be fostered. A large part of international transactions and trade of R&D is managed inside MNE. Incentives of this management are probably to reduce tax, spread knowledge by technology transfers, and benefit from cost reduction or the use of competence.

Case studies

The following part will describe the R&D structure in seven companies in Sweden. Together they will give a good picture of Swedish R&D in business enterprises, even if they all differ from each other. The reference year is 2005/2006.

Case company 1

This company is Swedish-owned. They perform half of their R&D in Sweden and half in 3 foreign countries. All R&D is financed within the enterprise and no R&D is outsourced on contract either in Sweden or abroad. They have no reported export or import of R&D, but they import IPR (patent, license, franchising etc.) from 17 countries. The IPR import amounted to three percent of total in-house R&D spent in Sweden, and has increased sharply during 2006. The part of the group located in Sweden primarily performs R&D. This company is involved with merchanting, i.e. they produce and sell goods abroad and the profit margin from the sales is transferred back to Sweden and pays for R&D costs etc.

10 Ownership of companies is another increasing problem to handle in a more internationalised world when more companies are becoming foreign-owned or changing nationality

Case company 2
This company is Swedish-owned. They perform half of their R&D in Sweden and half in 18 foreign countries. Four fifths of the R&D performed outside Sweden is on contract from the home country (Sweden) and about one fifth from other companies abroad, outside the group of enterprises. The company has no R&D export, but they import a lot of R&D from all over the world (78 countries). This company exports IPR amounting to about half of their Swedish in-house R&D budget (to 70 countries) compared to IPR imports which amounted to only 1/16 of the IPR export (from 45 countries).

Case company 3
This company is Swedish-owned. They perform more than half of their R&D in Sweden. The remaining part is conducted in 15 countries from which 2 countries account for a big part. About 10 percent (in size) of in-house R&D is on contract abroad to enterprises within or outside the group of enterprises. Roughly 5 percent of in-house R&D is financed from abroad. Due to foreign trade statistics they have no or almost no R&D export or import. A fractional volume of IPR import and export was reported in the foreign trade statistics.

Case company 4
This company is foreign-owned. About 40 percent of the group's total R&D is spent in Sweden. Approximately 2 percent of in-house R&D is on contract abroad to companies within and outside the group of enterprises. All R&D is financed by the company's own funds. They export a little bit less than half of their R&D, mainly with the home country (location of head-office) and to another 4 countries. The volume of R&D import is about twice the size of R&D export, amounting to about 90 percent of R&D spent on in-house R&D. The R&D import comes from 37 countries where one country accounts for two-thirds (not the country of group's headquarter). They also export IPR to 14 countries, even though 2 countries account for almost all of it, amounting to 70 percent of in-house R&D (not the country of group's headquarter). Only 3 percent of IPR is imported (from 2 countries).

Case company 5
This company is foreign-owned. The size of contract R&D is about 27 percent of total in-house R&D. About 64 percent of contract R&D goes abroad to other enterprises. Only 0.1 percent of in-house R&D is financed from abroad. About 16 percent of the groups total R&D is spent in Sweden. The amount of export and import of R&D is high in proportion to in-house R&D performed. They import 112 percent and export 168 percent the size of in-house R&D performed

in Sweden. The R&D foreign trade of service is mainly with the home country (location of head office). The trade with IPR is insignificant.

Case company 6

This company is foreign-owned. About 25 percent of the group's in-house R&D is performed in Sweden. In contrast to the other case companies, they have a significant part of in-house R&D financed from abroad, 21 percent (mainly within their own group of enterprises). Only one percent the size of in-house R&D is on contract abroad. One fifth of this company's contract R&D goes abroad and the remaining is on contract in Sweden. They export and import approximately 3 percent the size of total in-house R&D and the trading partners are located in about 10-15 countries. Regarding foreign trade of IPR, they import 9 percent the size of in-house R&D mainly from the home country (location of head-office). The IPR export amounts to only 0.4 percent.

Case company 7

This company is Swedish-owned. Almost all R&D is performed in Sweden while 4 percent is performed in a few other countries. They do not have any R&D on contract abroad. About 4 percent of in-house R&D is financed from abroad and is mainly from other enterprises. They have no foreign trade of R&D, no IPR export and a small amount of IPR import from many countries.

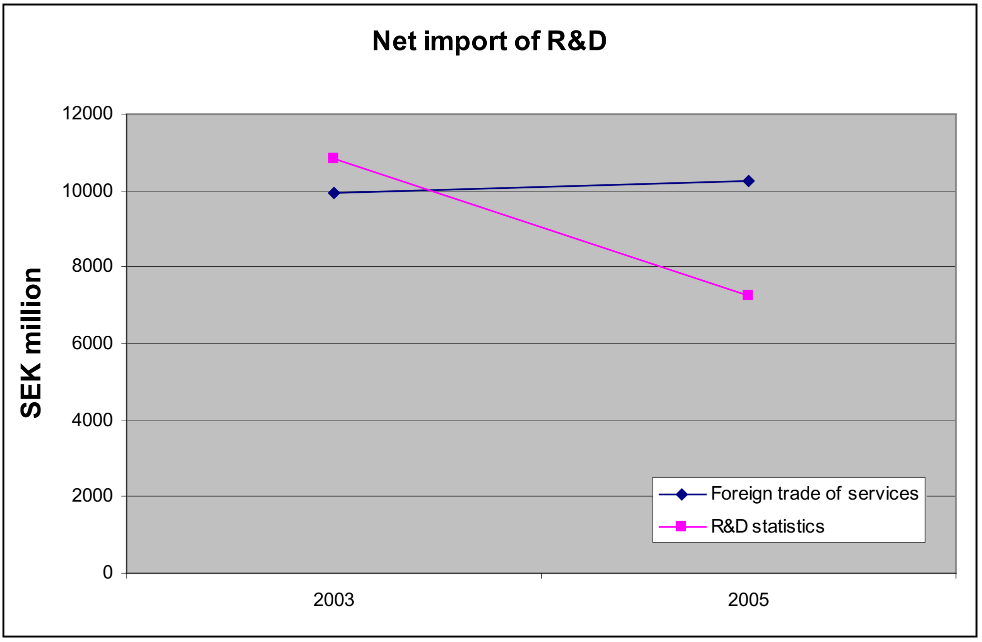
R&D survey versus foreign trade of services

This section compares import and export data on R&D from the foreign trade of services statistics with the R&D survey's contract R&D from abroad (approximately equal to R&D import) and the amount of in-house R&D financed from abroad (compared with R&D export data). Of course this involves different data sources with different types of questions and is thus not fully comparable. In particular, the R&D financed from abroad is probably underestimated since most R&D is financed with the companies' funds.

The results illustrated in figure 1 show a net import (export minus import) from both data sources used. The level of export and import is however almost double in foreign trade statistics compared to R&D statistics. This is exactly what to anticipate because the survey question captures more information in the foreign trade statistics.

Comparisons on micro-level data show that a handful of companies account for a big part of the R&D trade volume. Among the dominating firms some report export but do not get any funding from abroad (R&D finance with the company's funds), some report import but do not have the same volume in contract R&D abroad (maybe these are transfers of R&D among affiliated enterprises). The net

Figure 1 Net imports of R&D



import of R&D is due to two enterprises that account for more than half of R&D import.

Pros and cons with each data source

Differences exist between the two data sources as to population, survey design and definitions.

- Presumably there is underestimation of R&D exports in the R&D survey because this survey asked about R&D financed from abroad and not about R&D exports. Business enterprise R&D is to a large extent financed by a company's funds and some of it may then export.
- Presumably there is underestimation of R&D imports in the R&D survey because this survey asked about contract R&D and not R&D import. Contract R&D is probably a part of R&D imports, but not all.
- The R&D survey is based on international definitions (Frascati Manual) which are not used in the foreign trade statistics. Moreover, the R&D survey is only about R&D and in many firms the head of the R&D department is involved in deciding what to include in the questionnaire. According to these aspects, the source of error risk may be larger in the foreign trade of services statistics.

Conclusions and future projects

Intangible investments like R&D, innovations or any other intangibles are for certain hard to measure but to ignore these intangibles would be to miss what the economy is telling us. It is surly also important to study the impact they will have on productivity measures.

The move to capitalise R&D is probably a good idea to improve the National Accounts in concept, but when it comes to practical aspects there seem to be difficulties in bridging R&D into the NA. Those difficulties need to be overcome.

The R&D survey is presumably the best adapted source to collect R&D internationalisation data (import and export). However, supplementary questions are needed to increase the quality for inclusion in NA. Otherwise, the foreign trade of services statistics can be used, but that implies an increased amount of quality checking of R&D and coordination with the R&D statistics.

According to the case studies, the chosen level of in-house R&D in relation to the level of contract R&D differs considerably among companies and industries, and so do flows of funds to/from abroad for R&D. Some of the included MNEs were largely involved in international activities of R&D, some where not.

Before implementation of R&D as capital formation in the National Accounts further investigations need to be done. One such example is to construct bridge tables for a couple of years concerning comparability over time and among industries. Moreover, these bridge tables should guarantee to not overlap with software R&D, because software is already capitalised. Furthermore, needs for investigate a range of alternatives to get R&D service lives (depreciation rates) for building up stocks of R&D capital.

In the present revision of SNA changes will be made and R&D will be treated as investment by 2011.

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Table 2 **R&D expenditure by industry 2005, SEK millions**

	Net sales	In-house R&D (Intramural)[1]	R&D intensity	Contract R&D total (extramural)[2]	Contract R&D abroad (extramural)	Contract R&D abroad, within group of enterprises	R&D financed from abroad	R&D financed from abroad, within group of enterprises
Total	5 606 718	76 949	1.4%	20 433	13 823	10 226	6 054	4 504
Pharmaceuticals (NACE 24.42)	64 915	12 421	19.1%	732	426	262	313	199
Electronics (NACE 30-33)	196 225	15 673	8.0%	12 654	10 449	8 707	434	427
Transports (NACE 34-35)	358 500	15 758	4.4%	1 903	1 233	102	760	466
All other industries	4 987 078	33 097	0.7%	5 144	1 715	1 155	4 547	3 412

Table 3 **A few typical enterprise groups' international R&D activities. percentage of in-house R&D performed inSweden**

	Ownership (Swedish/ Foreign)	Contract R&D	Contract R&D abroad	In-house R&D financed from abroad	Export of R&D[3]	Import of R&D	Export of IPR[4]	Import of IPR
Case company 1	S	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.1%
Case company 2	S	95.5%	79.8%	0.2%	0.0%	107.6%	57.7%	4.3%
Case company 3	S	18.2%	9.0%	4.7%	0.2%	0.2%	0.0%	0.0%
Case company 4	F	6.2%	3.6%	0.0%	43.1%	84.3%	73.6%	3.4%
Case company 5	F	27.5%	17.7%	0.1%	168.7%	111.6%	0.1%	0.0%
Case company 6	F	5.0%	1.1%	21.1%	2.7%	3.2%	0.4%	9.3%
Case company 7	S	0.1%	0.0%	4.1%	0.0%	0.0%	0.0%	0.6%

1 *R&D survey in the business enterprise sector*

2 *R&D survey in the business enterprise sector*

3 *Foreign trade of services*

4 *Foreign trade of services*

Measurement of ICT capital – Plans and progress

Tomas Skytesvall, Statistics Sweden

Abstract

This document describes the work at the National Accounts on capital stocks of information and communication technology, ICT. It describes both what has been done earlier but especially focuses on the work of a newly initialised project.

Introduction

ICT capital serves as an important part of the capital input in analysis of economic growth and productivity. For instance, in order to reach a more accurate estimate of the growth in multifactor productivity, MFP, a separate ICT capital stock is a vital part of the production function.

The National Accounts at Statistics Sweden do not publish any official estimates on ICT capital stocks either on an aggregate level or a detailed level. But in connection with the work of the committee for the review of the economic statistics in 2002 the National Accounts constructed a separate ICT stock.

The committee was interested in productivity and the"New Economy". In order to perform a productivity analysis and to illuminate the relationship between the use of information and communication technology and the growth in production per hour, the committee needed the National Accounts to construct a stock of ICT capital for a number of major business aggregates.

Regarding the uncertainty in the estimations of the ICT capital, the final committee report concluded that a cause was the lack of direct annual estimates on ICT investments. An example was the lack of data on enterprises' investments in computers, which was instead included in total investments in machinery. At that moment there was no separate estimation of stocks of computers; instead they were included in the total stock of machinery affecting the assumption of mean service life.

At the present time the National Accounts have initiated a project which aims at an overall revision of the capital stock calculations. A part of this project focuses on estimations and accounting of a separate ICT stock on a disaggregate industry level.

This document will focus on the part of the project which concerns the estimation of the ICT stock at the National Accounts.

Project description

The Committee commented on a number of imperfections regarding the National Accounts estimations of capital stocks. It was emphasized that the users wished for updated assumptions of mean service lives. Separate ICT stocks were also lacking and wished for as they are useful in productivity analysis. In order to correct for this, among others, this project has been initiated.

One of the goals of this project is to improve the basis of the calculations of all capital stocks in the National Accounts. This regards primarily a review of the service lives or depreciations rates. The project is firstly limited to deal with these parameters and not to be concerned about whether to use a geometric or linear model of depreciation or investment series for earlier years. No formal investigations of service lives and depreciation rates have been performed in recent years at the National Accounts. The service lives and depreciation rates used for most types of capital have been collected from the Bureau of Economic Analysis in the US.

Another goal is that all capital stocks should also be accounted for sector-wise and industry-wise in as long time series as possible. This will make it necessary to find methods for back-calculation of the capital stocks. Yet another goal is to develop a model for separate accounting of the ICT stocks.

The outcome of the project will eventually contribute to better estimations of the capital stocks, especially the ICT stocks, which will thereby produce a better basis for, among other things, productivity analysis.

A description of the first attempt estimating ICT stocks

As was mentioned above the first attempt estimating a separate ICT stock was performed in connection with the work of the committee reviewing the economic statistics. The definition of the ICT stock, and also for which business aggregates the stock would be estimated for, was decided by the committee. Data and methods of the calculation were provided for by the National Accounts.

ICT capital was defined as computers, telecommunications equipment and software; purchased and produced on own account. The time period was to start in 1993.

In order to estimate starting values for the hardware parts, with 1993 as the starting year, so-called investment matrices for the years 1980 to 1992 were being used. They consist of an allocation of the industries' total investments in a number of groups of products. The problem arising when using these matrices was the breaks in the time series regarding the years 1985, 1991 and 1993. However, nothing was done to deal with these problems in the calculations. Stocks of the software parts already existed for the time period.

In order to estimate starting values for the hardware stocks longer time series of data than available were actually needed, especially for products with relatively long mean service lives e.g. telecommunication equipment used for broadcasting. In these calculations a mean service life of 15 years was assumed for this type of capital. With such a long service life, investment data for 30 years is normally needed to perform an adequate estimation of the value of the stock. The investment data available stretched from 1980 to 1992, and for obvious reasons, given the relative short time series, it was therefore necessary to make an assumption of the level of the stock even in the starting year 1980.

The starting value of the stock of telecommunication equipment in 1980 was estimated using the investments in that same year. It was assumed that one-quarter of the investments consisted of re-investments on behalf of depreciation and three-quarters corresponded to new investments. A reverse assumption regarding the investments and re-investments would have resulted in an 11 percent higher stock value in 1993, that is to say only a marginal difference, bearing in mind that the assumed starting value in 1980, in this case, would have been three times higher.

Regarding the telecommunication equipment, there is a difference concerning the sensitivity in the assumptions of the mean service life and the level of the starting value. The sensitivity regarding the level of the stock is obviously largest in the beginning of the period and diminishing closer to the end of the period.

But in the case of the assumed service life the sensitivity is more constant over time. Changes in the starting level by 10 percent would result in only 0.75 percent changes in value of the stock in 1993. But the corresponding change in mean service life would alter the stock value at the end of the period by 5.4 percent.

In the case of computer hardware a different approach regarding the investments and the mean service life was used. In this case it was assumed that three-quarters of the investments were regarded as re-investments on behalf of depreciation, and one-quarter was regarded as new investments. Using this assumption together with an assumed mean service life of 7 years, a starting value for the computer stock was estimated in 1980. In 1985 the mean service life was then shortened to 6 years and in 1991shortened again to 5 years.

The method used for calculating the starting value in 1993 is in principle the same as for the calculations in the following years. The equation below describes the relation between the starting value, investments, depreciation δδand the resulting value of the stock at the end of the period, which also forms the basis for the next periods starting value.

$$N_{t+1} = N_t + GFCF_t - \delta_t N_t - (\delta_t /2)^* \ GFCF_t \qquad (1)$$

N_{t+1}, stock value at the end of the period, (beginning of the next period)
N_t, stock value at the beginning of the period
$GFCF_t$, gross fixed capital formation during the period (investments)
δNt + (δ /2)* GFCFt, depreciation of capital

The starting value, N_t, in the next period is then calculated, using implicit price indices regarding corresponding investments, to reflate the end value in the present time period.

The present situation

Since a couple of years back there has been some ongoing work regarding calculations of multifactor productivity at Statistics Sweden. Examples include projects initiated by the *Nordic Councils of Ministers*, and internal analysis projects.

In connection with this work, the multifactor productivity has been estimated both on aggregate levels and for industries on a 2-digit NACE level. The effects of ICT capital on production and productivity have been considered a crucial issue in these projects demanding the construction of an ICT stock at the same detailed industry level.

Regarding the previous work of the committee the prevailing estimates of the ICT stock for the main business aggregates consisted of sub-stocks of hardware and software. The hardware and software parts was in turn divided into four separate stocks of computers and telecommunication equipment, and purchased software and software produced on own account.

To create starting values in 1993 for each of these four sub-stocks for each industry at a 2-digit NACE level, investments in 1993 and 1994 in corresponding industries and types of capital were used as a distribution quota. By distributing the starting values for each component of the ICT stock and main aggregate using this quotation, the starting values for each of the four components in every industry at a 2-digit level were created.

Next, with the created starting values on industry level and investments in each type of capital, sub-capital stocks were then constructed for all industries using the Perpetual Inventory method. These sub-stocks of hardware and software were then finally compiled into a total ICT capital stock for each industry on a detailed industry level.

When comparing the above described stocks of software with stocks of software already existing in the capital accounts the result was surprisingly good. The result of this comparison encouraged our beliefs in using the compiled ICT stock at a detailed industry level.

When breaking down the hardware of the major business aggregates into a more detailed industry level, certain problems occurred in some industries. As mentioned above, ICT hardware is included in total machinery capital. When comparing the level of the stock of hardware with the stock of total machinery in a few industries at the end of the period, total machinery would have consisted of ICT hardware only. Or vice-verse, the total stock of ICT hardware would have been depreciated leaving total machinery consisting of other types of machinery only. These consequences being exceptions, the final estimates of the growth in ICT capital per industry, according to our beliefs, were not too biased.

According to these results in some of the industries, there still are some problems to be solved regarding, among other things, the starting values for each type of hardware and industry.

Related projects

There is a scarcity of statistics and surveys about ICT investments both in Sweden and in other countries. In order to estimate investments in ICT, the National Accounts use both individual and combinations of surveys. The surveys used neither provide full coverage of industries nor direct estimates of investments in hardware and software.

In order to improve the estimations of ICT capital stocks, there is a need to improve the investment estimations in ICT capital. Two surveys from Statistic Sweden regarding enterprises' investments in and use of ICT capital have been developed in recent years. Hopefully the outcome of these surveys will provide for a better basis in estimating the level of investments in ICT capital and thereby help to improve the estimation of ICT stocks.

