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http://europa.eu.int/comm/resarch/fp6/ssp/kei_en.htm
http://www.corids.lu/citizens/kick_off3.htm
http://kei.puplicstatistics.net/

[1] Several of the chapters in this report are based on papers that were written in collaboration with other authors, some of which were funded by different EC projects. These include Catalina Bordoy, Hugo Hollanders, Bart Van Looy, Edward Lorenz, B-A Lundval, Robert Tijssen, and Antoine Valeyre.

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Introduction

As noted in the KEI report WP 4.1 *State-of-the-art report on developing new KBE indicators*, many indicators of relevance to measuring and understanding the knowledge economy are simply unavailable. The problem is most acute in the following areas:

1. Human resources: mobility, effect of education and skills on performance

2. Knowledge production and diffusion: university – firm linkages

3. Innovation and entrepreneurship: how firms innovate, demand for innovative products, organization and innovative capabilities

4. Economic and social outputs: environmental innovation, public sector innovation, globalization.

New indicators can be developed by combining existing data in new ways, or from conducting new surveys. The latter are expensive and increase response burdens to the managers of firms, so wherever possible this report concentrates on the former option. There are also two conceptual options for providing solutions to missing indicators. The first is to develop quick, 'back of the envelope' solutions that would require extensive further research to complete. The second is to take a limited number of issues and to develop concrete examples as to how the indicator 'gap' could be solved.

This report concentrates on the second option. The methodology has been to fully develop papers, intended for publication, on specialized aspects of indicator development. Several of the papers were written in collaboration with other authors. The papers cover each of the topics in points 1 to 4 above with the exception of economic and social outputs.

New indicators of relevance to human resources are covered in Chapter 1 (Hansen *et al*) and partly in Chapter 2 (Arundel *et al*). Indicators for university-industry linkages are examined in Chapter 3 by Arundel and Bordoy. Indicators for innovation and entrepreneurship (how firms innovate and demand) are covered in Chapter 4 by Arundel and in Chapter 2 by Arundel *et al* (organizational innovation).

All four papers were presented to the international Blue Sky II conference in Ottawa, September 25-27, 2006: "*What indicator for Science, Technology and Innovation Policies in the 21st Century*?" The conference was attended by over 250 experts in innovation policy and science, technology and innovation indicators.

Chapter 1 - Linking human resources in science and technology with scientific performance

The use of existing data to develop new indicators to analyze the scientific base of high and medium high technology manufacturing industries

Wendy Hansen, Hugo Hollanders, Bart Van Looy and Robert Tijssen[2]

1. Introduction

Slow growth of high- and medium-high technology industries has been associated with weak science and technology linkages that can be explained, in part, by a lack of a strong scientific base.[3] Industries are operating in a knowledge economy, an economy in which one of the main challenges for measurement and indicator development is to consider knowledge capital and develop linkages to the more traditional science and technology indicators. Few studies have tried to link industries' scientific base and scientific disciplines.

The overall goal of the study is to characterize the scientific base of high and medium high technology manufacturing industries. Indicators are being developed to make links between R&D expenditures and other S&T indicators and human capital. This work represents a valuable addition to the indicator family of innovation, technology and scientific performance and human capital.

The link between scientific knowledge and scientific and technological performance, for the most part, has been left to econometric studies, bibliometric analysis and innovation surveys. Some of these surveys and studies have explored the relationship between a country's scientific base and technology/industries. There is little evidence of empirical work to link scientific and technological performance of industries and scientific disciplines.

Although indicators of scientific performance include some measures of human capital (e.g. degree in S&T, labour force level of educational attainment, R&D personnel (FTEs and headcount), S&T occupation, etc.), measures of scientific and technical performance continue to focus on a core group of indicators, and within this group R&D expenditures and R&D intensity are key. Indicators on human capital are analyzed but they are not linked to other indicators that are used to analyze scientific performance.

The aim of this study then is to suggest a method to link the scientific and technological base of HMHT intensive manufacturing industries and scientific disciplines as defined by education (e.g. UNESCO ISCED '97). The successful 'linking' of scientific performance to science disciplines will provide the possibility to link to other S&T indicators such as R&D expenditures and human capital indicators such as the flows of graduates and the mobility of researchers.

2. Why the Interest in HMHT Intensive Manufacturing Industries?

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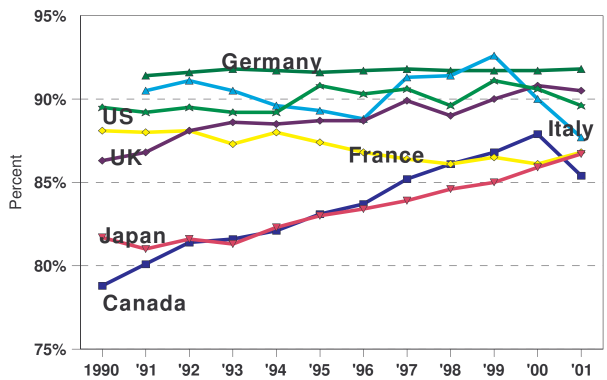
[2] Hugo Hollanders is from UNU-MERIT, Bart van Looy from INCENTIM and Robert Tijssen from CWTS.
[3] From the Terms of Reference for *S&T Linkage Indicators*, European Commission, 2004.

High- and medium-high technology (HMHT) intensive manufacturing industries are important contributors to economic growth. According to a 2006 report of the National Science Foundation, the global market for high technology manufactured goods is growing faster than for other manufactured goods. While the EU led for some fifteen years (1980 to 1995) with the world's largest high technology manufacturing sector, it has lost its position and since 1996, it is the U.S. high technology manufacturers that generated more domestic production (value added) than the EU or any other country.[4]

Figure 1. Employment in HMHT intensive manufacturing industries as a percent of total employment in manufacturing, 1990 to 2001.



Source: UNU-MERIT based on OECD data.

HMHT intensive manufacturing industries account for the lion's share of employment in the manufacturing sector. Figure 1 shows employment in HMHT intensive manufacturing industries as a share of total employment in manufacturing.[5]

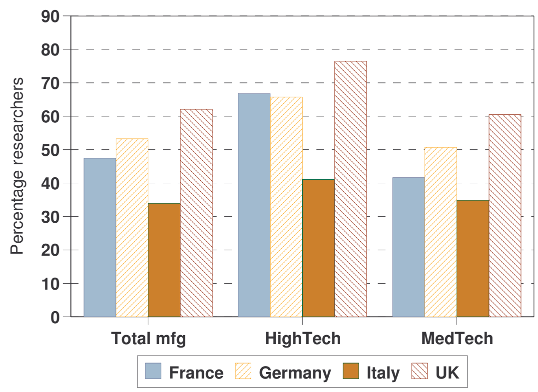
For countries like Canada and Japan, the share of manufacturing employment in HMHT intensive manufacturing industries rose almost every year between 1990 and 2000 with the trend in Canada extending to 2001. Germany shows a consistent picture — more than nine in ten employed in manufacturing industries were in HMHT intensive manufacturing industries throughout the period 1990 to 2001.

In the EU in 2005, human resources in science and technology (HRST) accounted for only 29% of employment in the manufacturing sector compared with 47% of employment in the services sector. Within the manufacturing sector though, the presence of S&T workers varied. Among the high technology (HT) intensive manufacturing industries, HRST accounted for more than half (52%) of total employment; in the medium technology (MT) intensive manufacturing industries, HRST accounted for 39% of total employment.[6]

[4] National Science Board, *Science and Engineering Indicators 2006*, National Science Foundation, Chapter 6-4.
[5] We include seven countries in our analysis for this paper for Blue Sky: four EU countries (France, Germany, Italy, United Kingdom), Canada, the United States and Japan.
[6] Eurostat, *Statistics in Focus*, 13/2006.

Figure 2 shows the concentration of researchers among the R&D personnel[7] in HT intensive, MT intensive and total manufacturing industries.

Figure 2. Researchers as a percentage of total R&D personnel, 2003



Source: MERIT based on Eurostat data.

For each of the EU countries, it is in HT intensive manufacturing industries one observes the highest concentration of researchers as measured by share of R&D personnel. At almost nine researchers out of ten R&D personnel in the HT industries and three in five in the MT industries, the UK reports the highest concentration of researchers to total R&D personnel.

3. Methodology in Brief

The challenge is to develop a methodology to explore the scientific knowledge base of HMHT intensive manufacturing industries by field of education.

3.1 Concordance

Concordance tables are the necessary ingredients to link scientific and technological performance and scientific knowledge as measured by education (ISCED fields of S&T). There are three concordance tables needed:

1. A concordance table to link scientific and technology fields by means of non-patent citation data (NPRs).[8] Figure 3 provides a 'snapshot' view of the concordance table being developed by INCENTIM and CWTS that is used for this study. It is extracted from 120 fields of S&T and over 100 IPCs.

[7] According to the OECD Frascati Manual 2002, R&D personnel include persons performing the scientific and technical work, persons planning and managing research projects, persons preparing the interim and final reports for R&D projects, persons providing internal services for R&D projects and persons providing support for the administration of the financial and personnel aspects of R&D projects.
[8] This developmental work is being carried out by INCENTIM and CWTS.

Figure 3. A ‘snapshot’ of concordance table for science and technology.

Science domains	A01	A21	A22	A23	A61	A62	A63	B01	B02	B03	B04	B05	B06
ACOUSTICS	4	0	0	1	406	0	0	13	0	4	0	4	2
AGRONOMY	1141	4	0	31	23	0	0	2	0	1	0	0	0
BIOCHEMICAL RESEARCH METHODS	218	1	0	42	1003	0	8	254	0	4	7	4	2
BIOCHEMISTRY & MOLECULAR BIOLOGY	4727	19	0	423	13473	7	34	268	0	21	2	32	2
BIOLOGY	193	1	0	28	765	0	2	4	0	0	0	14	0
BIOPHYSICS	440	2	0	74	2410	0	8	82	0	1	5	5	0
BIOTECHNOLOGY & APPLIED MICROBIOLOGY	1204	14	8	232	1609	10	1	81	0	4	0	17	0
CARDIAC & CARDIOVASCULAR SYSTEMS	183	0	0	20	3225	3	0	27	0	0	0	9	0
CELL BIOLOGY	1373	1	0	67	3826	1	10	40	0	12	0	19	0
CHEMISTRY, ANALYTICAL	97	0	0	51	684	4	4	870	2	11	2	11	1
CHEMISTRY, APPLIED	215	23	3	236	446	6	4	57	0	0	0	25	0
CHEMISTRY, INORGANIC & NUCLEAR	28	0	0	13	217	0	0	144	0	0	0	15	0
CHEMISTRY, MEDICINAL	379	0	0	21	3720	3	0	39	0	0	0	3	0
CHEMISTRY, MULTIDISCIPLINARY	366	2	0	23	3035	9	2	511	0	7	0	63	0
CHEMISTRY, ORGANIC	528	0	0	31	3569	1	0	238	0	1	0	22	0
CHEMISTRY, PHYSICAL	34	0	0	9	260	35	0	413	1	4	0	113	0
CLINICAL NEUROLOGY	89	0	0	2	1495	1	0	1	0	0	0	0	0
COMPUTER SCIENCE, HARDWARE & ARCHITECTURE	0	0	0	0	5	0	4	2	0	0	0	13	1
COMPUTER SCIENCE, SOFTWARE ENGINEERING	0	0	0	0	18	0	7	0	0	0	0	0	0
COMPUTER SCIENCE, THEORY & METHODS	0	0	0	2	17	0	8	0	0	0	0	0	1
CRYSTALLOGRAPHY	1	0	0	3	42	0	0	63	0	0	0	19	0
DERMATOLOGY & VENEREAL DISEASES	52	0	0	3	683	0	0	2	0	0	0	0	0
DEVELOPMENTAL BIOLOGY	183	0	0	12	319	0	0	0	0	0	0	4	0
ELECTROCHEMISTRY	4	0	0	2	62	0	0	38	0	0	0	91	0
ENDOCRINOLOGY & METABOLISM	234	0	0	28	2562	0	0	2	0	0	0	1	0
ENGINEERING, BIOMEDICAL	42	0	0	0	1462	3	2	52	0	0	11	28	0
ENGINEERING, CHEMICAL	32	0	0	23	189	38	4	537	0	26	0	62	0
ENGINEERING, ELECTRICAL & ELECTRONIC	7	6	1	5	281	0	6	40	11	5	0	86	11
ENVIRONMENTAL SCIENCES	53	0	0	13	101	6	0	88	0	5	0	19	0
FOOD SCIENCE & TECHNOLOGY	313	46	19	653	379	6	4	46	2	0	0	0	0
GASTROENTEROLOGY & HEPATOLOGY	68	0	0	17	825	0	0	3	0	1	0	0	0
GENETICS & HEREDITY	1018	5	0	31	1151	0	2	49	0	2	0	2	0
HEMATOLOGY	450	0	0	28	2638	0	0	123	0	0	29	9	0
IMMUNOLOGY	821	4	0	75	5199	0	2	65	0	10	10	10	1
INFECTIOUS DISEASES	149	2	0	18	1244	0	0	4	0	0	0	2	0
INSTRUMENTS & INSTRUMENTATION	0	1	0	2	126	2	1	42	0	2	0	26	0
MATERIALS SCIENCE, COATINGS & FILMS	6	0	0	3	33	0	2	44	1	0	0	130	0
MATERIALS SCIENCE, MULTIDISCIPLINARY	15	0	0	3	136	6	6	103	4	1	0	193	0
MEDICAL LABORATORY TECHNOLOGY	60	0	0	13	330	0	0	28	0	2	0	1	0
MEDICINE, GENERAL & INTERNAL	232	0	0	66	2275	0	0	27	0	0	5	4	0
MEDICINE, RESEARCH & EXPERIMENTAL	461	0	0	31	2902	0	0	30	0	3	3	7	0
METALLURGY & METALLURGICAL ENGINEERING	1	0	0	0	11	0	0	22	0	6	0	15	0
MICROBIOLOGY	851	15	6	160	1737	12	1	28	0	2	0	2	0

Note: the yellow shading has been applied to dominant science domains.