The purpose of the first survey, *ICT Investments in Enterprises,* is to describe the effects of ICT on the development in society. While asking enterprises direct questions about their investments in certain ICT products, this survey will be able to provide direct and more accurate estimates on ICT investments. This will certainly improve the basis for the calculations of investments in computers, telecommunication equipment and purchased software.

The purpose of the second survey, *ICT in Enterprises,* is to illuminate the use of information technology. This survey already started in 2000 and is conducted yearly thereafter. The benefit of this survey, according to ICT investments, is that it captures data on own account production of software within the enterprises. Together with data from other surveys it is then possible to produce estimates on the investment level in software produced on own account. The results of this survey are already being used by the National Accounts.

The next steps

The first step will include a revision of the definition of ICT capital used in the National Accounts previous calculations. The aim is to incorporate all missing types of ICT goods and services as far as possible in comparison to the definition proposed by the OECD. The OECD is though currently revising the ICT capital definition.

Regarding investments in hardware; computers and telecommunication equipment, information on that detailed level is lacking. Instead data on investments in *Total machinery* is collected from a business survey. This information on investments in machinery is then allocated to a number of investment products including computers and telecommunication equipment. This allocation is mainly performed by using last year's allocation pattern in the investment matrix.

Regarding enterprises' investments in purchased software, the National Accounts collect information from an investment survey. In this survey, lacking direct estimates of software, software investments are included together with expenditures in different types of ICT.

Given the new information in the survey regarding enterprises investments in ICT there are now direct estimates of hardware and software. This new information could serve as an alternative to the investment matrix regarding investments in computers and telecommunication equipment. Or at least it could serve as a tool in adjusting the allocation of investments in machinery.

In the case of software the same survey now provides direct estimates of investments in purchased software. This information will also be very useful in improving the estimates of these types of investments.

With a more accurate definition and new information on hardware and software investments within reach, better and more accurate estimates of the ICT capital stock should be possible to produce. And by reviewing the starting values for the existing ICT stocks for the major business aggregates together with continued testing of the distribution quota, better estimates on a more detailed industry level will eventually be the outcome in 2008.

Consumers Price Changes in Canada, 1995–2006

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Abstract

This paper provides explores on an experimental basis the degree of consumers price rigidity in Canada. The dataset covers the period 1995-2006 and contains almost 10 million price records. The paper reveals a substantial amount of heterogeneity in the frequency and size of price adjustments across products. Most price changes are increases, but price decreases are not uncommon. We explore how these features are affected by seasonality and the level of inflation. Our results suggest that price stickiness is not very important in Canada. We also find that, in terms of price stickiness, the results for Canada compare favourably to the U.S., and even more so the euro zone.

Introduction

Price stickiness is a standard assumption in macroeconomic models and considered to be a key ingredient for the understanding of the economy's reaction to a wide range of shocks. Despite the importance of pricing assumptions for macro models, the empirical evidence from micro data has remained relatively scarce. Taylor (1999) gives an overview of the stylised facts of price setting behaviour.

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More recently, Bils and Klenow (2004), followed by Klenow and Kryvtsov (2005), have studied price setting behaviour in the United States by examining a large dataset of prices used in the computation of the consumer price index (CPI). Similar comprehensive studies have subsequently been undertaken for the euro area countries within the Inflation Persistence Network (IPN), and also for other countries.

In this paper, we provide descriptive evidence about price setting behaviour in Canada. To that end, we analyze the micro data underlying the Canadian CPI for the 1995–2006 period. Our dataset covers about 82.1% of the expenditure basket and contains around 9.9 million price records on a monthly basis. We provide estimates of the frequency of price changes, including the duration of price spells and the size of price changes and an insight into hazard functions in the Canadian context. Price increases and decreases are treated separately, and special attention is devoted to the investigation of heterogeneity across commodities. We also examine how these features are related to the overall evolution of inflation. The analysis is descriptive and merely yields some indicative information regarding the importance of different pricing models. More structural analysis, including formal econometric testing of competing pricing models, is left for future studies.

The structure of the paper is as follows. The next section provides a description of the dataset and its descriptive statistics, and includes a discussion of data issues, as well as a brief overview of the inflation development over the sample period. Section 3 contains methodology and notation. Empirical results are presented in section 4, and in section 5 the interrelationship between inflation and price change frequency, and the size of price increases and decreases is analyzed. Finally, our main results are summarized in section 6.

The Dataset

The Micro Data Underlying the Canadian CPI

The dataset contains the micro data collected monthly by Statistics Canada in order to compute the Canadian CPI, covering the period January 1995 to December 2006. A general overview of the methodology for compiling the CPI is provided in Statistics Canada (1996).

The database is made up of 9,931,321 price records, which corresponds to around 70,000 records per month on average. Individual price quotes refer to a specific item sold in a particular retail outlet at a given point in time. For each record, we observe the following information: a numeric product code, the name of the product, the price of the item, the year and month, the name of the product category, a numeric product category code, a numeric provincial code, a numeric urban centre code, and a numeric outlet code.

The numeric codes allow us to identify and track each individual item, i.e. a specific product in a specific outlet. The product category code corresponds to the CPI commodity classification, also denoted as the basic class level. From this we aggregate into the CPI major components.

The Coverage of the Dataset and Weighting

In order to produce aggregate weighted average measures of the price changes frequency, frequencies of increases and decreases, duration, and the size of price increases and decreases, the official CPI weights published by Statistics Canada for the three baskets in effect during the 1995–2006 period were averaged using the length of time each basket was in effect. The basic class level is the most detailed level for which the weights are defined. All statistics at the basic class level and lower are computed as unweighted averages using all the observations of items belonging to that category. Aggregate statistics are then computed by averaging over basic classes using expenditure weights.

Table 1. Coverage of the Dataset, CPI Major Components: 1995-2006

	Weights[1]	Number of observations after filtering	Number of items	Coverage of major components[2]	Expenditure coverage
Food	17.5	4,835,144	173	78.6	16.7
Shelter	27.1	109,336	19	67.9	17.4
Household operations and furnishings	10.6	1,472,601	128	96.2	10.3
Clothing and footwear	6.2	1,111,206	151	100.0	6.0
Transportation	18.9	667,071	129	38.6	14.9
Health and personal care	4.5	748,710	56	93.3	4.5
Recreation, education and reading	11.4	681,768	200	76.6	8.6
Alcoholic beverages and tobacco products	3.8	305,485	88	100.0	3.8
Consumer price index	100.0	9,931,321	944	74.0	82.1

The filtered dataset constitutes 74 % of the number of items included in the CPI basket over the period of our sample (see Table 1), and comprises 149 basic classes. Overall, there are around 170 basic classes that enter the CPI calculation. About

20 classes were eliminated because they are subject to some manipulations before they enter the database. The majority of the eliminated expenditure components are services, leading to a significant reduction in their relative weight.

As a result of our filtering of data 1,700,159 monthly price records were eliminated, leaving us with a total of 9,931,321. The number of price records is very unevenly distributed across product groups to reflect the geographic level of price setting. Locally determined prices require that prices be collected in a larger number of urban centres, while fewer urban centres are required in the case of regional price setting.

Data Issues

Although the dataset is adequate for the purpose of tracking consumers' price changes, it was not necessarily designed to address research questions. Therefore, there are some issues that are worth mentioning, particularly in the context of this study. For a number of goods and services, prices are not collected monthly but only quarterly, biannually or annually as they are considered not to change very often.[3] Examples of this include license fees, local transit fares, golf memberships or motion picture admissions. In such situations, the price is mostly carried forward unchanged between the two collection periods. Consequently, the frequency of price changes could have been underestimated when prices change more often than is assumed by our collection pattern. The dataset has beforehand been subject to statistical editing – plausibility checks – by Statistics Canada in order to identify possible errors.

Another important characteristic of the price records is that most prices are inclusive of all types of sales, rebates and promotions. Compared to databases which do not consider these temporary price reductions as price changes, this can lead to a higher frequency of price adjustment, particularly for the products where sales are common, for example clothing and footwear. Most prices also exclude federal and provincial sales taxes, but include special taxes such as environment taxes. However, sales taxes are included for some products such as gasoline, some alcoholic beverages and cigarettes. Changes in sales taxes will therefore affect the results for only a small proportion of products.

3 *This dataset includes commodities whose prices can be observed within less than one year. Although this may overestimate the frequency of some representative products, the impact at the aggregate level may be negligible.*

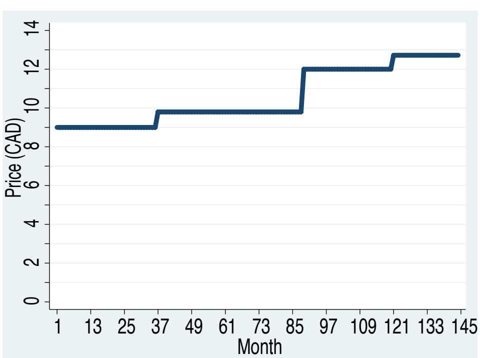
Price Trajectories and Price Spells

From the information in the dataset we constructed individual price trajectories, i.e. sequences of price quotes for a specific item sold in a specific outlet. We impose the – rather unrestrictive – rule that every trajectory should cover at least a period of two months, which is the minimum required to calculate a price change.

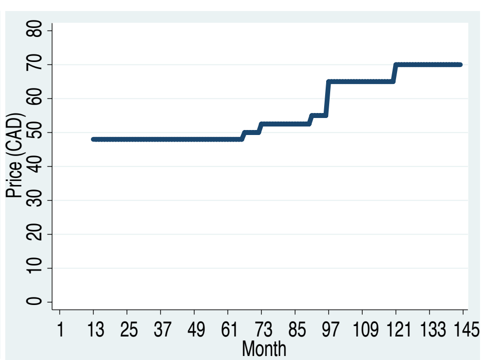
Chart 1 illustrates some price trajectories, selected for their typical pattern. Pricing behaviour is visibly very heterogeneous and the average length of a price spell – defined as the sequence of price quotes that remain unchanged – varies significantly between products. For example, the annual price of a driver's licence in Nova Scotia remains on average unchanged for 2 to 3 years, while the prices for an adult pass for local transit fares in Alberta are adjusted annually. In contrast, gasoline prices in Quebec change at least every month.

Chart 1. Examples of Individual Price Trajectories

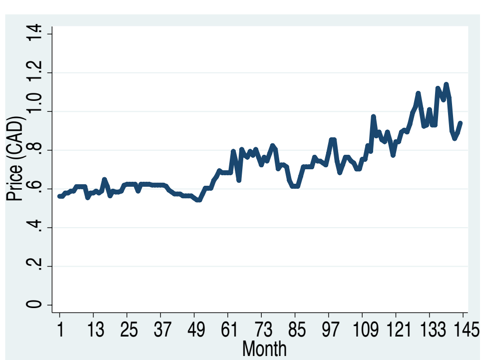
a) Driver's Licence in Nova Scotia[1]



b) Local Transit Fares in Alberta



c) Gasoline in Quebec



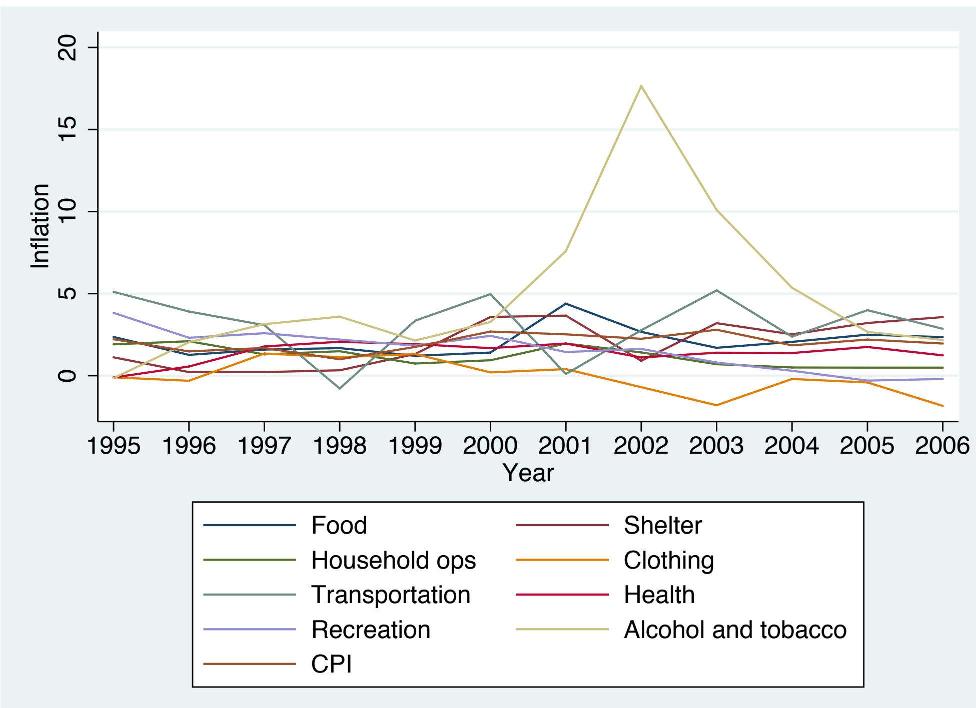
1 *The price for a driver's licence in Nova Scotia is on a five-year basis, but for the purpose of the CPI it is converted to an annual price which explains the low price level showed in this graph.*

2.5 Consumer Price Developments Over 1995–2006

For reference purposes, it is helpful to describe the evolution of consumer prices throughout the sample period. Chart 2 illustrates the twelve-month variation of the CPI and its major components.

The major components display significantly different inflation developments. While aggregate annual inflation (light brown curve) was relatively stable over the sample period, the evolution of the indices of some major components such as shelter and transportation were more volatile. The large movements in the transportation index were primarily the result of fluctuations in gasoline prices, while the shelter index was affected by variations in natural gas prices. The significant peak in 2002 for the major component alcoholic beverages and tobacco products is mainly due to a considerable increase in both federal and provincial taxes on cigarettes throughout the year.

Chart 2. Annual Variation in the CPI All-Items and its Components (%)



Methodology

In order to gain an insight into the qualitative nature of the price setting process, we look at the frequency of price adjustments, the duration of price spells, the size of price variations and estimates of empirical hazard functions.

This section contains an overview of definitions, notation and formulae used in the computations, as well as an assessment of potential biases and aggregation issues.

Frequency of Price Changes and Duration

Let I_{jt} be an indicator for price changes for item *j* in period *t*:

$$I_{jt} = \begin{cases} 1 \text{ if } & p_{jt} \neq p_{jt-1} \\ 0 \text{ if } & p_{jt} = p_{jt-1} \end{cases}$$

where p_{jt} is the price of observation *j* at time *t*.

For each basic class *n* the average frequency of price changes can be written

$$\overline{F}_{jt} = \frac{\sum_{j=1}^{J} \sum_{t=1}^{T_j} I_{jt}}{Q_n}$$

Qn is the number of observations in product category n for which it is possible to observe a price change, J the number of items in that category and Tj the number of periods during which we observe j. Let N be the number of basic classes, the aggregate frequency of price changes is then given by the weighted average of the frequencies at the basic class level,

$$\overline{F}^{w} = \sum_{n=1}^{N} \omega_n \overline{F}_n$$

where ω_n denotes the weight.

Alternatively, the duration could be computed directly as the average length of a price spell. However, calculating directly the duration from the raw data can be biased due to the presence of censored spells in the sample. Nonetheless, we compute the average weighted duration for our major components, and for CPI-All items. We assumed that since both left-truncated spells and double-censored spells can be defined as during at least y month, which is the characteristic of right-censored spells, they could be treated as such. On the other hand, the frequency approach allows the use of the full dataset and avoids the potential bias from the censored data, but relies on specific assumptions about the distribution of price changes over time.

Size of Price Changes

The size of price changes is computed as the rate of growth between *t* and *t-1*. Similar to the other aggregate statistics, the aggregate size of price changes is computed as a weighted average. To get a complete overview of the price setting strategies in Canada, we need to focus not only on price changes frequencies and signs, but also to have an insight into the size of the price changes.

Hazard Functions

The hazard function represents the probability of observing a price change in *t* given that the price remained unchanged until *t*, and is defined as

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr\{t \leq T < t + \Delta t \mid T \geq t\}}{\Delta t}$$

To obtain our estimates of the hazard functions, we compute as a first step the survival distribution function (SDF) as $S(t) = \Pr(T > t)$ and then derive the hazard function using $h(t) = f(t)/S(t)$ where $f(t)$ is the first derivative of the cumulative distribution function.

In practice, the empirical hazard function is estimated by using survival data and allows to take into account particular characteristics of the data such as censored price spells, unobserved heterogeneity and/or repeated events. In this paper, we focused only on censored spells, leaving the control of other potential biases for further studies. As before, we assume that both left-truncated and double-censored spells can be treated as right-censored spells.

Deriving hazard functions across heterogeneous items, such as a combination of flexible-price products and sticky-price products, introduces a downward bias in hazard function at the aggregate level. This is the case even when individual hazards are non-decreasing, as items with frequent price changes are split into many short price spells. As time passes, more and more spells with short durations exit the sample, leaving it with an increasing concentration of spells with long durations, which decreases the probability of observing a price change. Goette et al. (2005) address the problem of heterogeneity by analyzing a small dataset of homogeneous items known to have sticky prices and similar baseline hazards. As expected, they find the shape of hazard functions to be increasing, i.e. price-setters become more likely to adjust their prices the longer the time period elapsed since the last price change.

Empirical Results

Frequency of Price Changes

Table 2 presents weighted monthly frequencies of price changes for the CPI major components. On average, 28.1 % of prices for CPI All-items are adjusted from one month to the next, 15.7 % are increased and 13.2% are decreased. Prices are, therefore, lowered nearly as often as they are raised, so prices do not appear on average to be more rigid downwards than upwards.

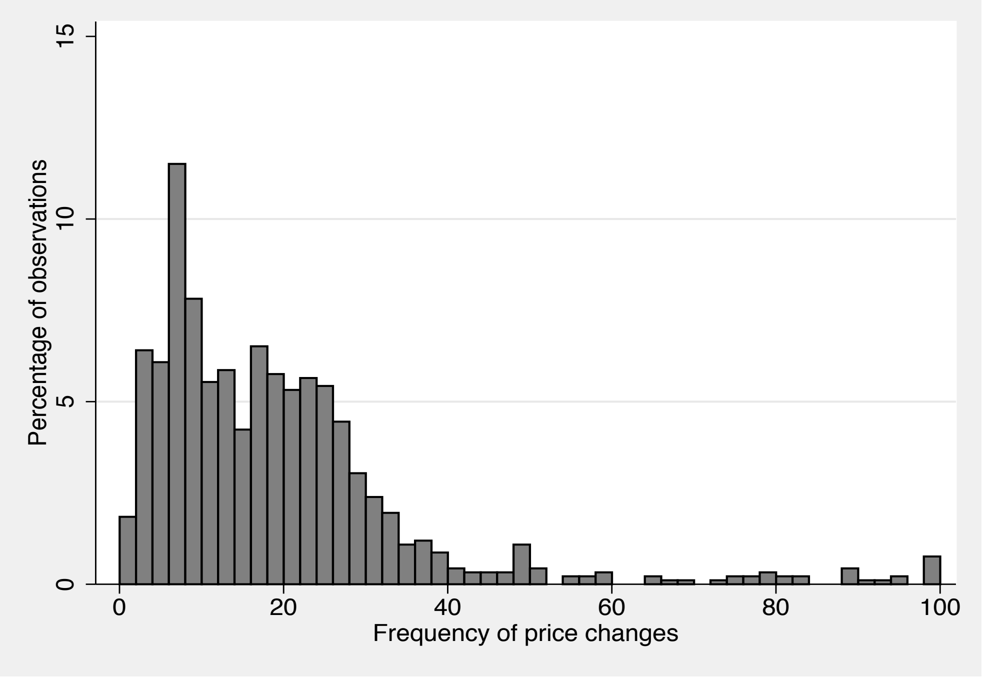
Price setting is very heterogeneous across components. Price decreases for alcohol and tobacco occur relatively infrequently, as only 4.3 % of prices, corresponding to a quarter of all price changes, are lowered every month. This reflects the fact that sales are not as common for these products. As well, a big proportion of their prices correspond to taxes that once increased are very seldom lowered. Prices for shelter and, to a lesser extent, transportation and food are by far the most flexible. For shelter and transportation, the highest frequencies of price changes are associated with heavily weighted products. The frequent price changes for transportation and food likely reflect the fact that these products are often hit by supply shocks, which have a substantial effect on their prices.