Source: © INCENTIM/CWTS

2. A concordance table to link OECD fields of S&T and ISCED fields of S&T.[9] Figure 4 presents an example of concordance being developed for OECD field of S&T and ISCED field of education.

[9] This developmental work is being carried out by UNU-MERIT and CWTS.

Figure 4. A snapshot of developing concordance from with OECD field of S&T and ISCED '97 field of education.

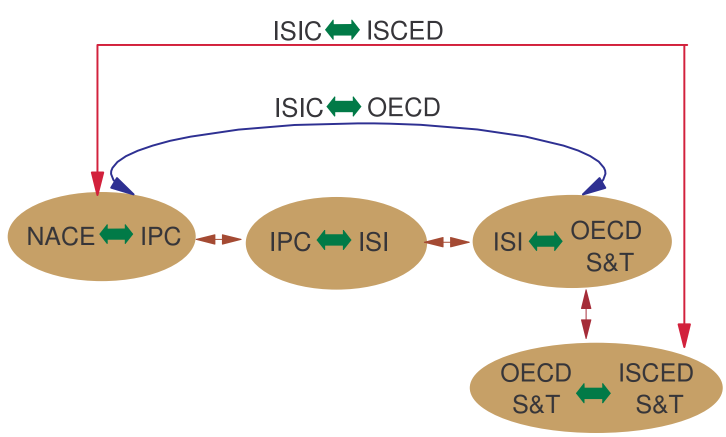
ISCED '97		OECD	
(Natural) sciences:	**42+44 +46+48**	**1**	**Natural sciences**
Life sciences	**42**	**1.5**	**Biological sciences**
Bacteriology	42	1.5	Bacteriology
Biochemistry	42	1.5	Biochemistry
Biology	42	1.5	Biology
Biophysics	42	1.5	Biophysics
Botany	42	1.5	Botany
Entomology	42	1.5	Entomology
Genetics	42	1.5	Genetics
Microbiology	42	1.5	Microbiology
Ornithology	42	1.5	
Toxicology	42	1.5	
Zoology	42	1.5	Zoology
Other allied sciences	42	1.5	Other allied sciences

Source: UNU_MERIT

3. A concordance table (s) between technological fields and industries. Concordance tables developed by Johnson (OECD) and OST/FhG-ISI (EC) are being adopted for this.

Figure 5 shows the integral parts of moving from HMHT industries' scientific base to scientific disciplines of education as defined by ISCED 97.

Figure 5. Moving from patents and non-patents references to ISIC and ISCED.



Concordance is relevant for the three key reasons:

1. Concordance enables the identification of the scientific and education base of technological fields and HMHT intensive manufacturing industries.
2. Concordance provides the means with which to analyse the relationships between innovative performance (technological, economic), scientific capabilities and human capital.
3. Concordance is the agent needed to translate the obtained insights into policy recommendations at the national, regional and industry level.

The concordance tables ensure that the analytic results are presented in the 'right way' — the results need to be considered in conjunction with economic activities or with education. For example, if the goal is to identify the fields that do matter to these industries then one needs to consider this in relation to the fields of science and technology that matter to these industries.

3.2 Elements used in the examination of the relationship between performance and human capital

The work carried out for Blue Sky to examine the relationship between technological performance and human capital used the following elements:

- Analysis on the level of national innovation systems
- Countries: France, Germany, Italy, United Kingdom, Canada, the United States and Japan.
- PhD degrees awarded from 1990 to 2000: number of PhDs in major fields of science and engineering (excluding social sciences), normalized by population count.
- Technological performance: EPO patent applications from 1990 to 2004 normalized by population count, allocated to high tech, medium tech, medium low tech, low tech industries (OECD classification).
- Country allocation based on inventor nationality, full count in the case of multiple nationalities. (Note: the approach based on assignee nationally yields similar results).
- R&D expenditures for 1990 to 2000 by in industries: high tech, medium tech, medium high tech, medium low tech, and low tech.
- Time lag (between education and technology): three and four years were used.

This is where the methodological description ends. The work is in early development and subsequent reports and publications will provide more details of methodological approach and concordance.

4. Preliminary Findings

Does education, in this case as measured by PhDs in S&T, contribute to HT technological performance?
The link between R&D expenditures and PhDs in S&T and productivity were analysed. According to the results, it appears that although money certainly matters, people really matter when it comes to HT technological performance. Figure 6 shows that although the correlation between R&D expenditures and HT productivity is not necessarily low, the correlation between education (PhDs in S&T) and HT productivity is significant.

Figure 6. Correlations between R&D expenditures, productivity and education.

	R&D Expenditures HT	HT Productivity	PhD Technological Productivity
R&D Expenditures HT	1		
HT Productivity	.258	1	
PhDs in S&T	.481**	.538**	1

** Correlation is significant at the 0.01 level.
Source: INCENTIM

Does educational strength (as measured by PhDs in S&T) contribute to HT technological performance?

Although clearly technological performance hinges on the combination of money (R&D expenditures) and people, people are important and not to be excluded from measurement of HMHT performance. Figure 7 shows the Fixed Affect Analysis — results suggest a distinctive and considerable impact of educational strength on technological performance.

Figure 7. HT technological performance — Fixed Effect Analysis

	Partial Correlation (controlling for R&D expenditures and Added Value within Industry)	Significance
High Tech Industries	0,532	p=0,000
Medium High Tech Industries	0,428	p=0,018
Medium Low Tech Industries	0,580	p=0,000
Low Tech Industries	0,405	p=0,018

Source: INCENTIM.

Does educational strength (as measured by PhDs in S&E) contribute to technological performance in general?
Is the correlation between human capital and performance unique to the HT intensive manufacturing industries (e.g. one might expect this correlation HT industries), or does

the result hold for other industries. Analysis was carried out on HT, MHT, MLT and LT industries for seven countries over six time periods. The findings suggest a positive relationship between PhDs and technological output and this is not limited to HT industries — this applies across all industries (Figure 8).

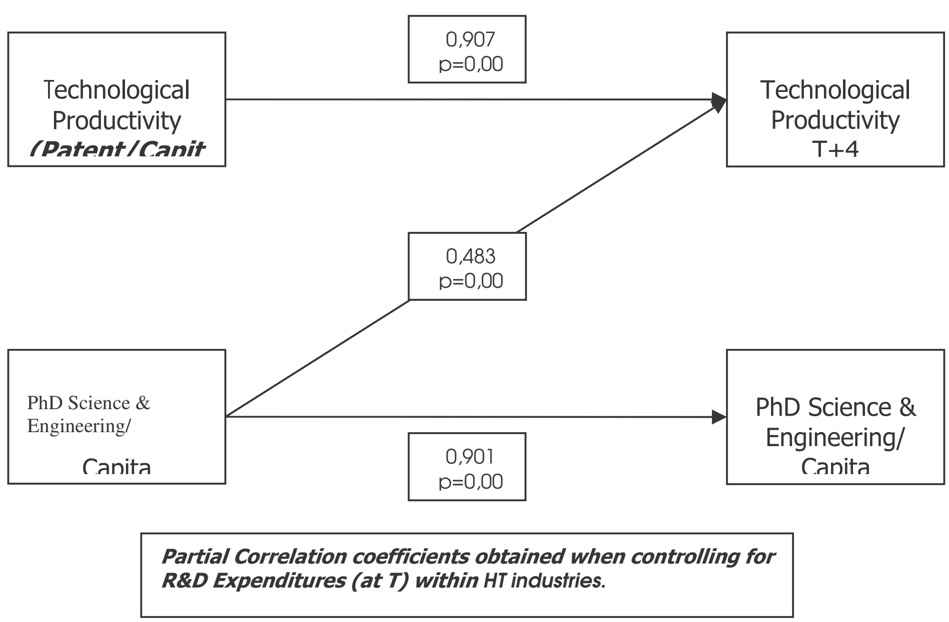
Figure 8. Education strength and technological performance and all industries.

	Partial Correlation (controlling for R&D expenditures and Added Value within Industry)	Significance
High Tech Industries	0,532	p=0,000
Medium High Tech Industries	0,428	p=0,018
Medium Low Tech Industries	0,580	p=0,000
Low Tech Industries	0,405	p=0,018

Source: INCENTIM.

Figure 9 gives a disentangling of causality: a path analysis. This is important not only for what it shows but for what it does not show. For example, technological productivity (patent/capita) has a high correlation to technological productivity T+4 —as one would expect. This is the traditional patent result — the rich stay rich; the rich get richer.

Figure 9. Disentangling causality: Path Analysis



Another result that could be expected is the correlation between PhDs in S&E/capita to technological productivity at T+4. The unexpected result is what is not on the diagram — a lack of significant correlation between technological productivity (patent/capita) and PhDs in S&E (capita T+4).

The results of this preliminary exploration of the scientific base of HMHT manufacturing industries are exciting. Based on a seven-country examination, there is evidence of the use and application of the methodology. Links between the scientific base of industries according to education can be explored.

A note of caution must be injected here. The work is in developmental and in early testing stages; much more work has to be done. Nevertheless, the results do suggest the need to explore links between human capital and performance. The results also suggest more attention needs to be paid to human capital and education for performance and R&D expenditures and other performance indicators need to expand scope to consider human capital and education indicators.

5. Implications of the findings

5.1 Implications for indicator development and future research

It is very early days in this developmental work but the results show further investigation is needed. The high correlations found between human capital, in this case limited to PhDs awarded in S&E, and technological performance as measured by patents, suggest a need to expand indicators to consider the link to human capital and scientific and technological performance.

The results of the preliminary use of the concordance tables suggest the methodology is valid for further development and it would be useful to apply it at the EU and OECD level.

Perhaps most importantly, the preliminary results of this work presents evidence of the viability of the methodology being developed under this study, evidence that existing data and indicators can be used to develop new indicators for human capital and scientific and technological performance. It presents an opportunity to use existing data and indicators to develop new indicators for human capital and scientific and technological performance.

5.2 Implications for policy and decision makers

Public policy focus is on increasing performance by increasing R&D expenditure. There is, for example, a fixation on R&D intensity goals such as the EU Barcelona target of 3% of GDP by 2010. An OECD report on R&D spending targets and policy implications tells us the EU is not alone planning its economic growth by expenditure targets. Canada has set a target of being among the top five R&D spending countries in the OECD in 2010 and Germany is aiming at 3.0% of GDP for 2010.[10]

Preliminary results of this study suggest:

- The focus on 'money' is too narrow. Money matters but human capital matters and perhaps more in some cases. The early results of this work show

[10] J. Sheehan and A. Wyckoff, *Targeting R&D: Economic and Policy Implications of Increasing R&D Spending*, OECD working paper DST/DOC (2003)8.

significant correlations suggesting human capital contribute to technological performance (as one might expect) BUT variations in PhD strength seems to be more important than variations in R&D expenditures. Moreover, testing on other industries (MLT and LT) produce similar results.

- It may not be appropriate for policy to continue to focus on researchers and S&T workers in terms of the more traditional supply/demand models; there needs to be a focus turned to the role of human capital with regards to the scientific base of industries and the relationship to scientific and technological performance. There needs to be efforts to bring human capital into mainstream measures of performance.
- The time frame to improve scientific and technological performance may be longer than anticipated. Although money is a factor (e.g. increasing R&D investment), human capital is linked to productivity. This means investing in education and waiting three to four years after the PhDs graduate to see measurable impact on technological productivity.
- Policy needs to support measurement and indicator development on human capital for integration with other innovation and economic performance measures.