Table 2. Weighted Frequency of Price Changes, Monthly (%): 1995–2006

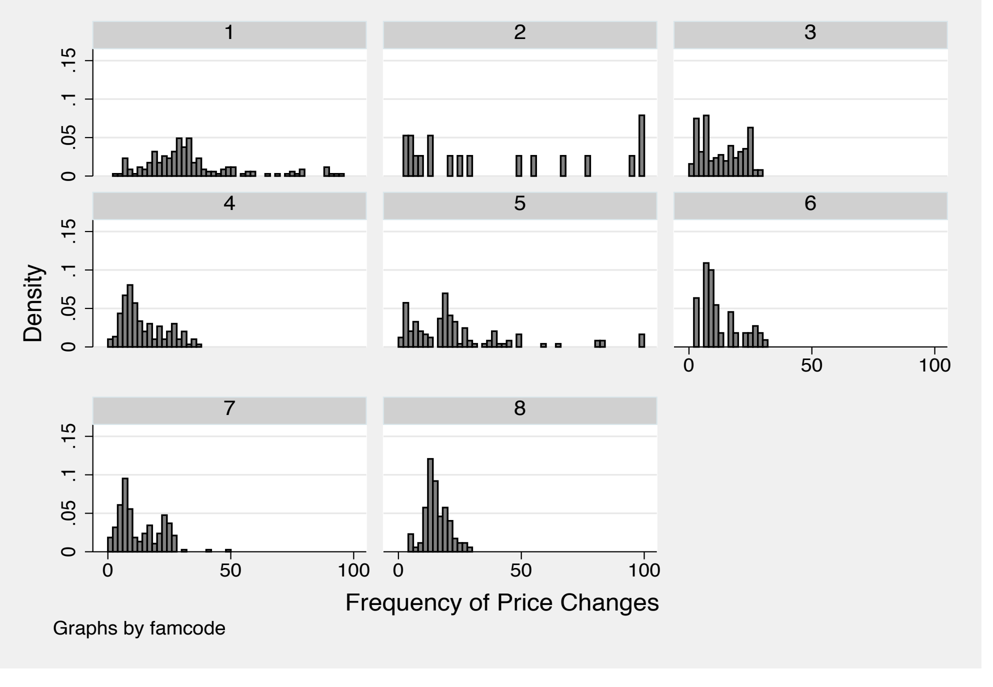
	Frequency of price changes	Frequency of price increases	Frequency of price decreases
Food	28.4	15.8	13.0
Shelter	50.7	28.2	22.5
Household operations and furnishings	11.01	6.1	5.3
Clothing and footwear	14.7	7.7	8.1
Transportation	35.9	19.1	18.8
Health and personal care	12.1	7.2	5.2
Recreation, education and reading	10.9	6.6	5.7
Alcoholic beverages and tobacco products	17.8	13.8	4.3
CPI All-items	28.1	15.7	13.2

Not all of the heterogeneity with respect to the frequency of price changes is captured by our breakdown of data, nor can it be detected from the distribution of frequencies for the CPI All-items (Chart 3 a)). This only becomes evident

Chart 3: Distribution of Monthly Frequency of Price Changes
a) CPI All-items



b) Major Components



when looking at the histograms in Chart 3 b), that use more disaggregated data. Transportation is composed of items whose prices are adjusted either very frequently, for example gasoline, and prices that change infrequently such as drivers' licenses. None of the other components display a similar dichotomy. Food is characterized by more evenly distributed frequencies, containing items with high, medium and low frequencies.

Seasonality seems to be an important characteristic of the frequency of price changes as the Charts in Appendix A demonstrate. For shelter, price increases are more frequent in winter months due to higher energy tariffs, whereas price reductions are more frequent in the mid-year.

The seasonality observed in clothing is to some extent driven by sales. Decreases are more prominent in June, December and January, where regular end-of-season sales take place, while the frequency of price increases is higher in March and September when the new season collections hit the stores. The frequency of price changes is particularly high in April for health and personal care due to its services component, for which prices tend to be raised once a year.

The frequencies for Canada are broadly in line with the estimates for the United States (26.1 %) but significantly higher than those of the euro area (15.1%) (see Table 3). Therefore, prices in North America appear to be more flexible than in euro areas. The higher rigidity in setting prices in the euro area in comparison to North America may be due to differences in the degree of regulation in the labour and product markets, and in the consumption patterns.

Table 3. International Comparison of Price Rigidity Studies

		Coverage ratio	Weighted mean frequency	Weighted mean duration	Weighted median duration	Average annual inflation rate
United States	Bills & Klenow (2004)	70	26.1	-	4.3	2.4
	Nakamura et Steinsson (2007)	70	26.5	-	4.6	-
France	Baudry et al. (2004)	64.3	18.9	7.24	4	1.5
Belgium	Aucremanne et Dhyne (2004)	68.1	16.85	-	13.25	2.2
Austria	Baumgartner et al. (2005)	90	15.1	14.1	11.1	-
Portugal	Dias et al. (2004)	-	22	-	8.5	2.6
Israel	Baharad et Eden (2002)	-	24	7.9	-	-
Spain	Alvarez et Hernando (2004)	70.1	15	11.4	8	-
Canada	Harchaoui et al. (2007)	74	28.1	9.2	4.8	2.0

Size of price changes

The sizes of price changes are reported in Table 4. Although individual price movements are larger on average, the resulting consumer price index variation is relatively moderate when increases are amalgamated with decreases. We can also note that when there are price variations, 59.2 % of these variations are prices increases. The upward inflation pressure in the Canadian economy is therefore the result of increases that are not only more frequent than decreases (15.7 % versus 13.2 %), but also larger in absolute terms (12.8 % versus -10.2 %). As well, components displaying the largest variations tend to have smaller frequencies, suggesting that some prices might be costly to adjust, in accordance with the menu-cost theory. As we can see from Table 4, prices for components such as household operations and furnishing, and recreation, education and reading are very seldom adjusted, but the variations in prices are greater in amplitude than those of the other components (except for food). On the other hand, prices for shelter are frequently adjusted, but their variations are very small.

The distribution of the size of price changes in chart 4 a) is slightly asymmetric even though fairly similar to a normal distribution when examined at an aggregate level, and has a weighted average value of 3.3 %. However, the major components in the CPI basket demonstrate a significant level of heterogeneity both across and within those components (see Chart 4 b)).

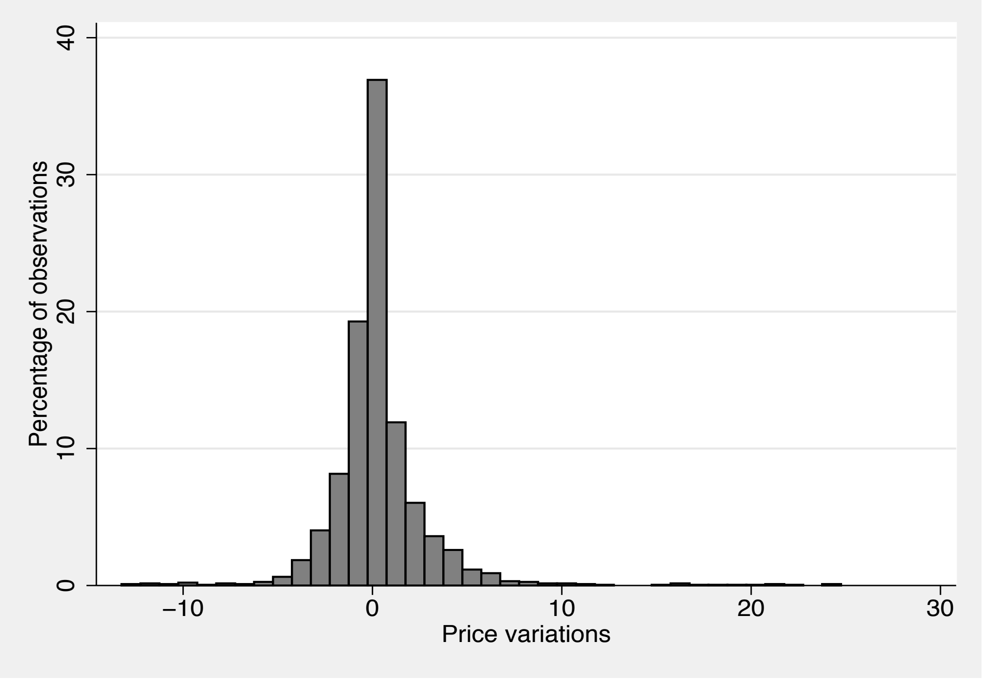
Table 4. Statistics on Positive and Negative Variations

	Positive variations			Negatives variations		
	Size	Frequency	Proportion	Size	Frequency	Proportion
Food	18.4	15.8	60.8	-14.5	13.0	39.2
Shelter	3.7	28.2	62.9	-2.9	22.5	37.1
Household operations and furnishings	16.2	6.1	51.6	-12.6	5.3	49.2
Clothing and footwear	30.6	7.7	49.6	-22.5	8.1	50.4
Transportation	8.0	19.1	56.5	-6.8	18.8	46.9
Health and personal care	13.8	7.2	67.7	-11.6	5.2	32.3
Recreation, education and reading	14.0	6.6	58.5	-12.2	5.7	43.1
Alcoholic beverages and tobacco products	4.7	13.8	74.1	-4.6	4.3	25.9
CPI All-items	12.8	15.7	59.2	-10.2	13.2	41.7

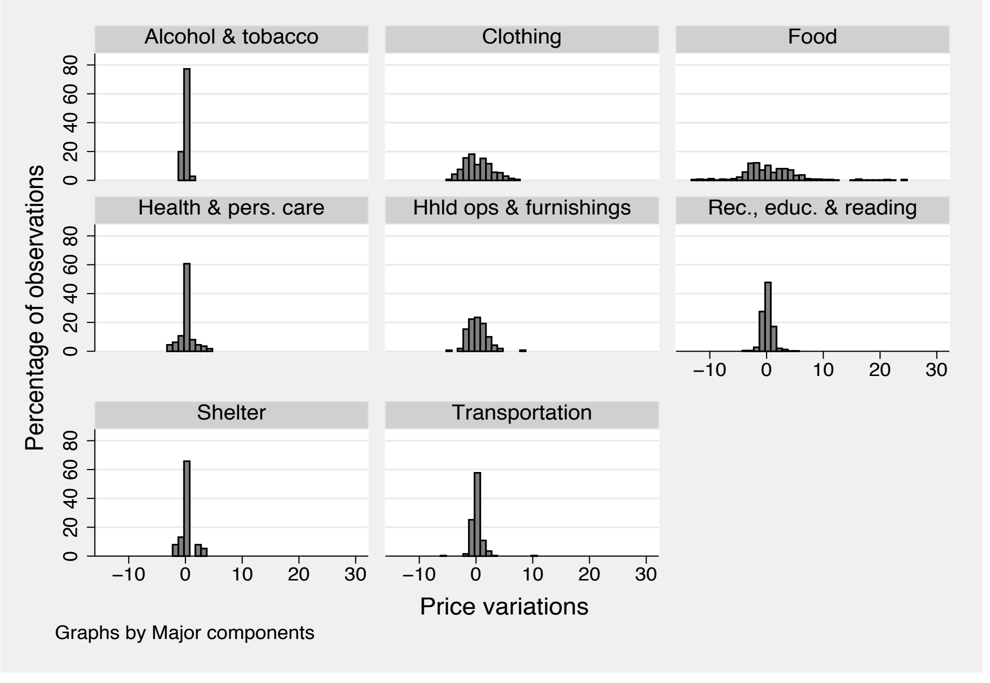
When we look at both Table 4 and Chart 4 b), we can infer some market price behaviour. While price variations are on average significantly large for the food products, we can see from the distribution of the size of price changes that most variations range from

Chart 4: Size of Price Variations – CPI and its Major Components

a) CPI All-items



b) Major Components



-10 % to +10 %, suggesting that a few heavily weighted representative products that display high positive variations drive the mean to a higher value. Those variations reflect the effect of supply shocks such as changes in weather conditions or diseases affecting livestock production. The distribution for clothing and footwear shows a double-bell shape, which is coherent with the presence of end-of-season sales (the peak in the negative side of the distribution) and the introduction of new collection (the peak in the positive side). For Shelter and transportation, the size of the price variations is highly concentrated around zero. As these components contain a considerable proportion of energy-related products, variations were expected to be relatively small while occurring rather frequently, reflecting both the gradual and moderate adjustment of energy prices. Similar observations can be made from the price dispersion for alcoholic beverages and tobacco products. As mentioned before, price variations for these products come mainly from federal and provincial taxes, and are therefore unlikely to be very sizeable.

Duration of Price Spells

The aggregate mean duration of all price spells is on average 9.2 months (see Table 5). As expected, the average price spells of transportation and food are the shortest, only lasting about 5 to 6 months. Contrasting with these major components that present high price flexibility, significant stickiness can be observed for the following major components: household operations and furnishings; recreation, education and reading; and health and personal care. For the first two, the longer duration of price spells can be explained by a high proportion of durable goods, while it is attributable to the importance of services for health and personal care.

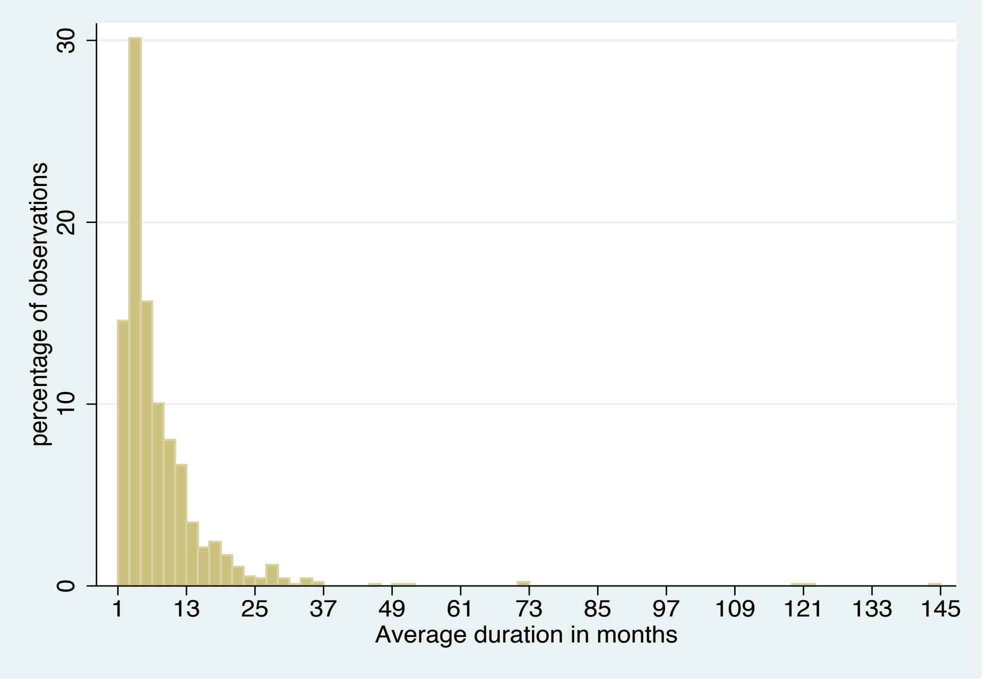
Besides aggregate mean durations, Table 5 also presents aggregate median durations. The median duration for CPI All-items is 4.8 months, nearly half the value of the mean duration. The gap between the two statistics is largest for components that comprise items with heterogeneous duration patterns.

Table 5: Weighted Durations of Price Spells (in months)

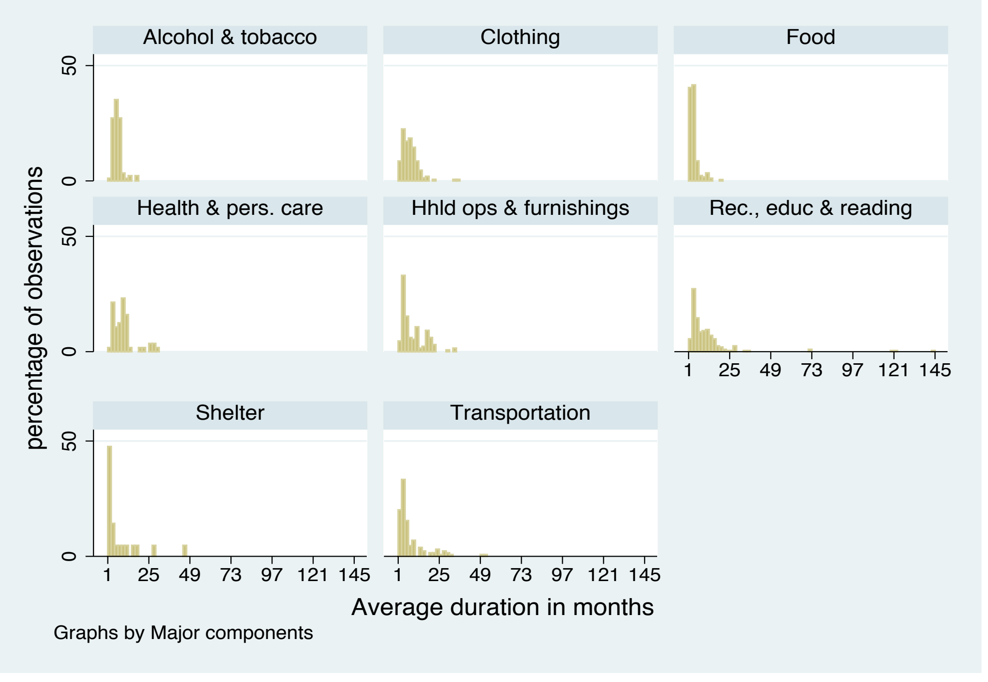
	Weighted mean duration	25th percent	Weighted median duration	75th percent	Average length of trajectories
Food	5.5	2.7	3.6	12.1	69.7
Shelter	11.6	1.0	1.8	7.0	70.7
Household operations and furnishings	12.6	5.9	11.5	22.1	70.2
Clothing and footwear	7.3	5.5	6.1	6.2	60.3
Transportation	6.2	1.2	3.8	3.8	68.3
Health and personal care	11.4	4.5	9.5	20.4	75.4
Recreation, education and reading	14.0	5.3	11.1	14.1	56.4
Alcoholic beverages and tobacco products	6.4	3.9	4.8	6.8	84.0
CPI All-items	9.2	3.2	4.8	12.1	68.2

Chart 5 . Distribution of Average Durations - Unweighted

a) CPI-All items



b) Major components



As can be seen in Chart 5 a), almost half of the spells in the CPI All-items last four months or less, while about 85 % last less than a year. Shelter presents an interesting divergence between the mean and median duration. As can be seen from Chart 5 b), a high concentration of observations have a survival expectancy of less than two months while we also find a few groupings of products with a much higher duration. These products are responsible for pushing up the value of the mean duration compared to the median.