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Chapter 2 - The organization of work and innovative performance: A comparison of the EU-15

Anthony Arundel, Edward Lorenz, Bengt-Åke Lundvall, and Antoine Valeyre[11]

1. Introduction

It is widely recognised that while expenditures on research and development and the skills of scientists and engineers with third-level training are important inputs to successful innovation, these are not the only inputs. Developing new products and services also depends critically on the skills developed by employees on-the-job in the process of solving the technical and production-related problems encountered in testing, producing, implementing and marketing new products and processes. Developing these sorts of skills in turn depends not just on the quality of formal education, but also on having the right organisational structures and work environments. Work environments need to be designed to promote learning through problem solving and to encourage the effective use of these skills for innovation.

Further, rather than viewing innovation as a linear process, recent work on innovation in business and economics literatures characterises it as a complex and interactive process involving multiple feedbacks between different services and functions as well as manifold interactions with customers and suppliers (Freeman 1986; Lundvall 1988; Rosenberg 1982; Kline and Rosenberg, 1985; Nonaka, 1994). The development of new products and processes will depend not only on the resources allocated directly to R&D and design work. Innovating producers need to interact and learn from early adopters within or outside the innovating organisation. Factors that block or slow

[11] Lorenz is from the University of Nice – CNRS, Lundvall from the University of Aalborg, and Valeyre from the Centre for Employment Studies – CNRS.

down innovation may be located down-stream and reflect rigid organisational frameworks that give limited incentives for employees to take part in and contribute to the innovation process.

These considerations imply that relevant indicators for innovation need to do more than capture material inputs such as R&D expenditures and human capital inputs such as the quality of the available pool of skills based on the number of years of education. Indicators also need to capture how these material and human resources are used and whether or not the work environment promotes the further development of the knowledge and skills of employees. Despite the wide acceptance of these views, there exists very little quantitative survey-based research focussing on organisational environments that promote learning and innovation.[12] To our knowledge, there exist no EU-wide studies of this nature.

The main contribution of this paper is to develop a set of EU-wide aggregate measures that are used to explore at the level of national innovation systems the relation between innovation and the organisation of work. In order to construct these aggregate measures we make use of micro data from two European surveys: the third European survey of Working Conditions carried out at the level of employees by the European Foundation for the Improvement of Working Conditions in the 15 EU member countries in 2000; and the third Community Innovation Survey (CIS-3) carried out at the firm-level in 2001 by each of the 15 member nations and referring to innovation activities between 1998 and 2000. The survey data on working conditions are used to develop what we believe to be the first EU-wide mapping of the adoption of different types of organisational practices and policies. The innovation survey data are used to develop a typology of innovation at the firm level and to calculate the distribution of these innovation types within each of 14 EU countries for which data are available. Although our data can only show correlations rather than causality and are aggregated at the national level, they support the view that how firms innovate is linked to the way work is organised to promote learning and problem-solving.[13]

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[12] A notable exception is work based on the DISKO survey for Denmark. See Laursen and Foss, 2003; Nielsen and Lundvall, 2006; and Jensen et al., 2005.

Specifically, we find that in nations where work is organised to support high levels of discretion in solving complex problems firms tend to be more active in terms of endogenous innovation, i.e. innovation developed, at least to some degree, in house. In countries where learning and problem-solving on the job are more constrained, and little discretion is left to the employee, firms tend to engage in a supplier-dominated innovation strategy. Their technological renewal reflects, almost exclusively, absorption of innovations developed elsewhere. Our results challenge some of the established ideas and they raise new questions about the link between work organisation, learning and innovation. For example, they raise doubts about whether the use of such organizational practices such as job rotation and teamwork are relevant indicators for how far firms engage in learning and innovation. It would be worthwhile to obtain disaggregated data to explore this and other issues in much greater depth.

Our analysis may be seen as contributing also to the literature on national systems of innovation. The systematic relations we observe between the organisation of work and innovation suggest that the way work is organised should be seen as a layer below the observed 'technological infrastructure' that is sometimes assumed to structure the innovation system. While differences in the technological infrastructure may be useful to characterise innovation systems, the underlying structure of how people work and learn may be both more fundamental and more deeply rooted in the national institutional framework. Attempts to benchmark innovation policies in order to locate 'best practise' may only give a view of the tip of the iceberg and they may therefore lead to mistaken conclusions.

The paper is structured as follows. Section 2 describes the variables used to characterise work organisation in the 15 countries of the European Union and presents the results of a factor analysis and a hierarchical clustering used to construct a typology of forms of work practice. Section 3 examines differences in the relative importance of these forms across the EU, controlling for the effects of sector, firm size and occupational category. Section 4 presents the data used to construct the typology of innovation modes developed by

[13] Of course, as with any comparative study based on survey questions that may be interpreted differently in different nations, there is a need to be careful in generalizing from the results.

Arundel and Hollanders (2005) in cooperation with Eurostat.[14] Section 5 uses the two typologies to examine, at the national level, the relation between the organisational practices adopted in a nation and its distribution of innovation modes. Section 6 considers how different aspects of a nation's social and institutional setting may influence the forms of work organisation adopted and the implications of this for innovation. The concluding section considers some of the main implications of the research for European policy.

2. Measuring forms of work organisation in the European Union[15]

In order to map the forms of work organisation adopted by firms across the European Union we draw on the results of the third European Survey of Working Conditions undertaken by the European Foundation for the Improvement of Living and Working Conditions.[16] The survey questionnaire was directed to approximately 1500 active persons in each country with the exception of Luxembourg with only 500 respondents. The total survey population is 21703 persons, of which 17910 are salaried employees. The survey methodology is based on a 'random walk' multi-stage random sampling method involving face-to-face interviews undertaken at the respondent's principal residence. The analysis presented here is based on the responses of the 8081 salaried employees working in establishments with at least 10 persons in both industry and services, but excluding agriculture and fishing; public administration and social security; education; health and social work; and private domestic employees.

The choice of variables for the analysis is based on a reading of two complementary literatures which address the relation between the forms of work organisation used by firms and the way they learn and innovate: the 'high performance work system' literature dealing with the diffusion of Japanese-style organisational practices in the US and Europe (Dertouzos, et. al. 1989; Gittleman et al. 1998; Osterman, 1994 and 2000; Ramsay et al., 2000; Truss, 2000; and Wood,1999) and the literature dealing with the relation between organisational design and innovation (Lam, 2005; Lam and Lundvall, 2006, Mintzberg, 1979, 1983). The 'high performance' literature focuses on the diffusion of specific organisational practices and arrangements that are seen as enhancing the firm's capacity

[14] Results for the UK were provided by the Department of Trade and Industry and results for Denmark by the Danish Centre for Studies in Research and Research Policy.
[15] This section draws extensively on Lorenz and Valeyre, 2005.
[16] The initial findings of the survey are presented in a European Foundation report by D. Merllié and P. Paoli [2001].

for making incremental improvements to the efficiency of its work processes and the quality of its products and services. These include practices designed to increase employee involvement in problem-solving and operational decision-making such as teams, problem-solving groups and employee responsibility for quality control. Many of the practices identified in this literature were innovations developed by large Japanese automobile and electronics firms in the 1970s and 1980s, and some authors refer specifically to the diffusion of the 'lean production' model associated with Toyota. (Womack, John and Roos, 1990; MacDuffie and Pil, 1997). The diffusion of these Japanese-style organisational practices is seen as having contributed to the progressive transformation of more hierarchically structured firms that relied Taylor's principles of task specialisation and a clear distinction between the work of conception and execution.

While the high performance literature makes a dichotomous distinction between hierarchical and flexible or 'transformed' organisations, the organisational design literature has tended to develop more complex taxonomies. For example, Mintzberg (1983), within the context of a broad distinction between bureaucratic and organic organisations, identifies two types of organic organisation with a high capacity for adaptation: the operating adhocracy and the simple organisation. The forms of work organisation and types of work practices that characterise these two organic forms are quite different. The simple form relies on direct supervision by one individual (typically a manager) and a classic example of this type of organisation is the small entrepreneurial firm. Adhocracies rely on mutual adjustment in which employees coordinate their own work by communicating informally with each other. Various liaison devices such as project teams and task forces are used to facilitate the process of mutual adjustment. While autonomy in work is low in the simple organisation it is high in the adhocracy.

In contrast to these 'organic' forms, Mintzberg identifies two basic bureaucratic forms with a limited capacity for adaptation and innovation: the machine bureaucracy and the professional bureaucracy.[17] The key characteristic of work organisation in the former is the standardization of jobs and tasks through the use of formal job descriptions and rules imposed by management. Thus there is a high degree of centralisation and limited

[17] Mintzberg also refers to a third bureaucratic form, the 'divisionalised' form. Unlike the other four configurations, he describes it as a partial structure superimposed on others (i.e. divisions) each of which is driven towards the machine bureaucracy.

employee discretion over how work is carried out or over the pace of work. In the professional bureaucracy, on the other hand, centralisation is low and behaviour is regulated and standardised through the acquisition of standardised skills and the internalisation of professional norms and standards of conduct. As a result operating procedures are quite stable and routinized despite considerable autonomy in work.

Lam (2005) in a recent synthesis and extension of these two literatures contrasts two ideal organisational forms that support different styles of learning and innovation: the 'operating adhocracy' and the 'J-form'.[18] She observes that the operating adhocracy relies on the expertise of individual professionals and uses project structures to temporarily fuse the knowledge of these experts into creative project teams that carry out innovative projects typically on behalf of its clients. High levels of discretion in work provide scope for exploring new knowledge and adhocracies tend to show a superior capacity for radical innovation. Compared to the operating adhocracy, the J-form is a relatively bureaucratic form that relies on formal team structures and rules of job rotation to embed knowledge within collective organisation. Stable job careers within internal labour markets provide incentives for members to commit themselves to the goals of continuous product and process improvement and the J-form tends to excel at incremental innovation.

In summary, both the high performance and organisational design literatures draw a relation between the forms of work organisation adopted by a firm and its innovative style and capacity. In order to capture the diffusion across the EU of the main types of work organisation identified in these literatures, we use the Working Conditions survey data to construct 15 binary variables as presented in Table 1 below.[19]

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[18] The term J-form is used because its archetypical practices and forms of work organisation are best illustrated by the 'Japanese-type' organisation discussed in the work of Aoki (1988) and Nonaka and Takeuchi (1995).

[19] For the questions and coding used to construct the measures upon which the statistical analysis is based, see Appendix 1.

Table 1
Work Organisation Variables

	Percent of employees
Team work	64.2
Job rotation	48.9
Responsibility for quality control	72.6
Quality norms	74.4
Problem solving activities	79.3
Learning new things in work	71.4
Complexity of tasks	56.7
Discretion in fixing work methods	61.7
Discretion in setting work pace	63.6
Horizontal constraints on work pace	53.1
Hierarchical constraints on work pace	38.9
Norm-based constraints on work pace	38.7
Automatic constraints on work pace	26.7
Monotony of tasks	42.4
Repetitiveness of tasks	24.9
n	*8081*

Source: Third Working Conditions survey, European Foundation for the Improvement of Living and Working Conditions

Four of the variables measure the use of the core work practices identified in high performance work systems literature: team work, job rotation, employee responsibility for quality control, and precise quality norms. Two of the variables capture whether employees engage in learning and problem-solving which are characteristics of both adhocracies and the J-form. One question captures whether work tasks are complex or not and is relevant to the operating adhocracy. The forms of discretion in work that are characteristic of adhocracies are measured by two variables that capture whether employees are able to choose or change their work methods and their pace of work. Four variables measure different constraints on employee discretion in setting their pace of work: ‘automatic’ constraints on work pace which is linked to the rate at which equipment is operated or a product is displaced in the production flow; ‘hierarchical’ constraints linked to the direct control which is exercised by ones immediate superiors; norm-based constraints on work pace linked to the setting of quantitative production norms; and ‘horizontal’ constraints linked to how one person’s work rate is dependent on the work of his or her colleagues. Hierarchical and automatic constraints are classic characteristics of taylorist work settings, while norm-based constraints characterise both taylorism and the Japanese forms of work organisation. The horizontal constraints variable provides a measure of whether work is carried out collectively rather than individually. Finally, the two variables measuring task repetitiveness and task monotony capture typical features of taylorist work settings.

Variety in European organisational practice

In order to assign employees to distinct categories or groups, we first undertake a factor analysis[20] to identify the underlying associations that exist among the 15 organisation variables described in Table 1. We then use the factor scores or the coordinates of the observations on the factors as a basis for clustering individuals into distinct groups of work systems, using Ward's hierarchical clustering method. This allows us to distinguish between four basic systems of work organisation as presented in Table 2.[21] For example, 64.3% of all employees with a job subject to discretionary learning report team work.

The first cluster, which account for 39 percent of the employees, [22] is distinctive for the way high levels of autonomy in work are combined with high levels of learning, problem-solving and task complexity. The variables measuring constraints on work pace, monotony and repetitiveness are under-represented. The use of team work is about at the average level for the population as a whole, while less than half of the employees in this cluster participate in job rotation which points to the importance of horizontal job specialisation. The forms of work organisation in this cluster correspond rather closely to those found in adhocracies and due to the combined importance of work discretion and learning we refer to this cluster as the 'discretionary learning' form.

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[20] The factor analysis method used here is multiple correspondence analysis (MCA) which is especially suitable for the analysis of categorical variables. Unlike principal components analysis where the total variance is decomposed along the principal factors or components, in multiple correspondence analysis the total variation of the data matrix is measured by the usual chi-squared statistic for row-column independence, and it is the chi-squared statistic which is decomposed along the principal factors. It is common to refer to the percentage of the 'inertia' accounted for by a factor. Inertia is defined as the value of the chi-squared statistic of the original data matrix divided by the grand total of the number of observations. See Benzecri, J.P. (1973); Greenacre (1993, pp. 24-31).

[21] For a graphical presentation of the positions of the centres of gravity of the clusters on the first two factors of the MCA, see Appendix 2.

[22] The percentages are weighted.

Table 2
Work Organisation Clusters

	Percent of employees by work organisation cluster reporting each variable				
Variable	**Discretionary learning**	**Lean production**	**Taylorism**	**Traditional organisation**	**Average**
Team work	64.3	84.2	70.1	33.4	64.2
Job rotation	44.0	70.5	53.2	27.5	48.9
Quality norms	78.1	94.0	81.1	36.1	74.4
Responsibility for quality control	86.4	88.7	46.7	38.9	72.6
Problem solving activities	95.4	98.0	5.7	68.7	79.3
Learning new things in work	93.9	81.7	42.0	29.7	71.4
Complexity of tasks	79.8	64.7	23.8	19.2	56.7
Discretion in fixing work methods	89.1	51.8	17.7	46.5	61.7
Discretion in setting work rate	87.5	52.2	27.3	52.7	63.6
Horizontal constraints on work rate	43.6	80.3	66.1	27.8	53.1
Hierarchical constraints on work rate	19.6	64.4	66.5	26.7	38.9
Norm-based constraints on work rate	21.2	75.5	56.3	14.7	38.7
Automatic constraints on work rate	5.4	59.8	56.9	7.2	26.7
Monotony of tasks	19.5	65.8	65.6	43.9	42.4
Repetitiveness of tasks	12.8	41.9	37.1	19.2	24.9

Source: Third Working Conditions survey, European Foundation for the Improvement of Living and Working Conditions

The second cluster accounts for 28 percent of the employees. Compared to the first cluster, work organisation in the second cluster is characterised by low levels of employee discretion in setting work pace and methods. The use of job rotation and team work, on the other hand, are much higher than in the first cluster, and work effort is more constrained by quantitative production norms and by the collective nature of work organisation. The use of quality norms is the highest of the four clusters and the use of employee responsibility for quality control is considerably above the average level for the population as a whole. These features point to a more structured or bureaucratic style of organisational learning that corresponds rather closely to the characteristics of the Japanese or 'lean production' model associated with the work of MacDuffie and Krafcik (1992) and Womack et al. (1990).

The third class, which groups 14 percent of the employees, corresponds in most respects to a classic characterisation of taylorism. The work situation is in most respects the opposite of that found in the first cluster, with low discretion and low level of learning and problem-solving. Interestingly, three of the core work practices associated with the lean production model – teams, job rotation and quality norms – are somewhat over-represented in this cluster, implying that these practices are highly imperfect measures of a transition to new forms of work organisation characterised by high levels of learning and problem-solving. The characteristics of this cluster draw attention to the importance of what some authors have referred to as 'flexible taylorism' (Boyer and Durand, 1993; Cézard, Dussert and Gollac, 1992; Linhart, 1994).

The fourth cluster groups 19 percent of the employees. All the variables are underrepresented with the exception of monotony in work, which is close to the average. The frequency of the two variables measuring learning and task complexity is the lowest among the four types of work organisation, while at the same time there are few constraints on the work rate. This class presumably groups traditional forms of work organisation where methods are for the most part informal and non-codified.

In summary, the cluster analysis allowed us to identify three work organisation clusters whose features correspond rather closely to the forms of work organisation found, respectively, in adhocracies, J-form organisations, and machine bureaucracies or taylorist firms. It is important to emphasize that what our employee-level data allows us to capture is the adoption of different forms or work organisation within private sector firms in the EU and not the diffusion of particular types of firms or organisational archetypes. Thus, our results are fully consistent with the possibility that multiple forms of work organisation are being used within the same organisation. This, however, is consistent with what the empirical literature in the field of organisational behaviour and design shows. Pure organisational types are unlikely to found in the real world. As Lam (2005) observes, adhocracies are likely to be found in the creative sub-units of firms and may well be combined with other forms of work organisation. Osterman (1994) in his study of US firms classifies 'transformed' organisations as those which involve at least 50 percent of their employees in four core high performance work practices: teams, job rotation, quality circles, and total quality management.

3. How Europe's economies work and learn

As the figures in Table 3 below show, the discretionary learning forms of work organisation are especially developed in several service sectors, notably business services and banks and insurance, and in the gas, electricity and water utilities. As one would anticipate, the lean model of production is more developed in the manufacturing sector, notably in the production of transport equipment, electronics and electrical production, wood and paper products, and printing and publishing. The taylorist forms are notably present in textiles, clothing and leather products, food processing, wood and paper products and transport equipment. The traditional organisational forms are to be found principally in the services, notably land transport, personal services, hotels and restaurants, post and telecommunications, and wholesale and retail trade.

Table 3

Forms of Work Organisation by Sector of Activity

	Percent of employees by sector in each				
	Discretionary learning	Lean production	Taylorism	Traditional organisation	Total
Mining and quarrying	42.4	41.5	3.4	12.7	100.0
Food processing	18.4	34.9	24.6	22.1	100.0
Textiles, garments, leather products	27.2	25.9	30.2	16.8	100.0
Wood and paper products	27.6	40.7	23.9	7.8	100.0
Publishing and printing	31.1	43.8	14.1	11.0	100.0
Chemicals and plastics	34.7	34.1	21.9	9.2	100.0
Metal products and mechanical	31.8	35.7	19.8	12.7	100.0
Electrical engineering and electronics	41.5	38.5	8.6	11.4	100.0
Transport Equipment	28.1	38.7	23.2	10.0	100.0
Other industrial production	50.9	22.1	18.4	8.5	100.0
Electricity, gas and water	58.5	19.4	6.2	15.8	100.0
Construction	40.9	31.4	10.6	17.1	100.0
Wholesale and retail trade	41.5	20.4	11.7	26.4	100.0
Hotels and restaurants	29.7	25.8	16.6	27.9	100.0
Land transport	26.3	24.0	10.2	39.5	100.0
Other transport	39.2	36.1	5.0	19.7	100.0
Post and telecommunications	38.1	27.1	7.7	27.1	100.0
Financial services	58.1	21.5	3.4	16.9	100.0
Business services	57.6	18.7	6.9	16.7	100.0
Personal services	39.7	18.9	7.6	33.8	100.0
Average	39.1	28.2	13.6	19.1	100.0

Source: Third Working Condition survey. European Foundation for the Improvement of Living and Working Conditions

Table 4 provides evidence on variations in forms of work organisation according to occupational category. As one would expect, the discretionary learning forms of work organisation are especially characteristic of the work of managers, professionals and technicians, while the lean forms of work organisation primarily characterises the work of employees in craft and related trades and machine operators and assemblers. The taylorist forms are most frequent amongst machine operators and the unskilled trades. Finally, the traditional forms of work organisation grouped in the fourth cluster are especially characteristic of the work of service workers and shop and market sales persons.

Table 4
Forms of Work Organisation according to Occupational Category

	Percent of employees by occupational category in each organisational class				
	Discretionary learning	**Lean production**	**Taylorism**	**Traditional organisation**	**Total**
Managers	69.1	24.7	0.2	6.0	100,0
Engineers and professionals	75.9	14.0	5.2	4.9	100,0
Technicians	61.0	24.6	2.4	12.0	100,0
Clerks	43.2	21.9	9.4	25.5	100,0
Service, shop & market sales persons	30.3	21.4	12.4	35.9	100,0
Craft & related trades	34.2	38.5	16.5	10.8	100,0
Machine operators & assemblers	15.7	37.7	24.3	22.3	100,0
Unskilled trades	14.8	23.9	26.7	34.5	100,0
Average	39.1	28.2	13.6	19.1	100,0

Source: Third Working Condition survey. European Foundation for the Improvement of Living and Working Conditions

Establishment size constitutes a relatively unimportant factor in the use of different organisational models. The learning forms of work organisation are somewhat underrepresented in the medium-size category of establishments (100 to 249 employees). The lean and taylorist forms increase with establishment size (> 250 employees) while the reverse tendency can be observed for the traditional forms of work organisation.

In combination tables 2, 3 and 4 gives us a better idea of what the different clusters represent. Discretionary learning refers to jobs where a lot of responsibility is allocated to the employee who is expected to solve problems on her own. Business services is a typical example where many jobs involve a continuous confrontation with new and complex problems. Although some of the tasks take place in a team, teamwork is not seen as imposing narrow constraints on the work. In this category team-work may involve brain-storming by professional experts as much as collectively solving narrowly defined problems.

Lean production also involves problem solving and learning but here the problems are more narrowly defined and the scale of possible solutions less broad. The work is highly constrained and it is often repetitive and monotonous. The extensive use of management techniques such as job rotation (between similar tasks within the same division) and team work may be seen as attempts to overcome the limits of taylorist production and to create some degree of active participation of production workers and sales staff in order to limit labour turnover and absenteeism.

Taylorism is distinctive for low levels of learning and for the virtual absence of problem-solving activity. The work is highly constrained and monotonous. It may be seen as the old-style factory work where the tasks to solve are narrowly defined and repetitive. It is a kind of work where the required qualifications are limited and the worker can easily be substituted by another worker or by a machine. In the era of globalisation this category of work is interesting for two reasons. It is a kind of work where immigrants can be as productive as domestic workers but it is also the kind of work that is most easily outsourced to low wage countries.

Traditional organisation involves even less complex problems. It is more individualistic than all the other categories and less monotonous than lean production and taylorism. It includes traditional service jobs. Many of those involve a direct and indirect interaction with local customers and they may therefore be less foot-loose than the taylorist jobs.

National effects on the diffusion of organisational practice

Table 5 shows that there are wide differences in the importance of the four forms of work organisation across European nations. The discretionary learning forms of work organisation are most widely diffused in the Netherlands, the Nordic countries and to a lesser extent Germany and Austria, while they are little diffused in Ireland and the southern European nations. The lean model is most in evidence in the UK, Ireland, and

Spain and to a lesser extent in France, while it is little developed in the Nordic countries or in Germany, Austria and the Netherlands. The taylorist forms of work organisation show almost the reverse trend compared to the discretionary learning forms, being most frequent in the southern European nations and in Ireland and Italy. Finally, the traditional forms of work organisation are most in evidence in Greece and Italy and to a lesser extent in Germany, Sweden, Belgium, Spain and Portugal.

Table 5
National Differences in Forms of Work Organisation

	Percent of employees by country in each organisational class				
	Discretionary learning	**Lean production**	**Taylorist organisation**	**Traditional organisation**	**Total**
Belgium	38.9	25.1	13.9	22.1	100.0
Denmark	60.0	21.9	6.8	11.3	100.0
Germany	44.3	19.6	14.3	21.9	100.0
Greece	18.7	25.6	28.0	27.7	100.0
Italy	30.0	23.6	20.9	25.4	100.0
Spain	20.1	38.8	18.5	22.5	100.0
France	38.0	33.3	11.1	17.7	100.0
Ireland	24.0	37.8	20.7	17.6	100.0
Luxembourg	42.8	25.4	11.9	20.0	100.0
Netherlands	64.0	17.2	5.3	13.5	100.0
Portugal	26.1	28.1	23.0	22.8	100.0
United Kingdom	34.8	40.6	10.9	13.7	100.0
Finland	47.8	27.6	12.5	12.1	100.0
Sweden	52.6	18.5	7.1	21.7	100.0
Austria	47.5	21.5	13.1	18.0	100.0
EU-15	39.1	28.2	13.6	19.1	100.0

Source: Third Working Condition survey. European Foundation for the Improvement of Living and Working Conditions

As Tables 3 and 4 have shown, each form of work organisation tends to be associated with particular sectors and occupational categories. This raises the question of what part of the variation in the importance of these forms across EU nations can be accounted for by the nation's specific industrial and occupational structure, or by other unexplained national factors that could influence the use of specific organisational forms. These unexplained national factors could include socio-cultural attitudes on the part of management and workers, historical developments, and the rate at which new organisational forms are adopted by firms. In order to determine the importance of 'national factors', we use logit regression analysis to provide estimates of the impact of national effects on the relative likelihood of adopting the different work models (See Table 6). Germany, the most populous nation within the EU, is the reference case for the estimates of national effects. In each case the dependent variable is a binary variable measuring whether or not the individual is subject to the particular form of work organisation. The independent variable for columns 1 through 4 in Table 6 is a categorical variable for the 14 countries plus the reference category of Germany. Thus column 1 gives the likelihood that employees are subject to the 'discretionary learning' form of work organisation in each country relative to the German case.