The heterogeneity of the duration pattern is once again demonstrated when we compare the distribution of shelter to that of food. While the distribution of the length of price spells for shelter is well spread, food displays the most concentrated distribution. In effect, about three quarters of the price spells for food last less than 4 months.

The Canadian duration figures are close to those for the United States but significantly lower than those for the euro area (see Table 3). The median duration of price spells for Canada is 4.8 months, compared to 4.3 months for the United States, and 4–5 quarters for the euro zone, adding evidence to the argument that North American prices are more flexible.

Empirical Hazard Functions

Empirical studies of price setting behaviour often draw attention to hazard functions of price changes. Different pricing models usually have different implications for the hazard function. In the simple Calvo (1983) model of time-dependent pricing, the probability that a firm gets the possibility to change its price in a given period is independent of the time elapsed since its last price adjustment, implying a constant hazard function. In the even simpler Taylor (1980) model of staggered price setting, the hazard function takes the value of zero during the duration of contracts and one at the expiration of the contract. In models of state-dependent pricing, things get more complicated; the shape of the hazard function will often be increasing as the optimal price, which is a function of the state of the economy, is likely to drift away from the current price as time passes, see e.g. the model by Dotsey, King and Wolman (1999). Furthermore, under state-dependent pricing – unlike time-dependent pricing – the hazard rates will be a function of factors such as the inflation rate and macroeconomic shocks.

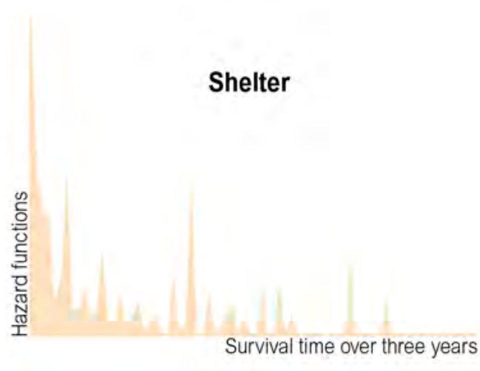
As expected, our hazard function graphs present a downward sloping trend, presumably induced by a high level of heterogeneity within products of a major components. We can also observe from the different shapes of hazards that there is also heterogeneity across major components.

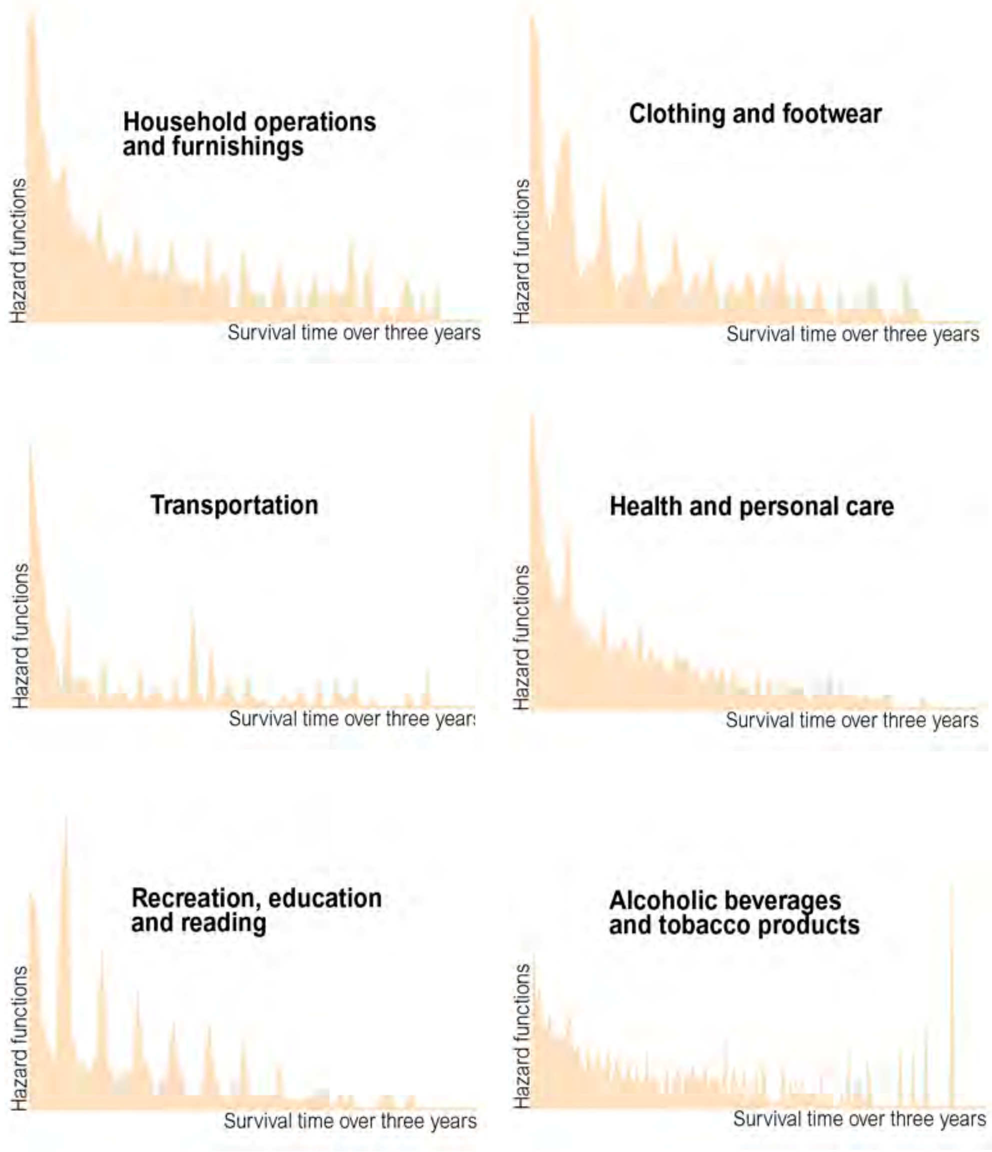
Besides recreation, education and reading, and alcoholic beverages and tobacco products, the products composing the major components of the Canadian CPI basket have their highest instantaneous probability of changing price in the two first months of a price spell. For recreation, education and reading, the price changes seem to happen mostly every year. It appears that price setters would be ready to wait another year before changing their prices when they miss their chance in the current period. That behaviour is coherent with the large concentration of seasonal products entering this major component.

It is not as obvious to draw conclusions about the behaviour of price setting in the alcohol and tobacco sector. The pattern observed from Chart 6 suggests no apparent pre-determined timing for a price change. This is in line with the fact that price variations come mostly from changes in government taxes which might be more erratic and are more likely to result from political strategies rather than from rational economic behaviour.

The clothing hazard function is similar to that of the recreation, education and reading component as both seem to display an annual price setting behaviour. While this pattern is coherent with the nature of the products included in recreation, education and reading, it is counterintuitive for clothing. Given that Canada has two very distinct seasons, we would expect a high concentration of price changes to be synchronized with the introduction of new collections on the market which would imply a semi-annual pattern.

Chart 6. Hazard Functions for Major Components – Life-Table Method

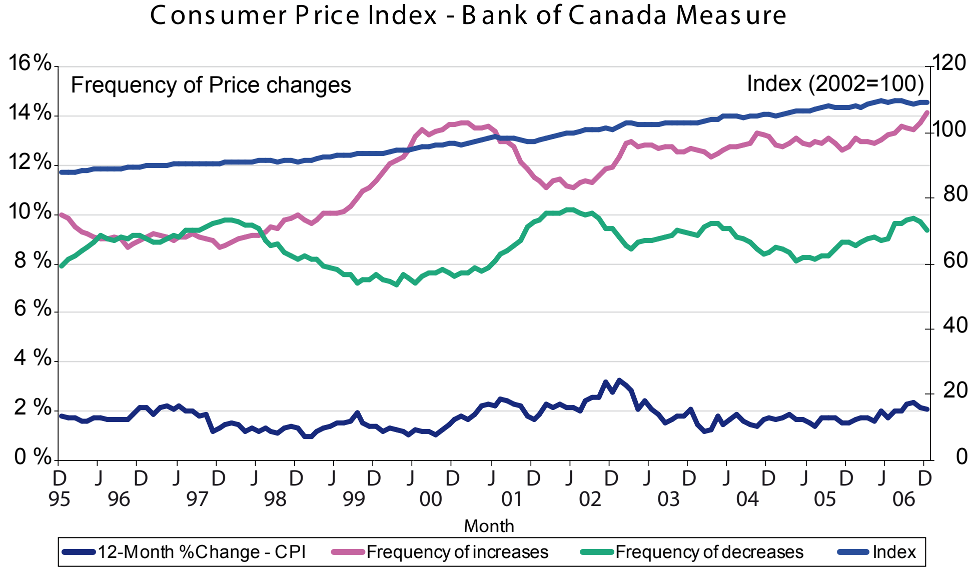




Inflation Compared to Frequency and Size

So far, we have found a great amount of heterogeneity in both the frequency and size of price changes over time and across products. In this section, we take a look at the relationship between inflation and the frequency of price changes through graphical analysis, leaving out more formal decomposition techniques for future studies.

Chart 7: Evolution of the Core CPI index, its 12-Month Change, and the Frequency of Price Increases and Decreases



To get a rough impression of the relation between the overall inflation rate and the frequency of price changes, we compare the core CPI index and its 12-month inflation rates to the frequency of price increases and decreases (Chart 7).4

We would normally anticipate a raise in the frequency of prices increases combined with a drop in the frequency of price decreases to translate into a higher inflation rate. This is the case for the periods from mid-1998 to late 1999 and from the fall 2002 to spring 2003. The opposite also holds true: a drop in the frequency of price increases combined with a raise in the frequency of price decreases results in a decline in inflation rate in late 1997 and 2001.

However, information for the second half of 2006 leads us to acknowledge that frequency is not the only variable to affect inflation. The raise in the frequency of increases and decreases can only lead to the observed increase in inflation if the size of price increases is larger than that of decreases. It is also possible that the products that were excluded from our study contribute significantly to the inflation which may explain why the correlation between inflation and frequencies is not as would be expected in some periods.

The fact that the frequency of price changes is somewhat correlated with inflation is consistent with state-dependent pricing strategies. Klenow and Kryvtsov (2005)

4 *Note that the estimates of the core CPI are the official ones and do not reflect the elimination of some products from our sample.*

also quantify the importance of fluctuations in the overall frequency and size of price changes for the variance of inflation. They find that 95 per cent of the variation in inflation is accounted for by changes in the size of price fluctuations, leaving almost no role for the variability in the frequency.

Nonetheless, Chart 7 shows that over the long-term, the trend in the CPI index seems to be correlated with the trends in the frequencies of price increases and decreases. While the frequency of price decreases does not present a significant change over the period, the frequency of price increases definitely presents an upward trend.

Many of the studies performed within IPN countries also find evidence of state-dependent pricing behaviour. For example, for Austria, Belgium, Germany and Portugal there exists a positive correlation between inflation and the frequency of price changes. Álvarez and Hernando (2004) provide evidence of state-dependence using econometric models, and Aucremanne and Dhyne (2005) find evidence of state-dependent pricing for Belgium using a logit model.

Concluding Remarks

In this paper, we have studied the price setting behaviour in Canada over the period 1995–2006 using CPI micro data. Through a comprehensive descriptive analysis, we have derived a set of stylised facts that are broadly in line with recent evidence from euro area countries. Our main observations are:

- Prices generally change rather frequently. On average 28.1 % of prices are adjusted from one month to the next and the weighted average duration of price spells lasts 9.2 months.
- There is no sign of downward price rigidity, except for alcoholic beverages and tobacco products. On average 41.7 % of the CPI All-items price adjustments are decreases.
- Pricing behaviour is very heterogeneous across sectors and products.
- Prices for shelter, transportation and food are more flexible.
- Although individual price movements are larger on average (+12.8 % versus -10.2 %), the resulting consumer price index variation is relatively moderate when increases are amalgamated with decreases.
- Seasonality is an important characteristic of the frequency of price changes.

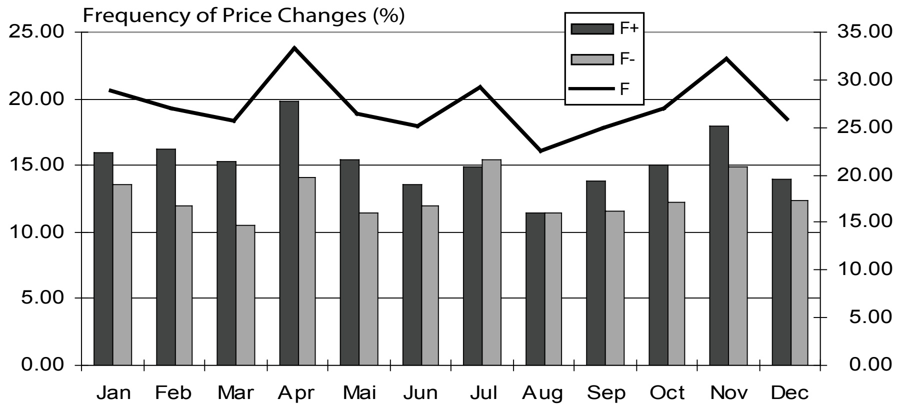
The results stress the importance of heterogeneity in price setting behaviour. To better understand the dynamics of aggregate inflation, this heterogeneity should be addressed when setting up the theoretical framework for microfounded macroeconometric models.

Our evidence supports the use of both time- and state-dependent pricing strategies. The application of time-dependent strategies is supported by the seasonal pattern in the frequency of price changes. Although the relationship between inflation and the frequency of price changes is in line with state-dependent pricing strategies, stickiness may be attributable either to the absence of chocks or the nature of the inherent nature of goods and services which remain insensitive to market forces. To the extent that our analysis is basically descriptive, we should refrain from drawing any premature conclusion about price rigidity without casting the results in their appropriate context. More structural interpretations await further econometric studies that rely on well-founded identification schemes.

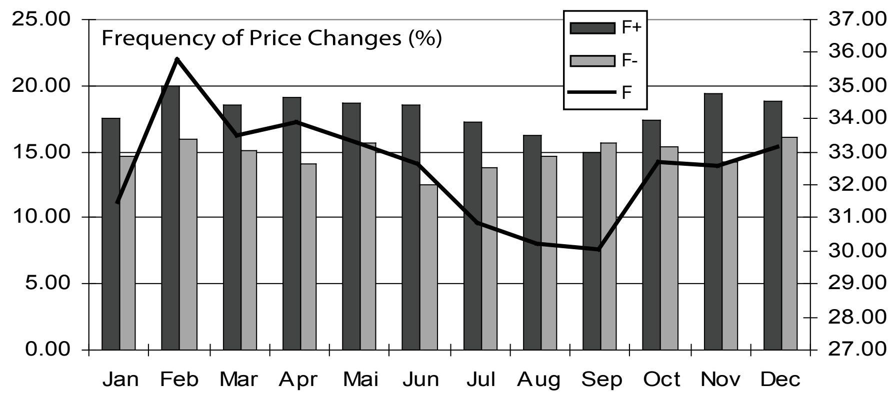
Appendix A

A. Frequency of Price Changes, Total, Increases and Decreases

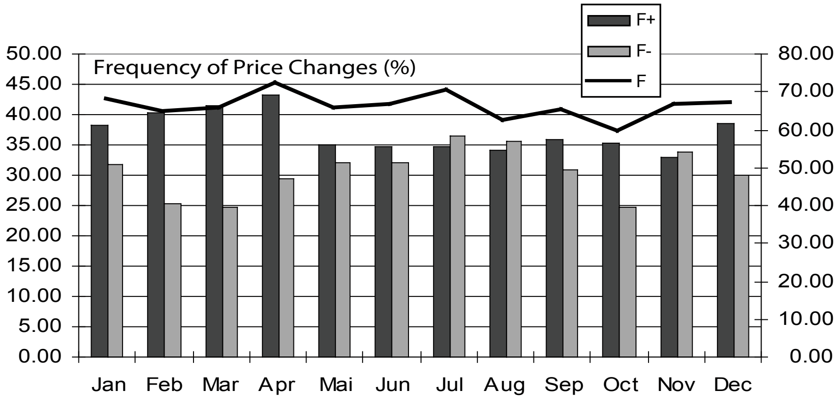
a) Consumer Price Index



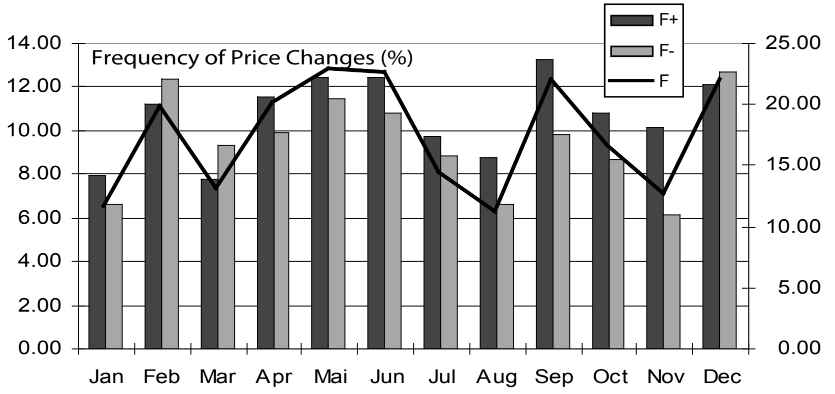
b) Food



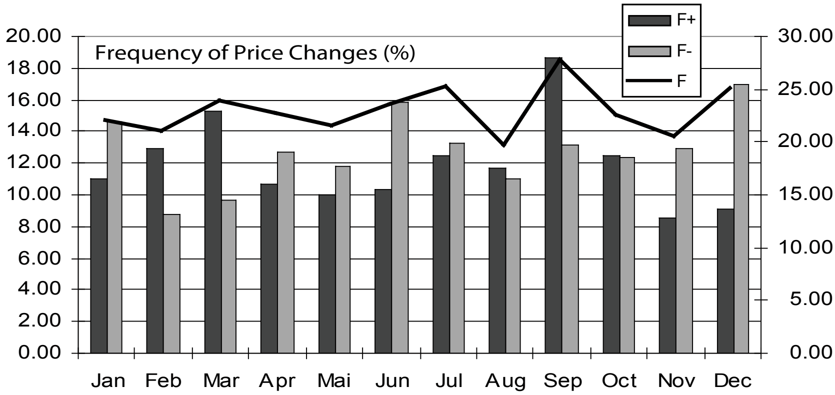
c) Shelter



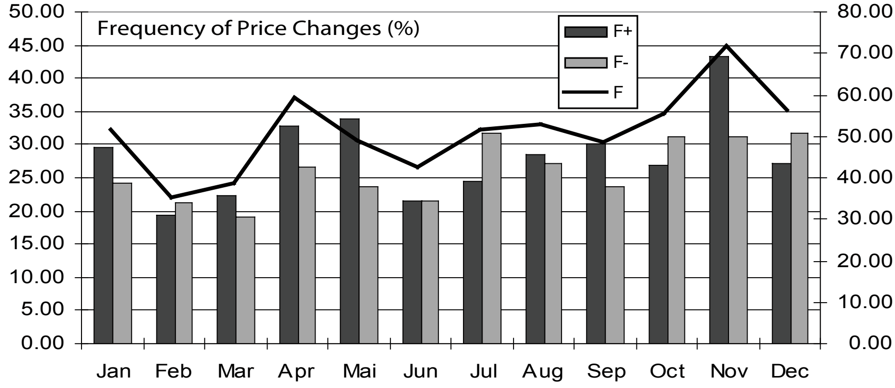
d) Household Operations and Furnishings



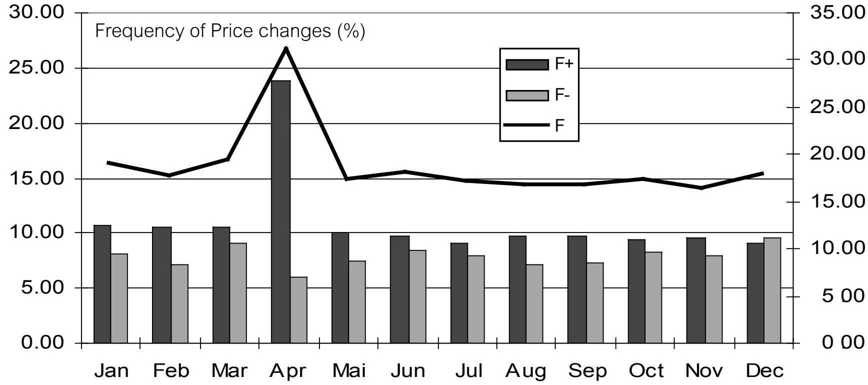
e) Clothing and Footwear



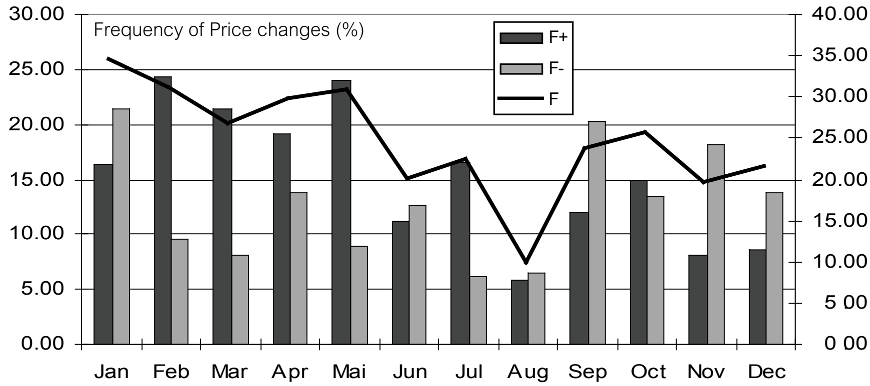
f) Transportation



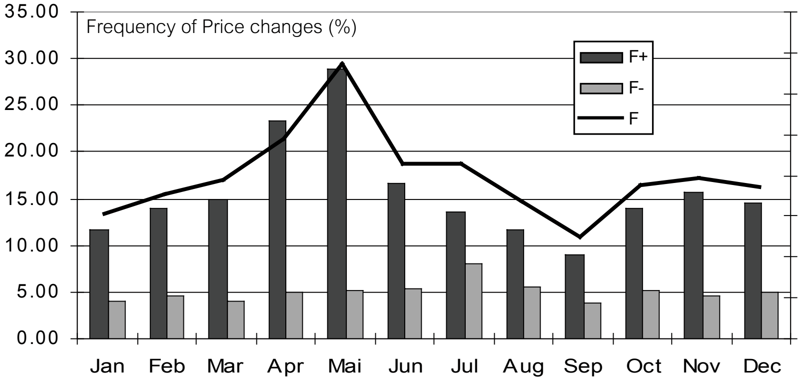
g) Health and Personal Care



h) Recreation, Education and Reading



i) Alcoholic Beverages and Tobacco Products



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1 *The weights are reported in per cent. The weights have been computed as an average of the different basket weights weighted by the length of time each basket was in effect.*

2 *This measure of coverage is in terms of the total number of items in the major component.*

Globalisation of technology captured with patent data. A preliminary investigation at the country level

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Abstract

This paper uses patent data to investigate the globalisation of technological activities as led by multinational enterprises since the early 1990s. Three questions are addressed: i) what are the major patterns in te globalisation of inventive activities? ii) what are the motivations of technological globalisation? and iii) what is the impact of globalisation on the inventive performance of the countries investing abroad in R&D and of those receiving the investment? Patent data give meaningful and rich insights into the globalisation of technology. Major findings are as follows. The share of cross border inventions in total inventions is increasing, reflecting the globalisation of R&D and technology. However, there is substantial variability across countries regarding the characteristics, motives and effects of cross-border R&D in terms of knowledge transfer. The dominant motive of MNEs in most countries for developing R&D abroad is to acquire lacking and complementary technological competences, expanding their knowledge base –

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while adapting products to local characteristics comes second only. Knowledge transfers from cross border inventions, both to the owner and to the inventor country, are high and rising steadily, in most countries.

Key words: globalisation, cross border research, patents.

Introduction

Productivity growth at the level of the firm is strongly influenced by the increase in technology implemented in the production processes.It can be newly produced knowledge (coming notably from R&D)Or it can be existing knowledge, acquired from another party (technology transfer).

The two sources of knowledge are not independent of each other as newly produced knowledge is based on existing knowledge, some of which can be transferred from other parties.

The role of multinational enterprises (MNEs) is central to both dimensions for the development of innovation and productivity at the country level:

- They allocate their R&D across countries (foreign affiliates)
- They transfer knowledge across borders: between their central lab (if they have one) and their affiliates, among their affiliates.

Hence cross border flows of technology play an important role in innovation performance of countries, and there is evidence that these flows have been gaining importance over the past decades. The R&D expenditure in foreign affiliates of MNEs represented USD 67 billion in 2005, more than 10% of world-wide business R&D (it was USD 30 billion in 1993). In certain countries this share is much higher, so that foreign firms have decisive influence on these countries' innovation patterns. Cross border patents (corresponding to MNEs inventions abroad) represented more than 17 % of all patents (PCT) in 2003 (10 % in 1990).

This new context raises particular policy challenges (OECD, 2007). The central debate has turned around the size and sharing of the benefits generated by these cross-border flows. What the the impact of MNEs foreign affiliates' R&D, on innovation at large, on the host country, on the owner country? Because globalisation of research implies a two-way channel (through inward and outward activities), national policymakers are confronted to a twofold policy challenge: How to stimulate the internationalisation of domestic firms while ensuring the reinforcing of national innovation capabilities? How to attract innovative companies that will strengthen domestic capabilities?

To date the evidence is not sufficient to discern how and to what extent globalisation of research will change the conditions for S&T production and its contribution to economic growth. One important limitation for answering these questions remains the lack of internationally comparable data addressing the different dimensions of globalisation.1 Patent data are in that regard a potentially fruitful source of information.

In that context, this study will address the following questions:

1 What are the major motivations for MNEs to conduct innovation activities abroad?
2 What is the impact of MNEs overseas' R&D on:
   a the efficiency of research (i.e. quality of R&D conducted aboroad compared to research conducted at the home country);
   b the owner country's technology ("hollowing out" vs. expansion of national capacity);
   c the host country's technology ("knowledge drain" vs. local development).

This study is conducted at the country level, from countries' perspective. There are advantages and drawbacks in conducting an investigation of this kind at the macro level. The investigation at the country level allow us to evaluate the overall effects in terms of knowledge transfer (inward and outward) associated to globalisation, regardless of the type of company. This is the best way to go when addressing the contextual aspects of MNEs' strategy, the general determinants and impact of internationalisation. We acknowledge though that, in order to capture the microeconomic aspects and to reflect more directly the strategy of the MNEs, the firm level dimension has to be integrated into the analysis. This is the next step of our work, not reported here.

Patent indicators of internationalisation

In order to address the questions above we use patent data.Patents are exclusive rights over inventions, which are granted by national patent offices. Information reported in patent documents, hence that can be used in statistics, includes:

- The name and address of the applicant (owner company).

1 Information from surveys on foreign affiliates' activities (e.g. OECD-AFA Database) is currently providing important insights but their coverage remains still limited to few countries. Other indicators available from R&D statistics and trade include the share of R&D financed by abroad sources, trade in high-technology products, receipts and payments in technology; mobility and migration of S&T workers, etc. (i.e. OECD, 1998; 2005).

- The name and address of the inventor (individual); it is most often the address of the laboratory where the invention was done.
- The technical field of the invention (international classification).
- Citations to prior art (antecedents, notably other patents).

The advantages of using patent indicators for tracking developments of technology are numerous. In spite of their drawbacks[2] (OECD, forthcoming), patents offer important advantages to investigate technological activities: broad availability and international comparability, exhaustive coverage across countries and technology fields, readily access in electronic formats, amongst others.[3] Furthermore, most significant inventions are patented; patents have a close (if not perfect) link to inventions. Patents provide a reasonably complete description of the invention, the technology field concerned, the inventor (name, geographical location, etc.), the applicant (ibid), cites to previous patents and scientific articles to which this invention relates to, amongst other things.

Patents used in this study are PCT ("Patent Cooperation Treaty") patent applications, monitored by the WIPO. The PCT is a route for filing patent applications in nearly all patent offices in the world at the same time. The advantage of the PCT, from a statistical perspective, is that they are far less biased, in terms of country repartition, than other types of patents, which are all tied with a particular country or region.

Patents corresponding to"cross-border"inventions (made by foreign affiliates of MNEs) are defined as those whose the applicant (owner) and inventor reside in two different countries.

This is interpreted as a patent coming out of research conducted at a laboratory pertaining to an MNE and located abroad, in a different country than the headquarters. Following Guellec and Van Pottelsberghe (2001), using this information contained in patents, two indicators of cross-border ownership can be computed at the country or technology/regional level:

- Foreign ownership of domestic inventions: It takes the host (i.e. R&D performing) country's perspective; it refers to patents which are applied by a company from abroad and which have at least one domestic inventor. The

2 Not all inventions are patented (and not all companies patent, some prefer secrecy, first to market strategies, etc.); the value distribution of patents is skewed, the propensity to patent differs across countries and industries, differences in patent regulations make it difficult to compare patent statistics across countries, etc (e.g. Griliches, 1990).

3 Patents cover a broad range of technologies and countries on which there are sometimes few other sources of data, patent data are available for a long time period (e.g. USPTO has been granting patents since 1836).

number of such patents can then be divided by the total number of patents invented domestically.

- Domestic ownership of inventions made abroad: It takes the owner (i.e. MNE's headquarters) country's perspective; it refers to patents which are granted to a country but whose inventions have been made abroad with at least one foreign inventor. The number of such patents can then be divided by the total number of patents owned by the country regardless of the country of residence of the inventors.

The first indicator reflects the extent to which foreign firms control domestic inventions. Symmetrically, the second indicator reflects the extent to which domestic firms control inventions made abroad, by residents of other countries.[4] Obviously, these indicators are not independent from each other. What is accounted as a foreign ownership in one inventor country implies a domestic owned invention abroad by domestic firms in another country.[5] In addition, domestic ownership includes inventions for which the owner country may have participated as a co-inventor; and the same logic applies for the case of domestic ownership.

The utility of patent indicators to measure globalisation are not however without shortcomings. A large part of the caveats have to do with the practical limitations in patents to properly identify companies' countries' of origin and their strategies for dispersion/location of ownership.

- The owner country as identified in the patent document may be in some cases, not the country where the headquarter of the company is located (where the resources come from), but the country of the subsidiary in charge of management of international intellectual property (i.e. an intellectual property holding company). Certain companies have set up an IP-holding company which files patents on its behalf world-wide and which is located in a low tax country.
- A second issue concerns the actual economic meaning of the cross-border ownership. A patent invented abroad may not necessarily mean a setting up of a R&D laboratory but rather from an acquisition or merger. Hence, such an invention would have become cross border only some time after it was made, and the cross border character could not have affected

4 *Some fraction of these patents subject to cross-border ownership might also represent a co-ownership between two companies located in different countries; but again this case more likely concern cases of co-ownership between headquarters and foreign subsidiaries. It represents however a very small share of total patents subject to cross border ownership.*

5 *Thus, the worldwide total of patents with foreign ownership of inventions is therefore the same as domestic ownership of inventions; total patents subject to cross-border ownership.*

the invention process. Patent databases do not register such changes in the ownership of patents. Changes in ownership, in our database, are registered until the grant of the patent (on average 3 to 5 years after application), not later. So, this problem should not be too large.

- A third issue is that a patent can be taken directly by the local affiliate of the foreign MNE, without the MNE being mentioned I te patent filing. The consequences are that ownership in fact does not belong to "domestic" firms and therefore foreign ownership for some countries is under-estimated (e.g. see the case of Belgium in Cincera et al, 2006); and symmetrically domestic ownership of foreign inventions is underestimated for the owner country.

While issue 2 might result in overestimating cross border inventions, issue 3 might lead to underestimate them. Casual evidence suggests that issue 3 is more widespread than issue 2, so that overall patent data tend to underestimate the degree of internationalisation of technology.

It has to be noticed that patent data used in this study come from the OECD Patent citations database, which was still experiemental at the time of data extraction. Hence, certin figures presented herein are subject to possible revisions.

Patterns of globalisation

Numerous studies conducted since the early 1980s have documented an unambiguous rising trend in the globalisation of technological activities (e.g. Cantwell, 1992, Patel and Pavitt, 1999). The driving forces include changes in the global value chain by multinational companies (OECD, 2006), a fierce technology based competition, but also a greater flexibility in handling cross-border R&D projects (lowering coordination costs), amongst others. The tendency to internationalise research and technological activities has also been favoured by major policy changes, notably the international strengthening of intellectual property rights (e.g. TRIPs agreement) and the improvement of conditions for direct investment and technology transfer activities.

These factors have led multinational companies to disperse increasingly their sources of knowledge in an effort to integrate worldwide learning process (e.g. access to foreign centres of excellence, seek of strategic partnerships in innovation, etc.) and produce competitive technology at lower costs. These strategies take part of new innovation models (the 'open-innovation' model, e.g. Chesbrough, 2003) where external sources of knowledge play an increasing strategic role in the production of technology.[6]

6 *These links include horizontal (competitors), vertical links (suppliers, clients) and public research organisations and universities, etc.*

Figure 1 **Cross-Border Ownership of inventions – World**

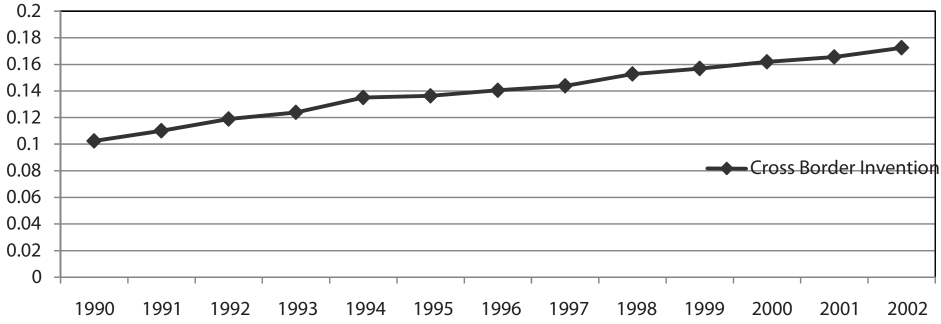
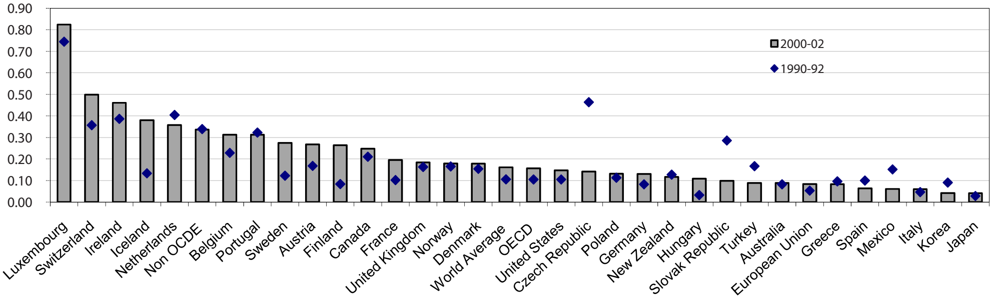


Figure 1–3: Source: OECD Patent Database.

The figures based on patent confirm the expansion of globalisation of technological activities. Cross-borders inventions represented more than 17 % of all patented inventions in 2003 world-wide; their share have been continuingly increasing since 1990.

Figure 2 **Domestic Ownership of inventions made abroad**



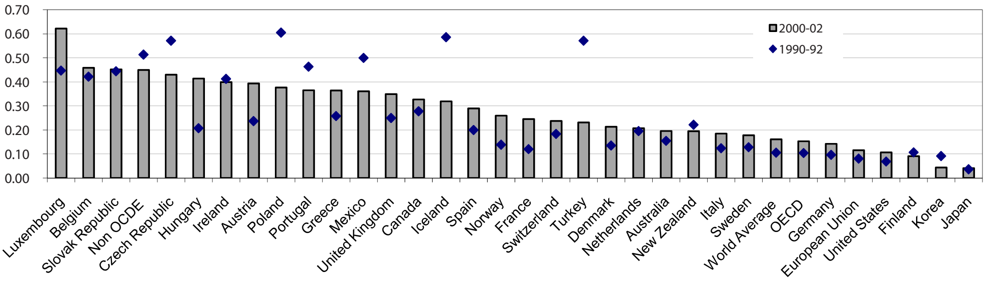
The host country's perspective is reflected in foreign ownership of domestic inventions, i.e. inventions made in the country and owned by foreign entities. Among countries for which data are reported, this share varied, in 2000–2002, from 4 % (Japan) to 62 % (Luxemburg). Most countries are between 10 % and 40 %. Among the large counties, the UK comes first with 35 %. Sweden is at 18 %. Some patterns emerge from the cross country comparison (see Guellec and van Pottelsberghe 2001). Overall, countries with a higher share of domestic inventions owned by foreign MNEs are:

- Smaller countries: this reflects a quasi-mechanical effect of size, which affects all economic variables (trade, foreign direct investment etc.)
- Countries with lower own R&D capability (R&D over GDP): this is probably related to the ability of domestic firms to generate new inventions. The lower it is, the more the country relies on foreign entities to set up such capabilities. As a matter of fact, most countries which experienced a decline

in the share of foreign owned inventions are those which experienced an increase in their national capabilities (Eastern European countries, non-OECD countries).

It has also to be noticed that, in view of their size and R&D intensity, Japan and Korea feature very low, and it is also the case of Finland and, although to a lesser extent, Sweden. This relative insulation could be related to the openness of the capital market, in the case of Japan and Korea. For Finland, linguistic factors could play a role.

Figure 3 Foreign Ownership of domestic inventions



The owner country's perspective is reflected in domestic ownership of foreign inventions, i.e. inventions made abroad and owned by domestic entities. This share varies from 4 % (Japan) to 82 % (Luxemburg). As for domestic inventions owned by foreign entities, the size factor plays a visible role. But the domestic R&D capability plays a role which is opposite: Countries with higher R&D intensity own a larger share of inventions made abroad. Hence, R&D intensive countries will in general have a higher share of their owned inventions made abroad than of their domestic inventions owned by foreign firms. That explains for instance the higher ranking of Sweden and Finland, or also Switzerland. It also explains the fact that the EU, considered as a single zone, has only 7 % of its inventions made abroad whereas the US has 11 %. Again, Japan and Korea feature the lowest, despite their high R&D intensity. MNEs from these two countries prefer to conduct their R&D at home.

What motivates cross border R&D?