Table 6
Logit Estimates of National Effects on Organisational Practice

	Logit estimates without structural controls				***Logit estimates with structural controls***			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
	Discretionary learning organisation	**Lean organisation**	**Taylorism**	**Traditional organisation**	**Discretionary learning organisation**	**Lean organisation**	**Taylorism**	**Traditional organisation**
Belgium	-0.22	0.32	-0.03	0.01	-0.23	0.42*	-0.11	-0.09
Denmark	0.63**	0.14	-0.82**	-0.79**	0.79**	0.29	-0.86**	-1.06**
Greece	-1.24**	0.35	0.85**	0.31	-1.33**	0.42	0.84**	0.12
Italy	-0.61**	0.24*	0.46**	0.20*	-0.51**	0.20	0.33**	0.16
Spain	-1.15**	0.96**	0.31*	0.04	-1.15**	1.08**	0.06	-0.17
France	-0.26**	0.72**	-0.29*	-0.27**	-0.32**	0.84**	-0.33**	-0.38**
Ireland	-0.92**	0.91**	0.45	-0.27	-1.11**	1.14**	0.47	-0.50
Luxembourg	-0.06	0.33	-0.21	-0.11	-0.17	0.42	0.00	-0.20
Netherlands	0.81**	-0.16	-1.10**	-0.59**	0.79**	0.02	-0.94**	-0.74**
Portugal	-0.81**	0.47**	0.58**	0.05	-0.78**	0.51**	0.44*	-0.01
UK	-0.40**	1.03**	-0.31**	-0.56**	-0.68**	1.32**	-0.24*	-0.72**
Finland	0.14	0.45*	-0.15	-0.71*	-0.01	0.63**	-0.07	-0.78*
Sweden	0.33*	-0.07	-0.77**	-0.01	0.22	0.06	-0.68*	0.00
Austria	0.13	0.12	-0.10	-0.24	0.33	0.14	-0.26	-0.43*

**: significant at 5% **: significant at 1% Reference country: Germany*

Source: Third European Survey of Working Conditions. European Foundation for the Improvement of Living and Working Conditions.

Columns 5 through 8 present estimates of the relative likelihood of adopting the various forms of work organisation with structural controls. We have introduced three control variables corresponding to sector, establishment size and occupational category. The respective reference categories for the estimates are the vehicle sector, firms with 10 to 49 employees, and the occupational category of machine operator and assembler.

As the column 1 results show, the country the employee works in has a significant impact on the relative likelihood of using the discretionary learning forms. Compared to the German case, for which the use of the discretionary learning forms of work organisation are near the 15-country weighted average (see Table 5 above), there are three countries where the learning model is more extensively used: Sweden, the Netherlands and Denmark. There are no significant differences in the use of discretionary learning in four countries: Belgium, Luxembourg, Finland and Austria. The learning model is less in evidence in the remaining seven countries. Column 5 indicates that these results are robust after controlling for the effect of firm size, industry structure, and occupation, with the exception of Sweden, for which the coefficient estimate though still positive is no longer significant.

Column 2 of Table 6 presents the estimates of national effects on the likelihood of using the lean forms without controls. Compared to Germany, where the use of the lean model is relatively low in relation to the 15-country weighted average (see Table 5), Spain, France, Ireland, Finland, the UK and Portugal display a relatively high propensity to use lean production methods. The coefficients are especially high for the UK, Ireland and Spain and they increase slightly and remain significant when structural controls are included.

Overall, the results show that structural factors such as firm size, industry and occupation do not explain the marked national differences in the use of the different forms of work organisation. Instead, unexplained national factors that could be due to historically inherited management-worker relations or attitudes to organisational innovation strongly influence national differences in the use of different sets of organisational practices.

These results suggest that as EU nations progressively have moved away from more traditional or hierarchical forms of work organisation and have sought to increase their capacity for learning and problem-solving, they have done this in different ways. Spain, the UK and Ireland stand out for their intensive use of the lean forms, while the Nordic nations and the Netherlands stand out for their use of the discretionary learning forms.

Germany, Austria, France, Luxemburg and Belgium present a more balanced picture regarding the use of these two forms of work organisation each characterised by strong learning dynamics. The countries in the south of Europe are all weak in terms of discretionary learning.

In so far as the organisational practices adopted by firms can influence their ability to develop and profit from innovation, the results in Table 6 suggest that the large differences within the European Union in national innovative performance[23] could partly be linked to national differences in the distribution of different types of practices, particularly the use of discretionary learning forms that could maximize the opportunities for learning. This possibility is explored in sections 4 and 5.

4. Measuring differences in innovation mode

Economists and business scholars frequently measure innovation by R&D expenditures or by the number of patents applied for or granted. The weaknesses of these measures are well known. R&D doesn't necessarily result in the development of new products or processes and many innovative firms do not perform R&D. A large fraction of innovations are not patented and the importance of patenting varies according to sector. Furthermore, R&D and patents entirely fail to capture innovation that occurs through diffusion processes, such as when a firm purchases innovative production equipment or product components from other firms. The Community Innovation Surveys (CIS) were in part designed to respond to these limitations by providing survey-based estimates of the percentage of manufacturing firms and selected service sector firms[24] that have developed or introduced a new product or process over a three-year time period. However, the CIS estimates of the percentage of innovative firms are based on a very broad definition of innovation ranging from intensive in-house R&D to develop a new-to-market product or process to minimal effort to introduce manufacturing equipment purchased from a supplier. Consequently, a broad all-encompassing definition of an innovative firm is both

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[23] As an example, the 2005 European Innovation Scoreboard finds a 2.5 fold difference between the best and worst EU-15 member states on the Summary Innovation Index.

[24] CIS-3, used for determining innovation modes, did not include firms in several sectors covered in the Third Working Conditions Survey: construction (NACE 45) and service sectors as retail trade (NACE 52), automobile trade and repair (NACE 50), hotels and restaurants (NACE 55), some business services (NACE 74.1 and NACE 74.4 to 74.8), and personal services (NACE 90 to 93). CIS-3 did include wholesale trade (NACE 51). The main effect is that the CIS innovation modes data will underestimate the percentage of firms with traditional forms of work organisation (see Table 3).

misleading in international comparisons and fails to provide a clear picture of the structure of innovation capabilities within individual countries.

In order to overcome these limitations, Arundel and Hollanders (2005), in collaboration with Paul Crowley of Eurostat, classified all innovative CIS respondent firms into four mutually exclusive innovation modes that capture different methods of innovating, plus a fifth group for non-innovators.[25]

The classification method uses two main criteria: the level of novelty of the firm's innovations, and the creative effort that the firm expends on in-house innovative activities. The four innovation modes are as follows:

Strategic innovators (21.9% of all innovative firms): For these firms, creative in-house innovative activities form an important part of the firm's strategy. All firms have introduced a product or process innovation that they developed at least partly in-house, perform R&D on a continuous basis, introduced a new-to-market innovation, and are active in national or international markets. These firms are the most likely source of innovations that are later adopted or imitated by other firms.

Intermittent innovators (30.7% of all innovative firms): All of these firms develop innovations at least in part in-house and all have developed a new for the market innovation. But, they are less likely than the strategic innovators to have developed important innovations that diffuse to other firms, either because they are only active on local or regional markets, or because they only undertake innovative activities intermittently, say when required by the introduction of new product line.

Technology modifiers (26.3% of all innovative firms): These firms primarily innovate through modifying technology developed by other firms or institutions. None of them perform R&D on either an occasional or continuous basis. Many firms that are essentially

[25] Data are available for all EU member nations in 2000 with the exception of Ireland. The classification system is dependent on the types of variables available in the CIS and is limited to variables with a reasonably high response rate. For full details on the methodology for innovation modes, see Annex B of the Trend Chart document 'EXIS: An Exploratory Approach to Innovation Scoreboards http://trendchart.cordis.lu/scoreboards/scoreboard2004/pdf/EXIS.pdf).

process innovators that innovate through in-house production engineering will fall within this group.

Technology adopters (21.0% of all innovative firms): These firms do not develop innovations in-house, with all innovations acquired from external sources. An example is the purchase of new production machinery.

Table 7 presents the distribution of firms according to innovation mode for 14 EU nations for which the necessary data are available and also includes the percentage of firms that did not innovate. The results are weighted to reflect the distribution of all firms within the industry and service sectors covered by CIS-3. The results show that Finland, Germany and Luxembourg have the highest percentage of firms in the strategic and intermittent categories of innovators, while Germany, Luxembourg and Austria have the highest percentages of firms that are technology modifiers. In Spain, Greece, and the UK over 80% of firms are either adopters or non-innovators.

Table 7

A Typology of Innovation Modes for EU Member Nations

	Percentage of all firms by country in each innovation mode					
	Strategic	**Intermittent**	**Technology modifiers**	**Technology adopters**	**Non - innovators**	**Total**
Belgium	7	13	16	14	50	100
Denmark	5	14	11	14	56	100
Germany	10	15	25	11	39	100
Greece	4	9	5	10	72	100
Italy	6	12	15	4	64	100
Spain	2	6	5	19	67	100
France	8	12	10	11	59	100
Luxembourg	7	17	20	4	52	100
Netherlands	8	14	16	8	55	100
Portugal	3	15	16	13	54	100
UK	4	7	5	16	68	100
Finland	13	19	10	3	55	100
Sweden	11	14	14	8	53	100
Austria	8	12	20	9	51	100

5. The relation between organisational practice and innovation mode

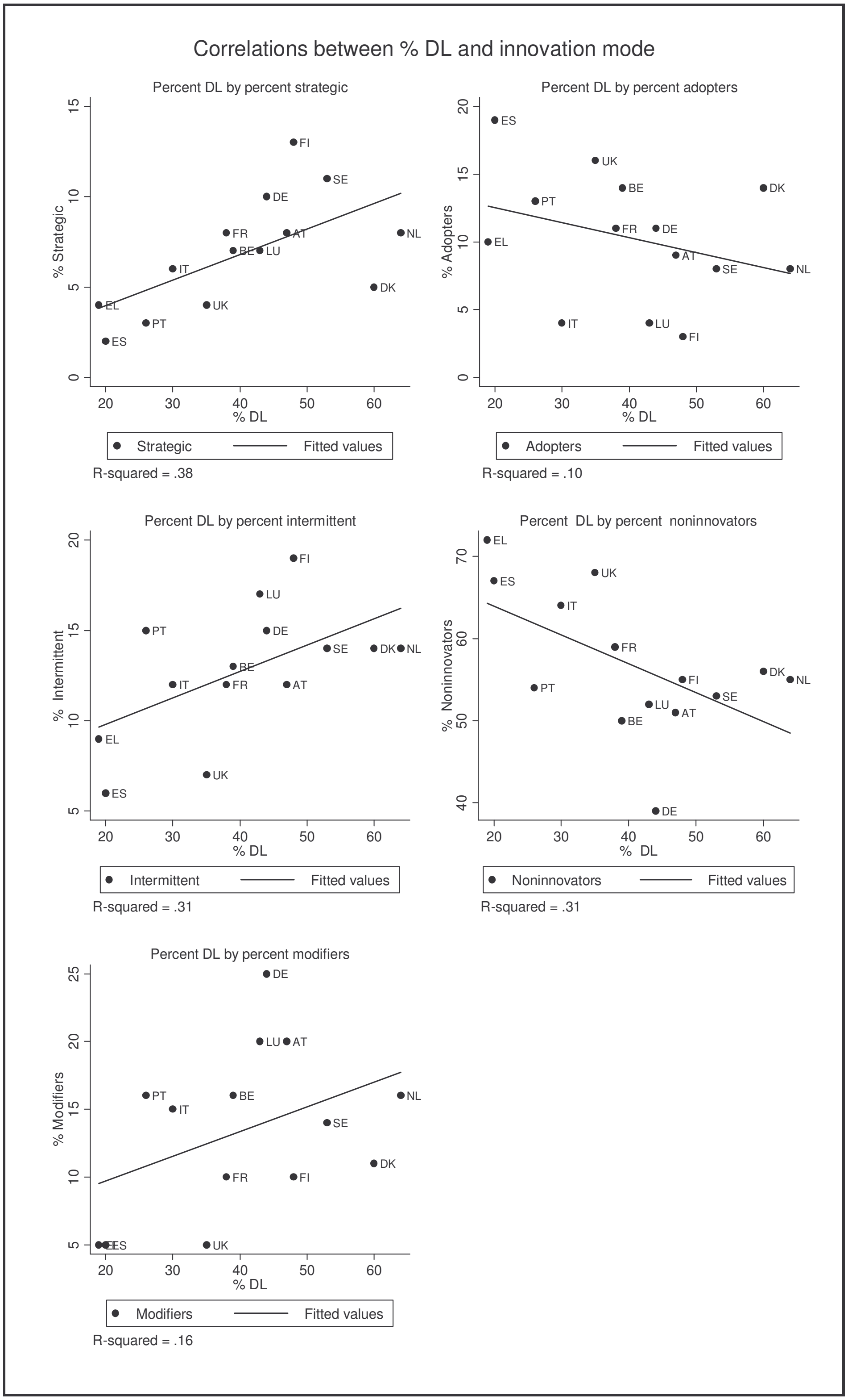
As our introductory discussion pointed out, much of the discussion in the organisational behaviour literature on the relation between organisation and innovation focuses on whether or not particular organisational designs are better suited for undertaking radical or incremental innovations. The radical/incremental distinction is often seen as corresponding to the degree to which innovations are competence destroying as opposed to competence enhancing. For example, Lam (2005) and Lam and Lundvall (2006) argue that Mintzberg's (1979, 1983) 'operating adhocracy' form of organisation, which relies on networks of professional experts and the creation of adhoc project teams, is especially adapted to novel or radical innovations characteristic of new emerging technologies. The firms of Silicon Valley provide good examples of this organisational form (Bahrami and Evans, 2000; Saxenian, 1996). In contrast, it is widely asserted in the literature on the Japanese firm that its organisational design is especially suited for progressive or incremental improvements in product quality and design. (Aoki, 1990; Coriat, 1991; Womack et. al, 1990). The Japanese organisation relies on firm-specific knowledge that is embedded in the firm's organisational routines and relatively stable team structures for continuous product and process improvement.

Since the business practices and forms of work organisation captured in our discretionary learning and lean clusters correspond rather closely to those that characterise the 'operating adhocracy' and the 'Japanese-firm', this literature led us to anticipate differences in the relative frequency of radical and incremental innovations in a nation depending on the relative frequency of diffusion of the discretionary learning and lean forms of work organisation. Developing empirical indicators to identify radical and incremental modes of innovation is problematic, however. Survey manuals, such as the Oslo Manual that provides the basis of the CIS questions, do not propose guidelines for how to measure radical innovations. This makes it difficult to bring survey-based evidence to bear on the various propositions developed in the organisational literature.

Our typology of innovation modes captures a different but related distinction in the nature of innovation by distinguishing between firms that have developed, in-house, 'new-to-market' product or process innovations (particularly strategic innovators) versus firms that have only introduced 'new to firm' innovations that were partly or entirely developed outside the firm (particularly technology modifiers and technology adopters). This distinction is not identical to the difference between radical and incremental innovations, since introducing a ‘new to the firm’ innovation that was originally developed elsewhere could require the firm to make radical changes to its mix of competences, while conversely a ‘new-to-market’ innovation need not be a radical innovation. However, there are large differences along the continuum between strategic innovators and technology adopters in each firm’s capacity to explore new knowledge, which is conceptually similar (although on a different scale) to the difference between radical and incremental innovations.

In order to provide evidence that bears on the proposed link between organisational practice and innovation modes, we present a series of scatter plot diagrams showing the correlations between the frequency of the four innovation modes and the frequency of the discretionary learning and lean forms of work organisation for the 14 EU nations for which the data is available.

Figure 1



Correlations between % DL and innovation mode
Percent DL by percent strategic
% Strategic
% DL
Strategic
Fitted values
R-squared = .38
Percent DL by percent adopters
% Adopters
% DL
Adopters
Fitted values
R-squared = .10
Percent DL by percent intermittent
% Intermittent
% DL
Intermittent
Fitted values
R-squared = .31
Percent DL by percent noninnovators
% Noninnovators
% DL
Noninnovators
Fitted values
R-squared = .31
Percent DL by percent modifiers
% Modifiers
% DL
Modifiers
Fitted values
R-squared = .16

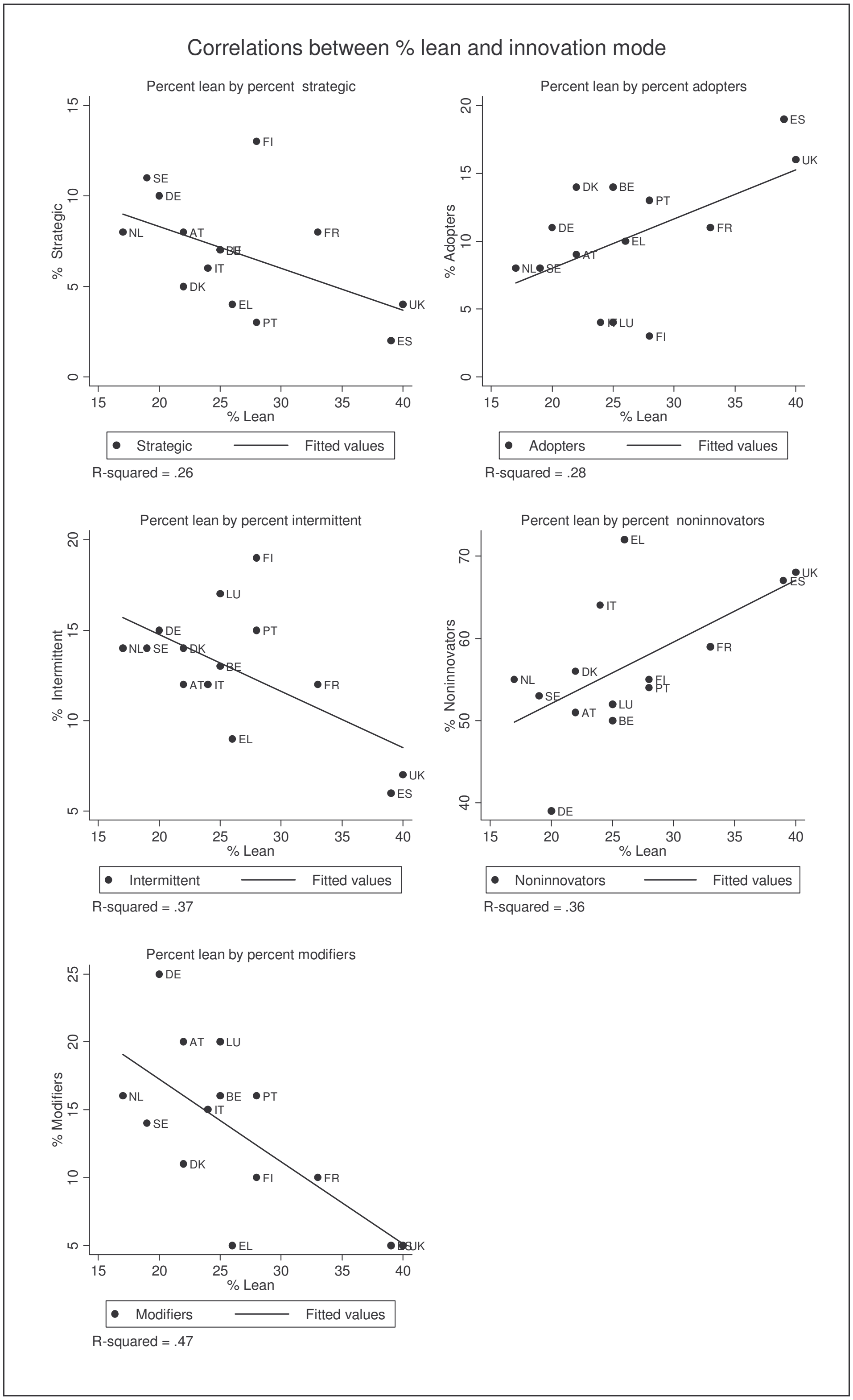
Figure 1 presents the results of this exercise for the discretionary learning (DL) forms. The main result is that there is a positive correlation between discretionary learning and the frequency of the two innovation modes for which the levels of novelty and creative in-house effort are the highest, the strategic and intermittent modes, while there is a negative correlation between discretionary learning and the frequency of non-innovators. Furthermore, the strongest positive correlation is between strategic innovators and discretionary learning, with 38% of the variation in the percentage of strategic innovators explained by the variation in the percentage of discretionary learning (R^2 of 0.38).[26]

Figure 2 presents the same analysis using the frequency of the lean organisational forms. The results tend to go in the opposite direction of those for discretionary learning. Thus they show a negative correlation between the frequency of the lean forms and the frequency of the three innovation modes which depend on in-house creative effort for innovation, and a positive correlation with the frequency of adopters and non-innovators.[27]

These results provide support for the view that there are systemic links between the way work is organised in a nation and the distribution of different innovation modes.[28] More specifically, the positive correlations between discretionary learning and the strategic and intermittent innovator modes provide support for the hypothesis developed in the qualitative literature that the forms of work organisation characteristic of operating adhocracies support the exploration of new knowledge that is needed for creative, in-house innovative activities that lead to the development of new-to-market innovations and possibly radical innovations.

[26] The correlations between discretionary learning and strategic, intermittent and non-innovators are significant at the .05 level or better. The relatively weak correlations between discretionary learning and the frequency of modifiers (positive) and adopters (negative) are not significant at the .10 level.
[27] All these correlations are significant at the .05 level or better with the exception of the negative correlation between lean and the frequency of strategic innovators which is significant at the .10 level.
[28] The innovation modes are only weakly correlated with the frequency of the traditional forms of work organisation (R-squared less than .10 in all cases). Strategic innovators are negatively correlated with the frequency of the taylorist forms (R-squared = .25, significant at the .10 level) and positively correlated with the frequency of non-innovators (R-squared = .18 but not significant at the .10 level). The taylorist forms are only weakly correlated with the other three innovation modes (R-squared less than .10 in each case).

Figure 2



Correlations between % lean and innovation mode
Percent lean by percent strategic
% Strategic
% Lean
Strategic
Fitted values
R-squared = .26
Percent lean by percent adopters
% Adopters
% Lean
Adopters
Fitted values
R-squared = .28
Percent lean by percent intermittent
% Intermittent
% Lean
Intermittent
Fitted values
R-squared = .37
Percent lean by percent noninnovators
% Noninnovators
% Lean
Noninnovators
Fitted values
R-squared = .36
Percent lean by percent modifiers
% Modifiers
% Lean
Modifiers
Fitted values
R-squared = .47

While the negative correlations shown in Figure 2 between the lean forms of work organisation and the frequency of the strategic and intermittent innovator modes are consistent with our reading of the organisational design literature, the negative correlation with the frequency of modifiers is not. Based on the Japanese experience, we expected the frequency of the lean forms to be positively correlated with the prevalence of technology modifiers, which are dominated by innovation based on minor incremental improvements. Furthermore, the results in Table 2 show that employees subject to the lean forms of work organisation report above rates of problem solving and learning. Nevertheless, the negative correlation with the frequency of technology modifiers is the highest observed (R^2 value of 0.47) while the lean forms are positively correlated with the prevalence of firms that either do not innovate or which only innovate through adopting new technology. Firms grouped in this latter category do not need to invest very much in exploring new knowledge in order to innovate[29].

The lack of a positive correlation between the lean forms and the prevalence of technology modifiers could be due to limitations with the data, but an alternative possibility is that the lean model could have been adopted by European firms as a more efficient alternative to Taylorism, without adopting the Japanese emphasis on the delegation of decision-making responsibility to shop-floor employees. Under these conditions, the problem solving and learning tasks reported by employees subject to lean organisation could be severely limited by the high prevalence of reported constraints (see Table 2), limiting opportunities to suggest or implement incremental improvements.[30] If true, the restrictions on lean organisational forms could explain part of the innovation performance gap between Europe and Japan. In the following section we turn to some of the 'unexplained national factors' that may influence why organisational practice varies by nation and the implications of this for innovation.

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[29] Some investment in learning will nevertheless be required, either to select new technology to adopt, or even to decide whether or not to innovate in a given time period.