Two main explanations (not exclusive of each other) have been given for MNEs to locate their R&D overseas:

- Knowledge sourcing (or"asset expanding","tapping talents"): the MNE intends to use (tap in) knowledge capabilities of the host country in order to expand its own knowledge capabilities. Hence the core knowledge of the firms is enriched by overseas' R&D.

- Product adaptation ("asset exploiting","market access"): the MNE uses local competences in order to adapt some of its products to local tastes, regulation etc. Core knowledge is transferred from the MNE to its local affiliate.

We test the relative importance of these two motives on the basis of the following assumptions:

- Knowledge sourcing is associated with host country inventions as a source of cross-borders inventions.
- Product adaptation is associated with owner country inventions as a source of cross-borders inventions.

The sources of a particular inventions can be tracked through patent citations. Any patent is published together with a search report, drafted by a patent examiner at the patent office, which includes references to the prior art, i.e. other inventions (most often other patents) which can be seen as a background for the invention. We can therefore track the use of inventions done in the host country in foreign owned inventions (how often they are cited) and the use of the owner country inventions in inventions it owns but made abroad (how often they are cited). We use the share of backward citations (average reported by patent) made to inventions produced by the host country (sourcing), and inventions produced at the home owner country (exploiting), in total backward citations made by patents produced with inventors located abroad.[7]

Figure 4 Knowledge Sourcing

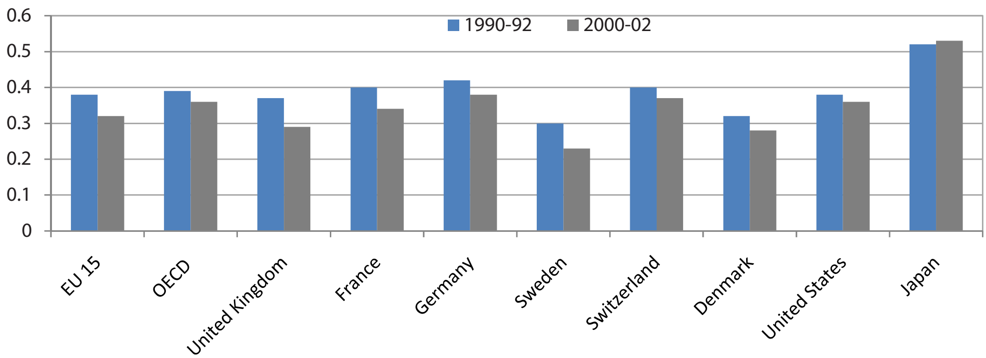
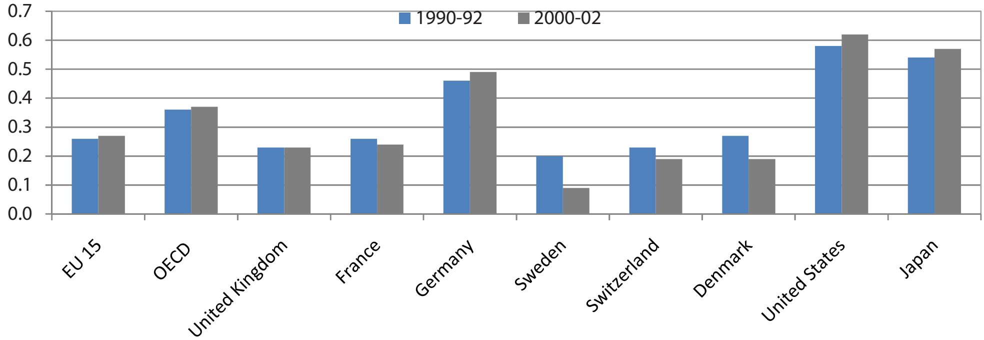


Figure 4–9: Source: OECD/EPO Patent Citations database, 2006

7 *This raw citation shares provide useful information on the gross flows of knowledge between the recipient and investor economies (totals). Further investigation at the partner-partner level, would allow to establish the intensity of such knowledge relationships across countries or regions, taking into account their size (e.g. number of patents). By looking by partner country, we should be able to compute the citation frequency, a measure of how intensively patents in one country cite patents from another after controlling for the size of the potential pool of citations between the two. In simple terms, it is the number of citations from country A to country B divided by the product of the potential number of citing patents in country A and potential number of citable patents in country B.*

Figure 5 Knowledge Exploitation



The identification of the use of knowledge originated at home and originated at the host country in cross border inventions provides some insights. First, the two objectives are present, together, but knowledge sourcing seems to be dominant OECD-wide. For inventions made during 2000–02, citations to the host country represent around 36 % of citations in cross border patents (average share by patent), whereas owner country citations represent 37 % only – despite the fact that the owner country is generally more advanced technologically than the host country. Thus, the two objectives co-exist; on average, same importance. There has been little change in that regard between 1990–1992 and 2000–2002. It should be noticed tough that knowledge sourcing was bit more important in the early 1990s (39 % vs. 36 %).

The importance of knowledge sourcing is particularly clear in the case of EU MNEs. At the opposite, in the case of the US it is the exploitaing knowledge motivation which seems to dominate: US MNEs do R&D abroad more for adapting their products. Lastly, Japanese MNEs appear as being driven by the two motivations: they locate research abroad for both reasons, to exploit knowledge assets as much as for tapping knowledge. It should be noticed though that for Europe as a single zone (15) both motives have relatively low importance apparently, as compared with the rest of reported countries.

The fact that the knowdge sourcing motive has not gained in relative importance over this period of time seems to contradict a claim often made in the literature and in policy discussions. But this has to be qualified however: first, this motive was very important already in the early 1990s; second, if one takes into account the increased share of cross border inventions in total inventions, then the role of knowledge sourcing in innovation systems, in absolute terms, have strongly increased over this period, although no more than prodyct adaptation.

The relative quality of inventions

This section investigates the quality of research conducted abroad compared to research made and owned within national boundaries. We measure and test the importance of cross-border inventions based on the citation impact of inventions, which is considered in the literature as a measure of technological importance and an indicator of economic value. It has been consistently reported in empirical studies that patents that receive more citations than the average are more valuable patents; are more likely to be renewed and opposed in tribunals.[8] *Our questions are the following: Are cross-border inventions different in quality as compared with domestically made inventions? How this difference has changed over time?*

The quality of inventions made overseas compared to the quality of domestic inventions can be interpreted as a measure of the efficiency of R&D activities conducted abroad. A decreasing gap in quality may explain in part the rising of international research activities. It would suggest that companies are becoming more able to overcome technology transfer costs (related to geographic and cultural distances) and other inefficiencies related to dispersion of knowledge (*e.g.* leakage-out, integration into host national innovation systems, etc.).

Different factors might contribute to make research activities abroad more efficient and with higher quality. It has been recently argued that the traditional shortcomings related to decentralisation of research might be less severe. Multi-location firms compensate inefficiencies with gains related to integration of diversified knowledge on a worldwide basis. Kogut and Zander (1993), Almeida (1996) or Singh (2006) have shown that subsidiaries may successfully tap into external knowledge sources geographically distant. Accordingly, MNEs implement formal and informal mechanisms (*i.e.* intra-firm mobility of experts, inventors with extensive social networks), which allow them to cross-regionally integrate dispersed knowledge and overcome coordination problems.[9]

Relying on forward citations, different approaches can be implemented to investigate the quality differential of cross-border inventions. A first approach

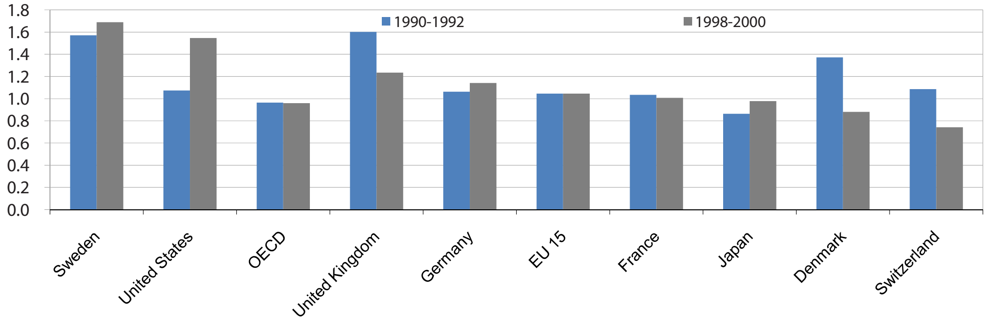
8 *Forward patent citations have been proven to be good indicators of economic value. Numerous studies have consistently corroborated the correlation between the citations received (notably no-self citations) and the economic value of patents as perceived by inventors, the likelihood of patent opposition or renewal (e.g. Harhorff et al, 2003). Further, patents being more frequently cited, as they have a strong technological impact, they are also more highly valued by investors in the stock market (Hall et al, 2001).*

9 *Singh (2006) has recently tested three of these informal mechanisms on the value of patents for multinational firms. He finds that while distribution of R&D appears to be negative associated to the average value of innovations; patents reporting knowledge sourcing from other R&D units (e.g. patent citations), having at least one inventor with cross-regional ties, and having at lest one inventor that has recently moved from another region; all seem to have higher quality.*

consists in comparing the citation impact of domestically made inventions and cross-border inventions.

- The *citation impact* (Hall *et al*, 2001) is an indicator on the quality of inventions. It is the number of times a patent is cited compared to the average number of citations received by a patent regardless in the same technology field (4 digit IPC class) and having the same invention date (priority date).[10]
- The *relative citation impact* (ibid) compares then the quality of cross border inventions relative to the quality of inventions made uniquely within domestic boundaries.[11]

Figure 6 **Relative Citation impact**



We examine the average relative citation impact across inventions for our sample of countries. It appears that overall cross border R&D has a technological impact as big as R&D conducted at the home countries (by the same owner country). The difference is particularly elevated for Sweden (60 %) and for the US (above 50 %). For the US, the gap has increased sharply since the early 1990s. For large European countries the gap is not significant, reflecting probably the fact that most foreign R&D owned by European countries is made in other European countries, which are not that different from doing R&D at home. It is pretty much the same level of quality between cross border and home made inventions between the two periods. The UK is the only country in the sample which has experienced a sharp drop in the relative quality of R&D conducted abroad. Finally, Japan used to have its MNEs R&D conducted abroad of lower impact than the one conducted domestically, but the two have converged since.

10 *This approach permits to control for the differences in citation frequency across technology fields and the truncation effect related to time (earlier patents having an intrinsic lower probability of being cited, see Hall et al, 2001).*

11 *It is a measure of advantage or disadvantage the country has in performing research abroad compared to the home country: an index superior (inferior) to one indicates that companies from that country produce inventions with higher (lower) quality average than those produced at home.*

The impact of cross border R&D on the owner country's inventions

It is sometimes argued that MNEs, by investing abroad, would be detrimental to their home country, as they reinforce the technological capacity of competing countries instead of their own. On the other hand, it can be argued that by investing abroad, MNEs strengthen the technology base controlled by entities of their home country, a base which can then serve for value creation appropriated by the home country.

A second hypothesis explaining the expansion of internationalisation of technological activities concerns the increase in efficiency of global research activities. In other words, international technological activities become easy to conduct as the ability of companies to integrate knowledge developed abroad has increased and companies become more competent in transferring knowledge back to headquarters (Criscuolo *et al*, 2004). This reverse knowledge transfer is achieved through different means: companies' knowledge management practices, mobility of experts within the network, increased flexibility in the management of information, etc. Indeed, opportunities for cross-border learning have been enhanced by an increased take-up of ICT technologies (Cantwell, and Santangelo, 1999).

This argument is in line with the idea that companies and so, investor countries can benefit from having technology "listening posts' in foreign countries. It is important to mention as well that the benefits of reverse knowledge transfer through multinational companies might be higher for the host economy as spillover-backs can be also disseminated to other companies into the source country. There might be some costs however associated to a growing delocalisation of technological activities; so far not yet confirmed. It has been argued that increasing off-shoring of technological activities may lead to an erosion of domestic capabilities (hollowing out), and employment and economic losses if results are only exploited outside the home market.

It has to be noticed however that most arguments in favour of the "hollowing out" theory ignore the non rivalry of knowledge: the fact that one piece of knowledge, even if used in one place, can also be sued in other places, by different entities, at the same time. It is therefore not contradictory to have knowledge being used both in the owner and in the host country.

We test here the extent to which cross border inventions are used as a source of knowledge for further inventions in the owner country. We use the share of backward citations (average reported by patent) made to inventions made abroad in inventions made exclusively with domestic inventors. This indicator reflects the weight of imported owned knowledge among inputs to the production of new knowledge.

Figure 7 **Reverse Knowledge Transfer**

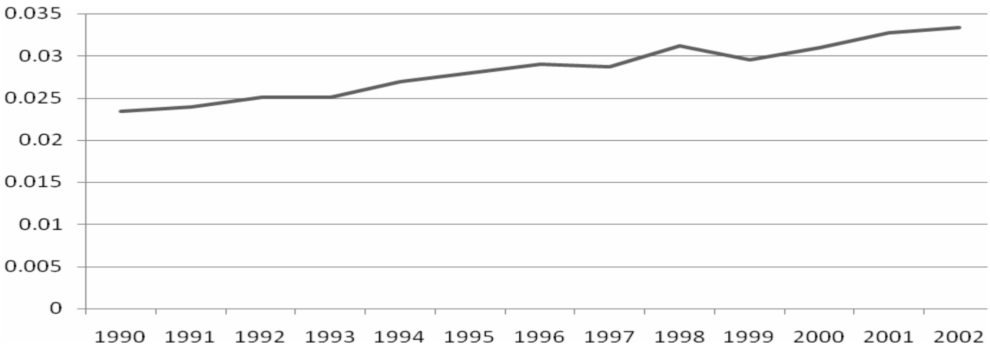
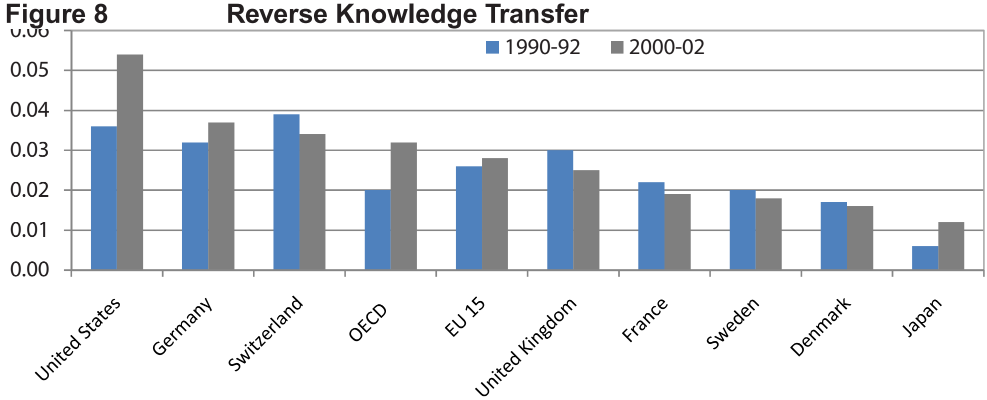


Figure 8 **Reverse Knowledge Transfer**



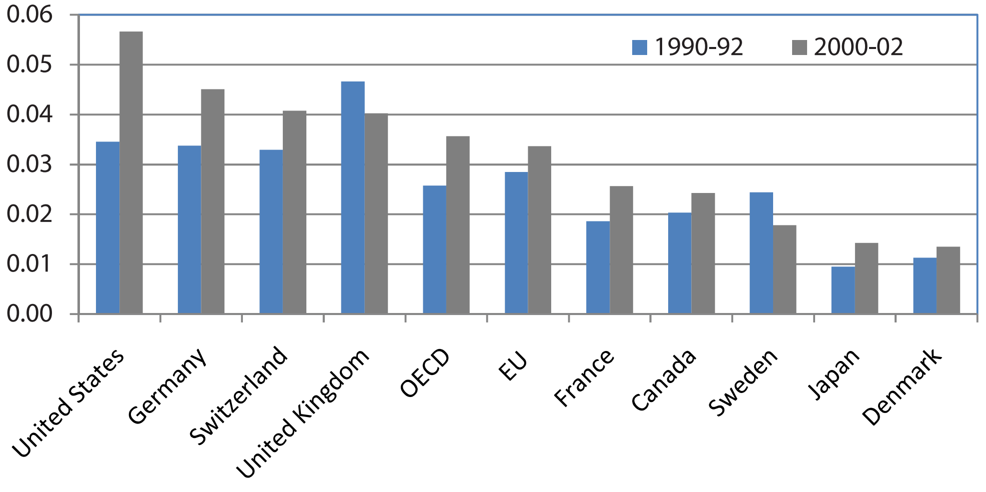
Citations to cross border inventions in domestic (owner country) inventions have been increasing since the early 1990s, although at a reduced pace in the late 1990s–early 2000s. Their share has grown from 2 % to 3 %. The level is particularly high for the US, Germany and Switzerland. It is very low France, Sweden, Denmark and Japan. In the UK, this share has been declining. Hence such imported knowledge plays a significant role in further inventions in the owner country.

The impact of cross border inventions on host country's inventions

Arguments exchanged around the effect of cross border R&D on the host country's inventive capacity mirror those exchanged on the effects on the owner country. On the one side it has been claimed that foreign owned R&D would drain local resources, picking some of the best researchers, creating value from local research of which domestic companies are then deprived. This "knowledge drain" argument is in fact a variant of the "knowledge sourcing" theory of cross border R&D, a variant which denies any benefit to the host country (all benefits being appropriated by the owner country). On the other side, it has been argued that foreign MNEs R&D facilities can be a source of local spillovers, allowing technology transfers from the owner entity (then owner country) to the host country.

We examine here the influence of cross border inventions on domestic inventions, in the host country by looking at the extent of knowledge transfer to local inventions. We measure it by the share of citations to cross border inventions in domestic inventions of the host country.

Figure 9 Knowledge Spillover from Foreign owned inventions



Such citations represented about 3.6 % of total (backward) citations in OECD in 2000–2002, against 2.5 % in 1990-1992, reflecting the growing spillovers which accrue to the host country. The growth in citations to cross border inventions is observed particularly in the US, where its level is also the highest in the triad. The EU 15 countries has barely changed, while Japan has experienced a significant increase, but keeps at the lowest level in the triad, just before Denmark.

Conclusion

- Patent data give meaningful and rich insights into the globalisation of technology.
- There is substantial variability across countries regarding the characteristics, motives and effects of cross border R&D.

- Increased share of cross border inventions in total inventions, reflecting the globalisation of R&D and technology.
- The dominant motive of MNEs in most countries for developing R&D abroad is to acquire lacking or complementary technological competences, expanding their knowledge base – while adapting products to local characteristics comes second only.
- For numerous countries, there has been upsurge in the efficiency of research conducted abroad, which indicates a higher ability to deal with inefficiencies related to dispersion and transfer of knowledge.
- Knowledge transfers from cross border inventions, both to the owner and to the inventor country, are high and rising steadily.

Further investigation will be conducted in the future at the company level (microdata). It will also make use of harmonised data on patent citations: hence results presented in this study should be considered as provisional.

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Innovation, intangibles and economic growth: Towards a comprehensive accounting of The knowledge economy

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Introduction

We live in an era of rapid, almost dizzying, innovation in products and processes. These innovations have improved consumer welfare through the introduction of new goods and services, improvements in the quality and lower costs of existing products, and greatly increasing the amount of information about available products. They also revolutionized the organization of production, not just the 'technology' of production as narrowly conceived, but also the management and global reach of corporations around the world.