[30] The vast literature on the transfer of Japanese management practices by Japanese multinationals to their affiliates located in Europe and the US and during the 1980s and 1990s provides evidence relevant to this issue. Most of this literature argues that Japanese management practices are modified in the process of transfer resulting in hybrid organisational forms combining elements of work organisation and HRM practices characteristic of the host country. See Kenney and Florida,1993; Liker et al. 1992; and Oliver and Wilkinson, 1992. For evidence on the limited delegation of decision-making authority to shop floor personnel in Japanese transplants located in the UK, see Lorenz, 2000; and Doeringer et al. 2003.

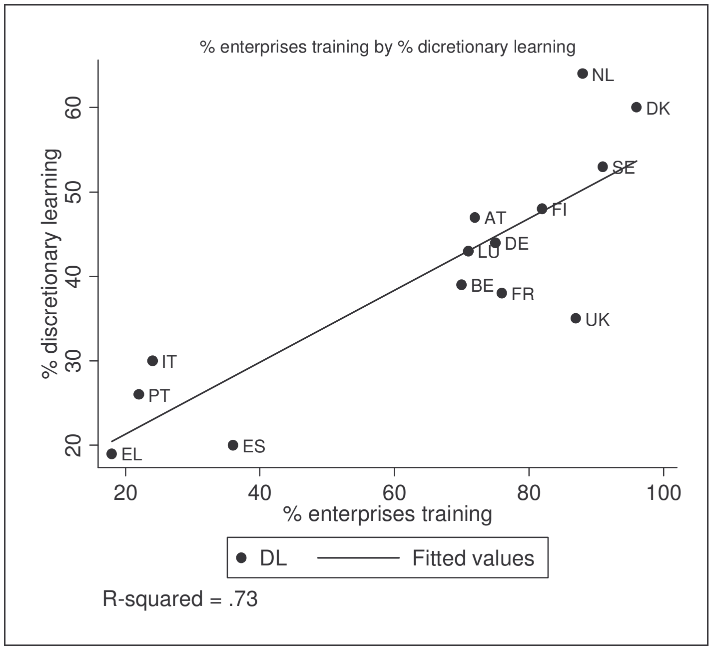
6. National factors and organisational forms

While the discretionary learning and lean forms of work organisation both depend on the capacities of their employees for learning and problem-solving, the former is correlated with in-house innovative capabilities while the latter is only correlated with technology adoption. This raises two questions: what unexplained national factors promote the use of discretionary learning, and what national factors constrain problem solving under lean organisational forms?

Education is clearly a factor. In nations where discretionary learning is widely diffused, there should be a tendency to invest more in the training of employees. Investments in training develop the firm and industry-specific skills of new entrants to the labour market. Life-long learning can also play a critical role in adapting the skills and knowledge of more mature employees' to the requirements of on-going changes in products and technology.

Some support for this proposition can be derived from Figure 3 which shows a strong positive correlation between the frequency of discretionary learning and the percentage of enterprises providing training to their employees. The figure also points to a possible north/south divide within Europe. The four less technologically developed southern nations are characterised by both low levels of enterprise training and low use of discretionary learning, while the more developed northern and central European nations are characterised by relatively high levels of enterprise training and by high level use of the discretionary learning forms.

Figure 3



Source: Continuing Vocational Education Survey, 1999 (Newcronos, Eurostat)

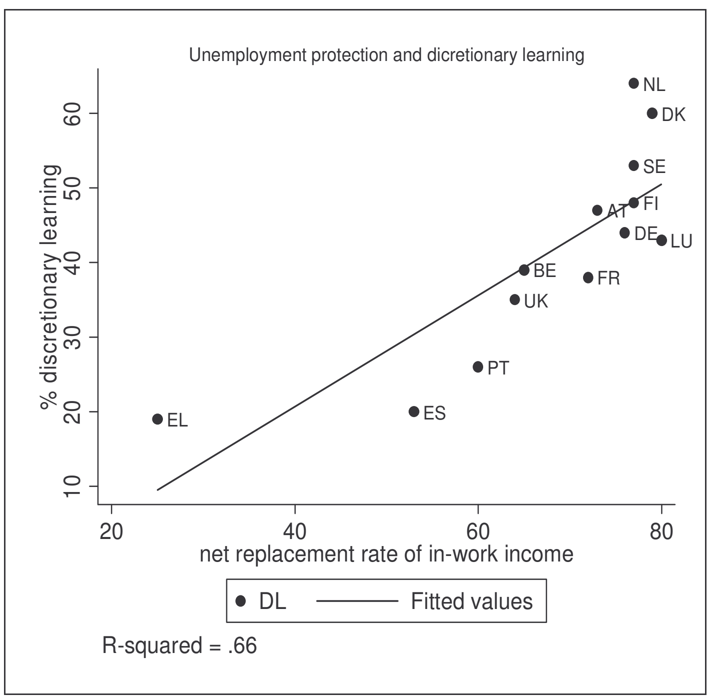
Figure 3 points to one anomaly: the UK is the only country within the group of high training nations that uses the lean forms more extensively than the discretionary learning forms (see Table 5). One possibility is that there are unique 'unexplained' factors at work in the UK that influence firms choices of organisational forms. Although it is very difficult to determine what these factors might be, a few clues are provided by Figures 4 and 5 below. Figure 4 shows the relation between the frequency of discretionary learning and an indicator of the strength of a nation's system of unemployment protection. Figure 5 shows the relation between the frequency of discretionary learning and an indicator of the level of national 'social capital'.

Figure 4 indicates that there is a positive relation between the frequency of discretionary learning and the proportion of in-work income being maintained by someone becoming unemployed.[31] One way to interpret this result has to do with the limited tenures that employees often experience in organisations that compete on the basis of strategies of

[31] The figures presented in Figure 4 are the net replacement rates of in-work income over 60 months averaged across four family types and two income levels for persons eligible for social assistance. See OECD, *Benefits and Wages*, 2004, p. 103.

continuous knowledge exploration. As Lam (2005, p. 128) has observed in her discussion of the operating adhocracy, in such organisations the mix of required skills and competences continuously evolves, and careers tend to be structured around a series of discrete projects rather than advancing within an intra-firm hierarchy. As a result, this kind of organisation has relatively porous organisational boundaries so as to permit the insertion of new knowledge and ideas from the outside. In such a context strong systems of unemployment protection can offer two complementary benefits. First, in terms of incentives, the security such systems provide in terms of income maintenance can encourage individuals to commit themselves to what would otherwise be perceived as unacceptably risky forms of employment and career paths. Secondly, such forms of protection can contribute to the longer term accumulation of knowledge for particular sectors or regions since in their absence unemployed workers would be under greater pressure to relocate with a resulting loss of skills and knowledge.

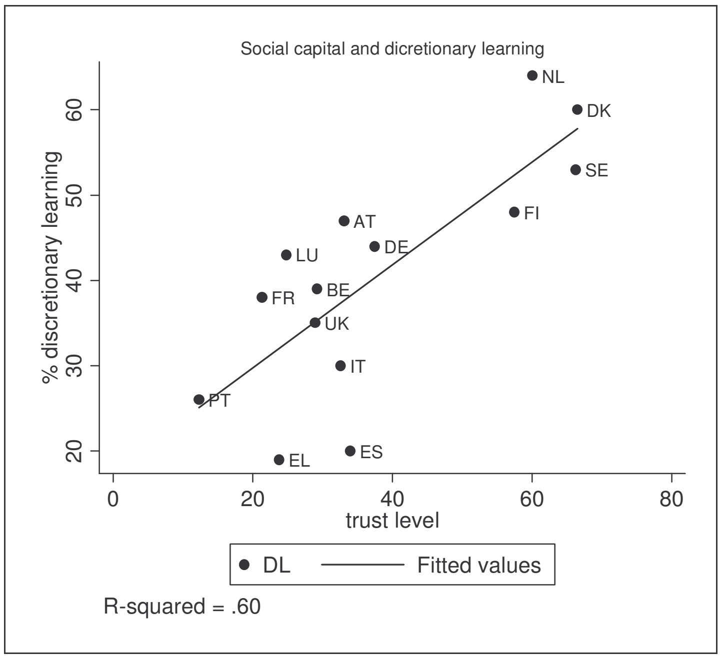
Figure 4



Source: *Benefits and Wages*, OECD (2004, p. 103)

Figure 5 shows a positive relation between the relative frequency of discretionary learning and a measure of the level of generalised trust in a nation that is commonly used in the literature on social capital and productivity growth.[32] The measure of trust is based on a question used in the World Values Survey in the 1999-2000 wave which provided information on 29 market economies.[33] The question used is: 'Generally speaking, would you say that most people can be trusted, or that you can't be too careful in dealing with people?' For the EU 15, the percentage of the respondents saying that most people can be trusted ranged from a low of 12.3 percent for Portugal to a high of 66.5 percent for Denmark.

Figure 5



World Values Survey, 1999-2000.

One way to interpret these results is that high levels of trust support high levels of autonomy in work whereas low levels of trust tend to give rise to relatively rule-bound and hierarchical forms of organisation. Trust supports autonomy in work for two related reasons. The first pertains to a standard issue raised in the principal-agent literature. The principal (employer) may be unwilling to give the agent (employee) large levels of discretion in work and rely on his or her good intentions in the absence of trust. This would be especially true of employees engaged in processes of knowledge creation which are by their nature complex and uncertain and thus difficult to monitor. The second has to

[32] See La Porta et al., 1997; Knack and Kneefer, 1997; and Zak and Knack, 1998.

do with the willingness of employees to bear risk. The outcomes of knowledge creation activities are by their nature uncertain and while the forms of autonomy in work which support such creative work may be of intrinsic value to employees they also increase individual responsibility and raise the question of fair treatment in the event of failure. Employees will be more prepared to bear these risks in setting characterised by high levels of trust. Of course even in low-trust national settings individual employers can adopt specific human resources policies to foster such trust which more or less goes against the national grain. But such trust will be much easier to foster and sustain in national settings where the presumption is that others can be trusted. Another way of saying this is that high levels of generalised trust in a society spill-over to the work place and have effects on relations of cooperation.

These considerations suggest that the UK's distinctive emphasis on the use of the lean over the discretionary learning forms of work organisation may reflect the way low levels of generalised trust combine with a weak system of unemployment protection to encourage the adoption of bureaucratic and rule-bound forms of organisation. Of course, institutional settings favourable to the adoption of the discretionary learning forms are not entirely absent in the UK. However, they tend to be found in only a few isolated contexts, such as the cluster of high-technology firms around the University of Cambridge, where localised networks of firms provide the necessary 'social capital' for the efficient accumulation of knowledge in an inter-firm career framework.

7. Conclusion

In this paper we have demonstrated that there is a close connection between how people work and learn in a country and the way firms' innovate. In countries where a big proportion of the labour force are engaged in activities that offer them some discretion in organising their work and that involve problem-solving and learning the frequency of 'endogenous' innovation is high. A high frequency of workers engaged in 'lean production' where work is highly constrained does not promote innovation. Management techniques such as job rotation, team working and quality control may be part of the successful Japanese model for incremental innovation. Our data indicate that in Europe

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[33] See: www.worldvaluessurvey.org

these forms do not necessarily stimulate endogenous innovation. It seems as if they need to be combined with some degree of discretion in order to do so.

Though based on simple correlations that cannot establish a causal relation, these results suggest that European policy efforts to improve innovation performance as part of the revised Lisbon strategy need to take a close look at the effect of organisational practice on innovation. The bottleneck to improving the innovative capabilities of European firms might not be low levels of R&D expenditures, which are strongly determined by industry structures and consequently difficult to change, but the widespread presence of working environments that are unable to provide a fertile environment for innovation. If this is the case, then the next step for European policy is to encourage the adoption of 'pro-innovation' organisational practice, particularly in countries with poor innovative performance. In this respect a better understanding of how the 'unexplained' national factors influence firms' organisational choices could be essential. Some examples of possible factors have been sketched out in Section 6.

The next step in more adequately addressing the relation between organisation and innovation is to obtain complementary firm-level data on both innovation modes and organisational forms. Our results provide a few tentative hypotheses that are consistent with the evidence and which could be explored when better data are available. One option is to develop better indicators of organisational innovation in future CIS surveys, as proposed by the third revision of the Oslo Manual in 2005. The CIS could respond to some of the limitations inherent in relying on the employee-level data of the European Survey on Working Conditions by supplying establishment-level data providing information on the way knowledge flows and knowledge sharing are organised within firms and how they relate to other aspects of corporate strategy.

We hope our results will widen the debate and stimulate further comparative research exploring the links between organisational forms, innovative performance, and the institutional context within Europe.