While the impact of innovation is evident 'on the ground,' and widely supported in the academic literature, it has proved surprisingly hard to develop an overall measure of the magnitude of the macroeconomic impact. How much of the recent growth in GDP is due to this revolution? What is the impact on living standards and worker productivity? Some progress has been made in answering these questions, particularly in measuring the impact of ICT capital on growth, but the answers tend to be piecemeal or incomplete.

Various attempts have been undertaken to construct comprehensive innovation indicators, both in the U.S. (for example, at the National Academy of Science) and in Europe (for example, the Community Innovation Survey), but the lack of a coherent analytical framework within which to evaluate these indicators and the difficulty to arrive at bottom-line financial metrics, have left many questions unanswered.

The need for better metrics of what constitutes the knowledge economy and how it contributes to economic growth presents both a challenge and an opportunity. There is a clearly a perceived need for improvements in official national statistics and international statistical systems. There is also a need to connect the large body of microeconomic survey and interview data on innovation to the macro statistics. The size and complexity of the connection process is daunting, but it is already beginning to happen. Piecemeal efforts at 'connecting the dots' may simply produce more dots. What is needed is an ongoing program that develops and maintains a set of macroeconomic innovation accounts built on official statistics, but going beyond them.

In this paper we argue that in order to improve our understanding of innovation, we need a systematic and comprehensive accounting framework for the knowledge economy. Growth accounting, which has become the empirical work horse of growth economics, involves a simple way of decomposing the growth rate of output per worker into its component sources, capital formation and innovation. Growth accounts are typically developed by researchers parallel to official national accounts, and can therefore be relatively easily linked to official statistics of NSI's.

Several national statistical institutes (NSI's) have begun to construct growth and productivity accounts in conjunction to their national income and product accounts. However, the quest for the contribution of innovation to growth needs to go beyond this – by now well-established – sources of growth model. The traditional model typically stops short of moving beyond the measurement of the contribution of tangible capital to growth. The outlays for research and development, other types of knowledge creation, organizational innovation and other economic competencies, such as branding and marketing, are usually expensed in the accounts framework. As a result, these expenses do not add to GDP and the residual growth that remains after accounting for the contribution of tangible investments, called multifactor productivity (MFP) growth, may hide the effects from unmeasured intangible investments.

All to the good, this has recently changed with some major attempts to capitalize the key components of intangible investments. Corrado, Hulten and Sichel (CHS, 2005) have developed an estimate of intangible investment for the past five decades in the United States. They subsequently integrated a measure of intangible capital in the growth accounts of the U.S. (CHS, 2006). This work has recently been replicated for some other countries, including the United Kingdom, Japan, and presently also for some continental European countries. Even though we are still in early days, it is clear that for a full understanding of how the knowledge economy operates in a macroeconomic setting, the extension of growth accounts towards including intangible inputs and output is a crucial component of this work.

The paper proceeds as follows. In section 2 we lay out the present situation with regard to the measurement of innovation and knowledge creation in relation to economic growth and we identify the areas that urgently require attention in future work. These are (1) the use of an extended growth accounts framework that allows for a detailed decomposition of output into the input components (labor, capital and intermediate inputs); (2) the measurement of intangible investment, covering ICT, knowledge inputs and economic competencies; and (3) the integration of the latter in a growth accounts framework.

In Section 3 we briefly describe the *EU KLEMS Growth and Productivity Accounts* as an illustration of the state of the art in growth accounting. The results from EU KLEMS are summarized in Timmer, O'Mahony and van Ark (2007) and van Ark, O'Mahony and Ypma (2007).[1] EU KLEMS is one of the most recent and

1 *See also the Economics Focus section on "Use IT or lose it" in The Economist, May19th 2007, p. 82.*

most comprehensive efforts to build a system of growth accounts across a wide range of European countries, as well as the U.S. and Japan, with a breakdown to industry level and a decomposition of the contributions from labor input, capital input and intermediate inputs to growth.

Section 4 summarizes the recent work in the area of measurement of intangible capital and growth in the United States, as developed in the work by Corrado, Hulten and Sichel (2005, 2006).

Section 5 provides an international comparison of measures of spending on intangibles in the early 2000s for those countries for which such measures are now available. It compares the pioneering estimates for the U.S. by Corrado, Hulten and Sichel (2005, 2006), with more recent estimates for the United Kingdom (Haskel and Marrano, 2007), for Japan (Fukao et al., 2007) and the Netherlands (van Rooijen-Horsten, 2007).

Finally, section 6 reviews the issues ahead of us.

Innovation and Growth: How Far Are We in Establishing the Link Empirically?

There is no doubt that the relationship between innovation and economic growth is not straightforward. Innovation refers to a broad range of activities aimed in part at incremental improvements to existing products, processes, services ("new ways of making current products better, faster, cheaper") and in part at revolutionary, breakthrough developments ("creating something not previously created"). The mix and relationship between incremental and radical innovations varies a lot and has very different impact on growth.

It has turned out very difficult not only to measure the innovation activities itself, but also to measure its relationship to economic performance. Real GDP per capita is the most widely used indicator, which is convenient because of its link to the closely related statistic on the production side, that is real GDP per worker ('labor productivity'). The productivity of labor in producing goods and services is a key determinant of the volume of products available for consumption, now or in the future, and is thus associated with the underlying utility-based standard of living. Real GDP per worker can also be linked to the economic factors that lead to increases in output per worker over time: capital formation and innovation in products and production processes. The relation between these factors and the resulting output is the subject of a huge theoretical literature on economic growth and development, and an even larger literature on empirical growth analysis and the estimation of production functions.

Growth accounting, as it developed since the early work of Tinbergen (1942), Solow (1957), Denison (1967) and Jorgenson and Griliches (1967) provides a simple way of decomposing the growth rate of output per worker into its component sources, capital formation and innovation. The measurement of the corresponding levels is also a part of this framework. Innovation appears in several forms in the sources of growth framework: through the explicit breakout of IT capital formation, through the addition of intangible capital to both the input and output sides of the source-of-growth equation, through the inclusion of human capital formation in the form of changes in labor "quality," and through the "multifactor productivity" (MFP) residual, which includes the effects of technological externalities and spontaneous improvements in organization and technology of production (although this cannot be separated from other factors in the residual, like measurement error).

In our view the growth accounts framework is the most promising way of developing a summary metric of the overall impact of innovation on output per worker, and through this, to changes in the standard of living. Still it is an incomplete and imperfect framework, whose defects are pointed out in various studies (see, for example, Hulten 2001), but it is by far the least incomplete and imperfect way of linking innovation to living standards in a reasonably comprehensive way.

Despite the significant contribution of growth accounting to our understanding of how innovation contributes to growth, the traditional growth accounts framework and the national accounts system as we have it today clearly cannot be seen as comprehensive. The lag between innovation in the economy and its appearance in the national statistics is due, in part, to the fact that innovation involves new ideas and products whose nature and significance take time to understand. However, a large part of the problem also results from the way both national statistics and firm financial data are organized. In neither case are the accounts organized to show innovation. In fact, accounting practice tends toward a conservatism that emphasizes accuracy and continuity with the past over innovation and approximation.2 Thus, accounting practice has traditionally concentrated on market data generated by arms-length transactions and avoided making imputations where possible. One important consequence of this conservatism is that non-market intangibles like internally produced like R&D are treated as a current expense rather than as an investment in the future of the company. This means, for example, that the typical biotechnology company does not add to the

2 *The account scandals of recent years illustrate the virtues of accounting accuracy. But the obvious need for investor confidence should not obscure the need for accounting metrics that reveal the true dynamism and future prospects of a company. Accounting practice should ideally be able to accomplish both objectives.*

GDP in the first years of its existence, nor is its research program deemed to have a long-run impact on value of the company or the economy.

The perverse treatment of intangibles is beginning to change in national accounting practice, with the decision in the late 1990s to capitalize software expenditures and include them as an investment that contributes to GDP. This treatment has recently been extended to scientific R&D in the U.S. national accounts, as a satellite account, and by the decision by the United Nations to do likewise in its System of National Accounts. Regrettably, financial accounting practices continue to be stuck in the past. Moreover, the full range of value-building intangible assets are not likely to be accorded the treatment of scientific R&D in the national accounts, even though surveys show that assets like marketing and employee-training expenditures are important coinvestments with R&D.

The treatment of intangibles is by no means the only problem area in understanding the link between innovation and economic growth. Product innovation is another aspect of the ongoing technological revolution but, with the exception of computer prices, it is poorly represented in official statistics. Improvements in the quality of existing products are picked up for some items (like computers), but this is not done systematically for a full range of products. The treatment of entirely new goods is even more troubling. The improvements in consumer well-being due to the introduction of cellular telephones, cholesterol–lowering drugs, and the internet are effectively ignored in the procedures used in constructing the consumer price index (see, for example, Hausman 1999). This reflects the conservatism of the statistical system noted above, which, in the case of price measurement, tends to treat product innovation as an adjustment to price indexes and not something that is valuable in its own right.[3] These price statistics are used in the national accounts to express income and product in constant prices in order to measure real GDP. The failure to capture innovation in the price statistics thus carries over to errors in the measurement of economic growth and productivity.

There are other problems as well. Data on research and development are one of the most important sources of information about the source of innovation in the economy. However, these data are collected for scientific R&D only and exclude research in important areas like financial services and retail distribution (the research and development of new financial products at places like Morgan Stanley

3 *Amazingly, there is still a debate over the question of whether the CPI should be based on a fixed market basket of products. In this view, apparently shared by some members of the recent NRC price-statistics panel, the CPI should reflect the change in the prices of the same bundle of items year after year (the "Cost-of Goods Index" discussed in the NRC report). If the logic of this view were to prevail, and it is not the dominant view of price-measurement specialists, it would virtually remove product innovation from official price statistics.*

and Goldman Sachs, the development of retailing models like that of Walmart or Carrefour). Significant efforts are being undertaken to fill the gaps in the data collection on innovation. For example, the European Union member states are collecting a wider range of statistics on innovation activities, including marketing and training, in their Community Innovation Survey (CIS). However, these surveys often lack important information on the euro expenses on innovation activities which seriously complicates economic analysis of its effects. The U.S. National Science Foundation (NSF) supports numerous projects that conduct surveys and interviews, and these provide an important base of information about the micro innovation process. But the consensus of a recent NSF workshop on innovation metrics was that broader innovation surveys are needed to help 'connect the dots.' There is a parallel need to insure that these new metrics can be connected to the dollar and euro metrics needed to improve current accounting practice.[4]

EU KLEMS Growth and Productivity Accounts[5]

The purpose of growth accounting is to support empirical and theoretical research in the area of economic growth, such as study of the relationship between skill formation, investment, technological progress and innovation on the one hand, and productivity, on the other. In addition, it may facilitate the conduct of policies aimed at supporting productivity growth and competitiveness. These policies require comprehensive measurement tools to monitor and evaluate progress. Growth accounts should also support the systematic production of high quality statistics on growth and productivity using the methodologies of national accounts and input-output analysis.

The EU KLEMS Growth and Productivity Accounts is the result of a research project, financed by the European Commission, to analyse productivity in member states of the European Union as well as Japan and the U.S. at the industry level. It includes measures of output growth, employment and skill creation, capital formation and multifactor productivity (MFP) at the industry level for individual countries from 1970 onwards. The input measures include various categories of capital (K), labor (L), energy (E), material (M) and service inputs (S).

4 *Other measurement issues related to innovation include the need to improve existing measures of tangible capital, particularly in the areas of capital-embodied technical change, depreciation, and obsolescence. More emphasis on the role of human capital and 'human-embodied' technical change is also needed, as well as on developing stronger links to data for the household sector.*

5 *A more detailed account of the EU KLEMS database is provided by Timmer, O'Mahony and Van Ark (2007). See also the EU KLEMS website (www.euklems.net).*

Growth accounting is theoretically motivated by, among others, the seminal contribution of Jorgenson and Griliches (1967) and put in a more general input-output framework by Jorgenson, Gollop and Fraumeni (1987) and Jorgenson, Ho and Stiroh (2005). It allows one to assess the relative importance of the contributions of labor, capital and intermediate inputs to growth, and to derive measures of multifactor productivity (MFP) growth. MFP indicates the efficiency with which inputs are being used in the production process and is an important indicator of technological change.[6] Under the assumptions of competitive factor markets, full input utilization and constant returns to scale, the growth of output in each industry is expressed as the (compensation share) weighted growth of inputs and multifactor productivity (MFP) growth.

Accurate measures of labor and capital input are based on a breakdown of aggregate hours worked and aggregate capital stock into various components. Hours worked are cross-classified by educational attainment, gender and age with the aim to proxy for differences in work experience, which provides 18 labor categories (3*2*3 types). Typically, a shift in the share of hours worked by low-skilled workers to high-skilled workers will lead to a growth of labor services which is larger than the growth in total hours worked. We refer to this difference as the labor composition effect.

Similarly, capital stock measures are broken down into stocks of different asset types. Importantly, we make a distinction between three ICT assets (office and computing equipment, communication equipment and software) and four non-ICT assets (transport equipment, other machinery and equipment, residential buildings and non-residential structures). Short-lived assets like computers have a much higher productivity than long-lived assets like buildings, and this should be reflected in the capital input measures. Aggregation takes into account the widely different marginal products from the heterogeneous stock of assets. The weights are related to the user cost of each asset. Finally, the contribution of intermediate inputs is broken down into the contribution of energy goods, intermediate materials and services.

The growth accounting analysis from the EU KLEMS Growth and Productivity Accounts concentrates on a sub-sample of eleven "old" EU countries. In Table 1, a decomposition of value added growth in the market economy is given for

6 Under strict neo-classical assumptions, MFP growth measures disembodied technological change. In practice, MFP is derived as a residual and includes a host of effects such as improvements in allocative and technical efficiency, changes in returns to scale and mark-ups and technological change proper. All these effects can be broadly summarised as "improvements in efficiency", as they improve the productivity with which inputs are being used in the production process. In addition, being a residual measure MFP growth also includes measurement errors and the effects from unmeasured output and inputs, notably intangible output and inputs (see Section 4).

the periods 1980–1995 and 1995–2004. GDP growth in the EU accelerated from 1.9 % before to 2.2 % after 1995, completely due a strong improvement in the contribution of labor input, increasing from a zero contribution to a 0.7 %age point contribution. About two thirds of this came from faster growth in total hours worked and one third from improved labor composition, as the overall skill level of the workforce has continued to increase significantly. GDP growth in the U.S. market economy accelerated much faster than in the EU since 1995 (from 3.0 % before 1995 to 3.7 % after 1995), but the contribution of labor slowed down rather than accelerated, even though it did not fall behind the European growth in labor input.

Table 1 Gross value added growth and contributions, 1980-1995 and 1995-2004 (annual average volume growth rates, in %)

A. European Union-15 (excluding Greece, Ireland, Luxembourg, Portugal and Sweden)

	VA	L	*H*	*LC*	K	*KIT*	*KNIT*	MFP
	(1)=(2)+(5)+(8)	(2)=(3)+(4)	(3)	(4)	(5)=(6)+(7)	(6)	(7)	(8)
1980-1995								
MARKET ECONOMY	1.9	0.0	-0.3	0.3	1.1	0.4	0.7	0.7
.Electrical machinery, post and communication	3.9	-0.7	-0.8	0.2	1.6	0.9	0.8	2.9
.Manufacturing, excluding electrical	1.2	-1.3	-1.5	0.3	0.8	0.2	0.6	1.7
.Other goods producing industries	-0.2	-1.2	-1.4	0.2	0.9	0.2	0.7	0.2
.Distribution services	2.6	0.4	0.0	0.3	0.8	0.3	0.5	1.4
.Finance and business services	3.6	2.2	1.9	0.3	1.9	0.8	1.0	-0.7
.Personal and social services	1.8	1.8	1.5	0.3	1.0	0.3	0.7	-1.1
1995-2004								
MARKET ECONOMY	2.2	0.7	0.4	0.2	1.2	0.6	0.6	0.3
.Electrical machinery, post and communication	6.0	-0.4	-0.6	0.2	1.7	1.2	0.5	4.7
.Manufacturing, excluding electrical	1.0	-0.3	-0.6	0.3	0.7	0.3	0.4	0.6
.Other goods producing industries	1.2	0.0	-0.2	0.2	0.7	0.1	0.6	0.5
.Distribution services	2.3	0.7	0.6	0.1	1.2	0.5	0.7	0.4
.Finance and business services	3.5	2.1	1.9	0.3	2.3	1.3	1.0	-1.3
.Personal and social services	1.7	1.5	1.4	0.1	0.9	0.3	0.7	-0.9

B. United States

	VA	L	*H*	*LC*	K	*KIT*	*KNIT*	MFP
	(1)=(2)+(5)+(8)	(2)=(3)+(4)	(3)	(4)	(5)=(6)+(7)	(6)	(7)	(8)
1980-1995								
MARKET ECONOMY	3.0	1.2	1.0	0.2	1.1	0.5	0.6	0.7
.Electrical machinery, post and communication	6.6	0.1	-0.3	0.4	1.9	1.0	0.9	4.6
.Manufacturing, excluding electrical	1.7	0.1	-0.2	0.3	0.6	0.3	0.3	0.9
.Other goods producing industries	0.7	0.7	0.4	0.3	0.7	0.2	0.5	-0.7
.Distribution services	3.9	1.3	1.2	0.2	1.2	0.6	0.6	1.3
.Finance and business services	4.4	2.9	2.7	0.2	1.8	1.0	0.9	-0.3
.Personal and social services	2.8	2.5	2.5	0.1	0.5	0.2	0.3	-0.2
1995-2004								
MARKET ECONOMY	3.7	0.7	0.3	0.3	1.4	0.8	0.6	1.6
.Electrical machinery, post and communication	8.9	-0.3	-0.9	0.6	2.5	1.5	0.9	6.8
.Manufacturing, excluding electrical	0.7	-1.1	-1.5	0.3	0.7	0.4	0.3	1.1
.Other goods producing industries	1.6	1.0	0.9	0.1	0.9	0.2	0.6	-0.3
.Distribution services	4.7	0.5	0.2	0.3	1.4	1.0	0.4	2.8
.Finance and business services	4.9	2.0	1.6	0.4	2.0	1.2	0.7	0.9
.Personal and social services	2.6	1.7	1.4	0.2	1.0	0.4	0.6	0.0

Source: EU KLEMS Database, March 2007, http://www.euklems.net. See Timmer, O'Mahony and van Ark (2007)

Notes:

VA= Gross Value Added growth

L= Contribution of Labour input growth

H= Contribution of Total hours worked

LC= Contribution of Labour composition

K= Contribution of Capital input growth

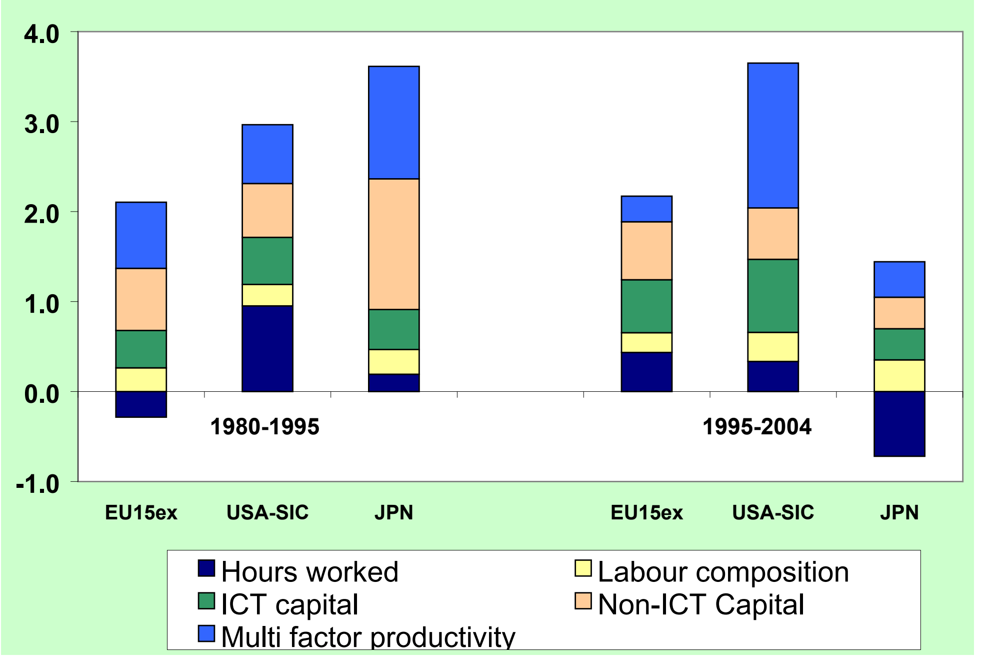
KIT= Contribution of ICT capital

KNIT= Contribution of Non-ICT capital

MFP= Contribution of Multi factor productivity growth

The contribution of capital input to value added growth has not changed much at the aggregate level, but the distribution has shifted somewhat from non-ICT capital to ICT capital. However, compared to the United States the shift towards intensive use of ICT capital has generally not been as pronounced. Notably, when comparing the ratio of capital to labor contributions to growth in the EU, there are signs of a declining capital intensity in the EU. This development is in contrast to the slightly increased U.S. trend in capital intensity since 1995. The factor contributing most to the diverging trends in Europe and the U.S. is the trend in multifactor productivity growth. While contributing 0.7 % to market economy GDP during 1980–1995 in both regions, the trend accelerated to 1.6 % in the U.S., but declined to 0.3 % in the EU after 1995 (see Figure 1).

Figure 1 Contributions to Market Economy GDP Growth 1980–1995 vs. 1995-2004 (in %), major regions



Source: EU KLEMS Database, March 2007, http://www.euklems.net. See Timmer, O'Mahony and van Ark (2007).

When decomposing the growth contribution further to industry level, it appears that market services tell a major part of the divergent performance of European economies since 1995, both among themselves as well as relative to the United States. Table 1 shows that while the contribution of factor inputs to growth has generally stayed up, multifactor productivity growth in the market services stagnated or even turned negative in many European countries. The reasons for the slowdown in multifactor productivity growth in market services are an important avenue for further research, not further pursued in this paper.[7] *Instead the focus here is on another possible factor affecting the MFP residual, which is the impact of unmeasured inputs, notably intangible capital.*

What does Intangible Capital Add to the U.S. Growth Story?

Despite its recognized importance, the challenges concerning the conceptualization of intangible capital, its measurement and integration into a production function or growth accounting framework are substantial (Van Ark, 2002). For example, Howitt (1996) classified some inherent measurement difficulties of intangible capital going beyond those of tangible capital as follows:

1) The knowledge-input problem, which concerns the measurement of the resources devoted to the creation of knowledge which can often not be distinguished unambiguously from other inputs, such as labor and capital.
2) The knowledge-investment problem, which refers to the output of the process of knowledge creation which is typically not measured at all because knowledge mostly does not directly produce a commodity or service.
3) The quality improvement problem, which relates to the need to pick up the improvement of the goods and services which results from knowledge creation.
4) The obsolescence problem which stresses the need with any type of capital to find a measure of depreciation, which is very difficult for intangible capital measures.

However, as clarified in Corrado, Hulten and Sichel (CHS, 2005), there is no clearcut distinction between tangibles and intangibles that would justify a distinction between the former being capitalized and the latter being expensed. In fact "any outlay than is intended to increase future rather than current consumption is treated as a capital investment" (CHS, 2005, p. 13). Various definitions of intangible capital are possible with different coverage of activities

7 *See, for example, Inklaar, Timmer and van Ark (2007)*

but most definitions are offsprings from Schumpeter's classification including the development of new products and production processes, organisational change, management, marketing and finance (Schumpeter, 1934).

CHS (2005) developed an estimate of a broad range of intangibles for the U.S. in the 1990s. This list is shown in Table 2 along with an annualized estimate for each category. The first general category is computer software, which has already been capitalized in the U.S. national accounts. Innovative property includes both NSF-style scientific property with what may be called 'non-scientific' R&D, although this is somewhat misleading because much of this category, which includes the development of innovative new financial products and architectural modeling, is conducted by personnel with scientific degrees. It is worth noting here that spending on nonscientific R&D exceeds the amount spent on the conventional science-lab type. The third category, firm-specific human competencies, includes three subcategories: brand equity, worker-training, and management capability. This is by far the most controversial group, and it is also the largest. The choice of what to include in this broad category was based on the studies noted in the bibliography in CHS (2005, 2006).

Table 2 Expenditures on a Broad List of Intangible Capital U.S. Nonfarm Business Sector, 1998–2000 (average) (billions of dollars)

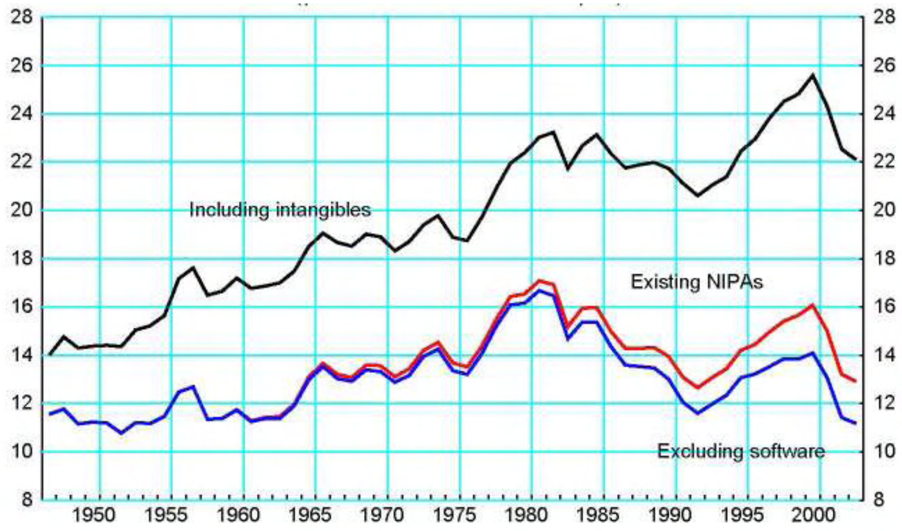
COMPUTERIZED INFORMATION	($154)
COMPUTER SOFT WARE	($151)
COMPUTERIZED DATABASE	($3)
INNOVATIVE PROPERTY	($424)
SCIENTIFIC R&D	($184)
MINERAL EXPLORATION	($18)
COPYRIGHT AND LICENCE COSTS	($75)
OTHER PRODUCT DEVELOPMENT	($149)
ECONOMIC COMPETENCIES	($642)*
BRAND EQUITY (ADVERTISING)	($236)
FIRM-SPECIFIC HUMAN CAPITAL (TRAINING)	($116)
ORGANIZATIONAL STRUCTURE MANAGEMENT	($291)

Source: Corrado, Hulten, and Sichel (2006). * *$505 of this category is considered investment*

The key finding of this research is that intangible investment by U.S. businesses averaged $1.2 trillion per year during the 1998–2000 period. This is also the amount by which U.S. GDP is increased by the capitalization of this broad list of intangibles. In percentage terms, the resulting estimate of GDP is 10 % larger. The software portion of this is already included in current GDP estimates, but this amounts to only 13 % of the $1.2 trillion increase. Moreover, even if scientific R&D were added to this %age, it would only rise to 28 %. In other words, intangibles matter.

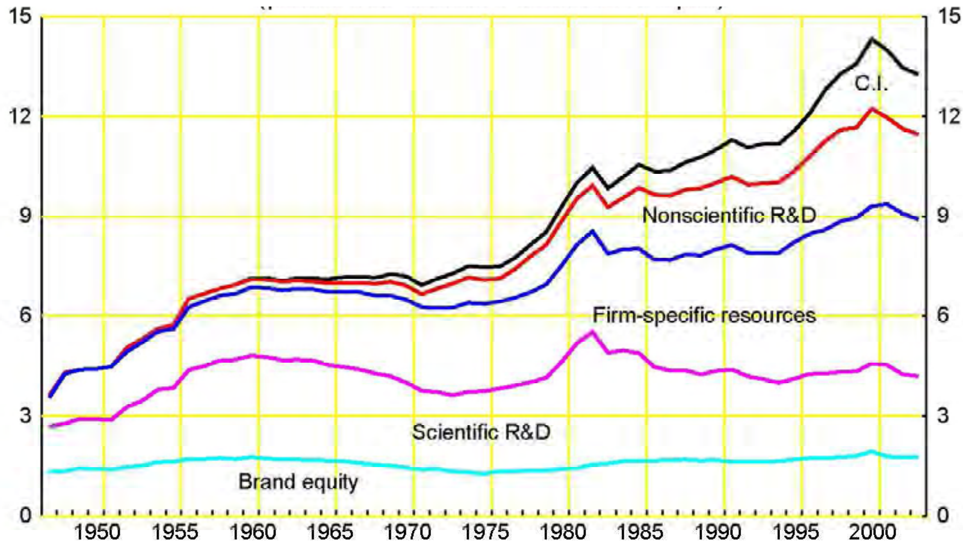
The $1.2 trillion of intangible investment equals the total amount spent by businesses for their tangible plant and equipment. When these figures are extended backward in time in order to obtain a broader perspective on economic growth, it also becomes apparent that these intangibles have become more important over the last five decades. Figure 2, from CHS (2006), shows investment as a fraction of business output over this period, and compares the results for tangible and intangible investment combined with those of tangibles alone. For the latter, the share of business output is around the 12 % for the period as a whole, while the combined share grows from 14 % of output to more than 22 %. Intangibles not only matter for the level of GDP, they also matter for the rate of growth. Figure 3 shows which intangibles have been the most dynamic growers, and surprisingly, scientific R&D has been a rather flat contributor to the overall increase (as has brand equity). Thus, the move to incorporate scientific R&D in U.S. GDP in 2010 will not lead to a boost in the growth rate of GDP, if current trends hold.

Figure 2 Investment Shares, United States
Per cent of business output



Source: Based on Corrado, Hulten and Sichel (2005, 2006)

Figure 3 **Intangible investments**
per cent of nonfarm business output



Note: C.I. = Computerized information

Source: Based on Corrado, Hulten and Sichel (2005, 2006)

It is important to recognize that in a growth accounts framework the capitalization of intangibles adds to income as well as output, in the form of increased gross operating income accruing to capital. The share of labor and capital compensation in total output changes as well. While the share of income going to labor in the traditional growth accounts for the U.S. has been relatively constant at around 70 % over the last 50 years, with intangibles CHS (2006) find that labor's share has fallen considerably.

There are also important productivity effects associated with intangibles. CHS (2006) show that capitalization leads to an estimate of the average growth rate output per hour in the U.S. non-farm business sector that is more than one tenth larger than the conventional BLS estimate of around three % for the period 1995–2003. This is not a huge effect, but the 2003 end point of the period saw a downturn in intangible spending, so that the gap between the old and the new estimates for the period 1995–2001 is even somewhat larger. However, the main effect of intangibles is to restate the relative importance of the various sources of growth. When intangibles are included in the analysis, they explain more than a quarter of the total growth rate of output per worker and become the most important *systematic* source of growth. The importance of multifactor productivity, a non-systematic residual category or 'measure of our ignorance', is considerably reduced.

The restated sources-of-growth analysis in CHS (2006) contains another message. The combined importance of intangibles, IT capital, and labor quality (which largely reflects human capital) explains nearly 60 % of productivity growth. This reflects the importance of 'knowledge capital'– our measure of innovation – as a driver of growth. This effect is enhanced by the high probability that R&D and human capital spillover externalities are an important component of the residual MFP measure. Conventional plant and equipment, excluding IT capital, accounts for less than 10 %.

An International Comparison of Expenditure on Intangible Capital

The extension of the conventional sources-of-growth analysis to include intangible inputs and outputs is still in its infancy, though the literature is expanding. The recent work of Haskell and Marrano (HM) (2007) for the United Kingdom, Fukao et al. (2007) for Japan and van Rooijen-Horsten for the the Netherlands are fairly complete reproductions of the CHS approach. Haskell and Morrano (HM) (2007) and Fukao et al. (2007) also provide growth accounting estimates for the UK and Japan respectively.

In this section we only provide an international comparison of expenditure on intangibles for the four countries mentioned above. Table 3 shows that the measures of intangibles expressed as percentage of GDP for the U.S. are about 1.5 percentage points higher than for the UK. The U.S. shows somewhat higher levels of innovative property, in particular R&D, and economic competencies, in particular brand equity and own-account organizational innovations. In contrast, the UK seems to be characterized by higher expenses of firms on human capital.

The intangible capital expenditure estimates as percentage of GDP for Japan and the Netherlands are lower than in the UK and the U.S. The estimates for both countries are 3.5 percentagee points below the U.S. and 2 percentage points below the UK. Before drawing too strong conclusions from these differences it should be stressed that there are some differences. Notably the Japanese estimates refer to the aggregate economy rather than to the business sector only. Furthermore the Japanese estimate may be somewhat understated relative to the UK and the U.S. due to the lack of reliable data for the estimation of investment in other product development, design, and research, firm-specific human capital, and organizational structure. Indeed the estimate for economic competencies (Fukao et al., 2007, p. 4). The estimates for the Netherlands exclude a figure for expenditure on own-account organizational structure. Indeed, taking account of the missing estimate for own-account organizational structure, the Dutch

Table 3 Expenditures on Intangibles as a % of GDP, U.S., Japan, UK and Netherlands

	US 1998-2000	UK 2004	Japan 2000-2002	Neth'lnd 2004
1. Computerized and information	1.7	1.7	2.0	1.2
a) Software and databases: purchased		0.6	1.4	0.8
a) Software and databases: own account		1.1	0.6	0.4
2. Innovative property	4.6	3.2	3.7	2.4
a) R&D incl. social sciences and humanities	2.9	1.8	2.1	1.5
R&D in financial industry	0.8	0.7		0.0
b) Mineral exploration and evaluation	0.2	0.0	0.1	0.1
c) Other innovative property	1.5	1.4	1.6	0.9
Copyright and license costs	0.8	0.2	0.9	0.1
New architectural & engineering designs	0.7	1.2	0.7	0.7
3. Economic competencies	6.9	6.0	2.5	4.6
a) Brand equity	2.5	1.6	1.0	2.6
Advertising expenditure	2.3	1.2		2.3
Market research	0.2	0.4		0.2
b) Firm specific human capital	1.3	2.5	0.3	0.8
Direct firm expenses	0.2	1.3		0.5
Wage and salary costs of employee time	1.0	1.2		0.3
c) Organizational structure	3.1	1.9	1.2	1.2
Purchased	0.9	0.6		1.2
Own account	2.3	1.3		---
Total intangible expenditure as % of GDP	13.1	10.9		8.3
Intangible capital expenditure as % of GDP	11.7	10.1	8.3	7.5

Note: Netherlands excludes own accounts expenditure on organizational structures
All countries are for business sector only (Netherlands for total economy excl. government sector) except Japan which is for total economy
Sources: Netherlands from van Rooijen-Horsten, van den Bergen and Tanriseven (2007)
U.S. from Corrado, Hulten and Sichel (2005), UK from Haskel and Marrano (2007)
Japan from Fukao, Hamagata, Miyagawa, and Tonogi (2007)

estimate is quite comparable to that for the UK. There is also some likelihood that the Netherlands study somewhat understate development expenditures by the financial sector and firm specific training.

Table 3 makes a distinction between total intangible expenditures and capital expenditures. Clearly expenditure on intangibles should only be treated as an investment when it concerns the acquisition or own account production of an asset, implying that it must lead to benefits for more than one year. Not all spending is necessarily capital spending.

The difference between expenditure and investment is especially relevant for the R&D category, as there is still debate on whether freely available (public) R&D should be capitalized. For example, the Dutch estimates exclude government consumption of R&D. Moreover, the Dutch estimates exclude some spending categories from advertising expenses, in particular free local papers and advertising pamphlets. Despite these larger deductions from expenditure, the Dutch estimate still shows a smaller adjustment than for the UK and the U.S. This is probably due to the fact that – with the exception of R&D – all capital spending estimates were directly obtained from the national accounts. This was not as easy for the UK and the U.S. which therefore had to go obtain total expenditure estimates requiring adjustments. CHS (2005) and HM (2007) assume that 60 % of their estimates of expenditures on advertising are investments, 80 % of own-account organisational structure expenditure and 100 % of other types (such as software, R&D and firm-specific human capital).

Work on estimates of intangible expenditure is also ongoing at Statistics Finland and at The Conference Board (for France and Germany) (see Hao, Manole, and van Ark, 2007). A European Union-funded consortium, funded from the 7th Framework Program, to get to an overall coverage of intangibles in European Union member states, is envisaged to start its work in 2008/2009.

Conclusions and future research

Achieving a rising living standard is a central objective of economic policy in nations around the world, rich and poor, and the growth in output per worker hour is a key determinant of the standard of living. If workers can produce more goods and services, they can consume more, both now and in the future. However, sustained growth in output per worker does not happen automatically or autonomously. The standard sources-of-growth model reminds us that it is the result of systematic investments in a broad range of capital assets and improvements in productive efficiency (measured as a residual). This is why it is important to count all the sources of innovation, not just those that are more easily measured.

As research proceeds, measures of the intangible components will hopefully be refined, though this may require major changes in corporate financial accounting practice. Unfortunately, so far no parallel development has occurred in corporate financial account practice, which continues to treat R&D and other intangibles as current expenses. Preliminary research suggests that this practice has the effect of understating the net income and total assets of some of the most dynamic companies in the economy.[8] The Conference Board is presently undertaking a project to measure intangibles at the corporate level. Using the accounting model established in the research of Corrado, Hulten, and Sichel as a guide, the financial statements of a collection of U.S. and foreign corporations are being restated to include a broad range of intangibles. The preliminary work uncovered areas in which more information is needed to improve the accuracy of the estimates (for example, the write-off periods over which intangibles are amortized, spending on human resource development and long-term strategic planning). Additionally, considerable effort will be required to develop a consistent time series, in light of the mergers and acquisitions that take place over time, and accounting changes like the recognition of employee stock options. These are challenging data problems, made all the more difficult by the fact that intangibles are not recognized on corporate financial statements, and because surveys of corporate leaders has revealed some confusion about the nature of intangibles.

The results from a project on corporate intangibles will not only provide richer insight into the true dynamism of firms, but will also be invaluable to national income accounting practice, which relies heavily on the data provided by the business sector. This, in turn, would enrich the macroeconomic analysis of the sources and drivers of growth.

8 *CHS provide references to the large literature documenting both a positive rate of return to R&D spending, and its positive impact on share prices (both are tests of whether R&D should be considered as an investment or as a current expenditure with no future consequences). For specific references to the value- building effects of the other categories of intangible capital, see the papers by Abowd et. al. (2005), Black and Lynch (1996), Brynjolfsson and Yang (1999), and Brynjolfsson, Hitt, and Yang (2000), and B. Hall (1993). The recent paper by Bloom and Van Reenen (2006) is especially noteworthy, since it links one of the most controversial forms of intangible capital, corporate management practice (an important aspect of corporate "culture"), strongly and positively to the value of a company's shares.*

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