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Appendix 1

Organisational Variables

Variable		Mean
Team work	1 if your job involves doing all or part of your work in a team, 0 otherwise	64,2
Job rotation	1 if your job involves rotating tasks between yourself and colleagues, 0 otherwise	48,9
Quality norms	1 if your main paid job involves meeting precise quality standards, 0 otherwise	74,4
Discretion in fixing work methods	1 if you are able to choose or change your methods of work, 0 otherwise	61,7
Discretion in setting work pace	1 if you are able to choose or change your pace of work, 0 otherwise	63,6
Horizontal constraints on work pace	1 if on the whole your pace of work is dependent on the work of your colleagues, 0 otherwise	53,1
Hierarchical constraints on work pace	1 if on the whole your pace of work is dependent on the direct control of your boss, 0 otherwise	38,9
Norm-based constraints on work pace	1 if on the whole your pace of work is dependent on the numerical production targets, 0 otherwise	38,7
Automatic constraints on work pace	1 if on the whole your pace of work is dependent on the automatic speed of a machine or movement of a product, 0 otherwise	26,7
Employee responsibility for quality control	1 if the employee's main paid job involves assessing him or herself the quality of his or her own work, 0 otherwise	72,6
Employee problem-solving	1 if your job involves solving unforeseen problems on your own, 0 otherwise	79.3
Learning new things	1 if your job involves learning new things on your own, 0 otherwise	71,4
Task Complexity	1 if your job involves complex tasks, 0 otherwise	56,7
Task monotony	1 if your job involves monotonous tasks, 0 otherwise	42,4
Task repetitiveness	1 if your work involves short repetitive tasks of less than one minute, 0 otherwise	24,9

Appendix 2

Graphical Representation of Factor Analysis - 15 Organisational Variables

Figure 1 : Forms of Work Organisation

Code :
Xxx : presence of the characteristic
_Xxx: absence of the characteristic
Dscrm: autonomy in work methods
Dscrc: Autonomy in work speed
Learn: learning new things
Pbsolv: probelms solving activity
Complx: complex tasks
QC: responsibility for quality control

QN: precise quality norms
Team: team work
Rot: job rotation
Mono: task monotony
Rep: task repetiveness
Flowc: automatic constraints on work pace
Nrmc: quantitative norm constraints on work pace
Hierc: hierarchical constraints on work pace
Horc: horizontal constraints on work pace

The figure above presents graphically the first two axes or factors of the multiple correspondence analysis (MCA). The first factor or axis, accounting for 18% of the inertia or chi-squared statistic, distinguishes between taylorist and ‘post-taylorist’ organisational forms. Thus on one side of the axis we find the variables measuring autonomy, learning, problem-solving and task complexity and to a lesser degree quality management, while on the other side we find the variables measuring monotony and the various factors constraining work pace, notably those linked to the automatic speed of equipment or flow of products, and to the use of quantitative production norms. The second factor or axis, accounting for 15% of the chi-squared statistic, is structured by two groups of variables characteristic of the lean production model: first, the use of teams and job rotation which are associated with the importance of horizontal constraints on work pace; and secondly those variables measuring the use of quality management techniques which are associated with what we have called ‘automatic’ and ‘norm-based’ constraints. The third factor, which accounts for 8 percent of the chi-squared statistic, is also structured by these two groups of variables. However, it brings into relief the distinction between on the one hand those organisational settings characterised by team work, job rotation and horizontal interdependence in work, and on the other hand those organisational settings where the use of quality norms, automatic and quantitative norm-based constraints on work pace are important. The second and third axes of the analysis demonstrate that the simple dichotomy between taylorist and lean organisational methods is not sufficient for capturing the organisational variety that exists across European nations.

The projection of the centre of gravity of the four organisational clusters coming out of the hierarchical classification analysis (see Table 2) onto the graphic representation of the first two factors of the MCA shows that the four clusters correspond to the quite different working conditions. The discretionary learning cluster is located to the east of the graph, the lean cluster to the south, the taylorist cluster to the west and the traditional cluster to the north.

Chapter 3 - Developing internationally comparable indicators for the commercialization of publicly-funded research

Anthony Arundel and Catalina Bordoy

1. Introduction

Over the past decade, innovation policy in many OECD countries has stressed the need to improve the commercialization of research results from 'public science' institutions such as universities and government research institutes. Within Europe, this policy focus is partly due to a perception that Europe has failed to benefit from its substantial investments in public research, in contrast to the American experience, where university research results are believed to lie behind the creation of several globally competitive firms and blockbuster products ranging from pharmaceuticals to computer hardware and software. Another measure of American success in commercializing public science is the substantial licensing income that universities such as Stanford, Columbia, MIT and the University of Florida have earned from patenting their inventions.

The policy discussion in Europe frequently refers to a 'European Paradox' of high public expenditure on research with few visible commercial benefits. A long-standing explanation for the paradox is a failure of public science institutes in Europe to actively commercialize their discoveries (EC, 1995). The causes of this failure have been linked in policy documents to a wide range of factors, including a lack of entrepreneurial spirit among scientists, barriers to the ability of public sector scientists to move to the private sector on a temporary basis to develop their discoveries, and to poor intellectual property rights for university inventions. Alternative explanations of the European Paradox, based on differences in the commercial potential of public research conducted in Europe versus the United States (Dosi et al, 2005), have not attracted much attention in the policy community.

European governments have responded to the European Paradox by introducing policies to promote commercialization, such as university courses on entrepreneurship for future academics, and a range of other programmes to encourage technology transfer by promoting formal contractual relationships between the business sector and public science. These include subsidies for the establishment of technology transfer offices (TTOs) at universities, changes in IPR regulations to encourage universities to patent and license inventions, and requirements for universities to obtain a higher share of their research funding from the private sector (Callan and Cervantes, 2006).

To date, there are very few national or internationally comparable indicators within Europe for evaluating the success of policies to promote the commercialization of public science. Internationally comparable indicators would be particularly useful for determining if a "failure of commercialization" is the cause of the European Paradox, or if other possible factors should receive more attention.

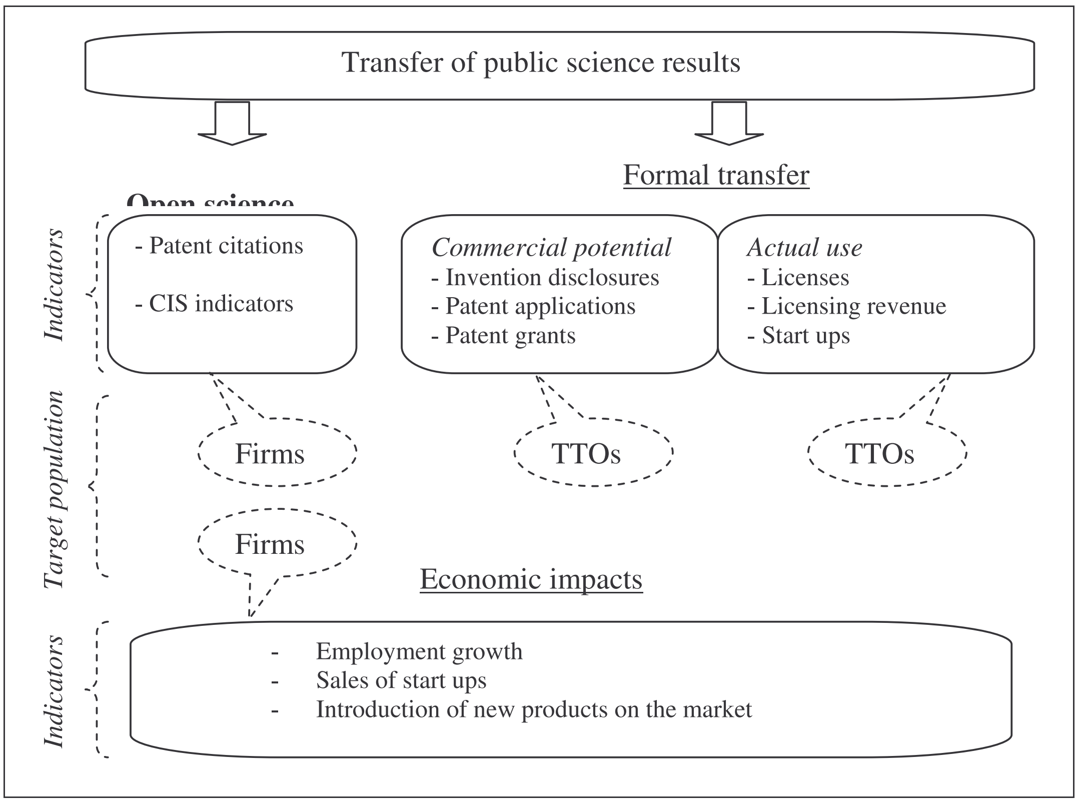
Potential indicators of relevance to the commercialisation of research by public science institutions range from citations to the scientific literature in business patents to the economic impacts of public science in terms of employment or value-added. Economic impact indicators are the most useful of all measures, but they are difficult to obtain and generally suffer from long lag times between public investment and outcomes. Consequently, they are not very useful for assessing the short and medium term effects of policies to encourage commercialisation.

Indicators of value to policy must be capable of measuring the commercial potential of public science results or, preferably, the current use of the outputs of public science by firms. As Figure 1 illustrates, firms acquire these outputs through two main pathways: freely available "open science" accessed by reading journal articles, attending academic conferences, or informal contacts between researchers in academia and business, and through formal relationships such as contract research or licensing. With the exception of citations to scientific articles in patents (Jaffe et al, 1993), the use of open science by firms to develop innovations rarely leaves a visible trace that can be readily identified and measured. Innovation surveys, such as the CIS in Europe, obtain data on the subjective value of public science to firms, but do not separate access to research findings through open science from access through formal relationships.

Formal relationships between firms and public science leave visible traces such as licensing or contract agreements that are more easily measured than open science. These traces are also directly relevant to current policies to encourage academic entrepreneurship and to permit public science institutes to obtain intellectual property rights (IPR) for discoveries with commercial potential. Another advantage is that indicators for the commercial potential of public science discoveries (invention disclosures and patenting), plus indicators for the use of public science outputs by firms (licensing and start-up establishments), can be obtained from a comparatively small number of technology transfer offices (TTOs) that serve public science institutions, rather than needing to survey a large number of firms about their use of the results of public science[34].

In Canada, federal departments and agencies collect indicators to monitor their R&D investments (Therrien, 2006). In the context of programs dealing with knowledge transfer and commercialization, results indicators such as patents, publications, citations, spin-offs, etc. are used. In addition to these more traditional measures, other indicators used include: 'qualitative assesments trying to measure the relevance of knowledge-transfer and the use of research results', for programs aimed at knowledge-transfer between academics and local community; 'advancement of emerging technology and their subsequent use by industry' in the case of collaboration between the public and the private sector; and indicators for the dissemination of research results to the public (including media coverage, web visits, non-scientific publications) and to the policy community (including number of policies and regulations created or modified and changes in research questions and political agendas).

Figure 1



Data on the commercialization of public science have been collected on a consistent basis from the 1990s for two countries, the United States and Canada. The Association of University Technology Managers (AUTM) has collected data on American TTOs since 1991 and on an annual basis since 1996, with the most recent results available for fiscal year 2004 (AUTM, 2005). Statistics Canada first surveyed Canadian universities in 1998 and on an annual basis since 2003, with complete results available for 2004 (Read, 2005; Read, 2006). Similar data are available for Australia for 2000, 2001 and 2002 for universities and other public research institutes (Commonwealth of Australia, 2004). All of these surveys collect data on both the commercial potential of public science and the use by firms of public science outputs.

[34] The distinction between commercial potential and actual use indicators is in line with the one described in

A main challenge for producing comparable indicators is to find a relevant denominator to normalize outputs from public science systems that vary enormously in size. There are two potential options, the number of researchers and the number of research expenditures, but the latter is more widely available.

Relevant data for Europe on the commercialization of public science have not been available until recently. Between 2001 and 2002, the OECD ran a multi-country survey of the technology transfer activities of universities and government research institutes in thirteen OECD countries, including eight in Europe (OECD 2002; OECD 2003), but inter-country comparisons were severely hampered by a lack of good denominators such as R&D expenditures or the number of researchers[35]. The ProTon study for fiscal year 2004 obtained relevant output data from 172 European public science institutes (Conesa et al, 2005), but did not provide results for a denominator[36].

Three recent surveys provide European data that are comparable to the AUTM, Australian and Canadian surveys. Two studies provide results for the UK (UNICO, 2005; HEFCE, 2005)[37] while the third provides results for public science institutes across Europe (Arundel and Bordoy, 2006).

In this paper we use the results of these six surveys to explore the possibilities and problems for developing internationally comparable output indicators for the commercialization of public science. The main purpose of the analysis is to illustrate what could be done, at relatively low cost, to fill an important gap in internationally comparable innovation indicators. This paper builds on preliminary work in several of these surveys to develop comparable indicators based on outputs per unit of R&D expenditures, but we provide a deeper analysis of the problems in using this approach to construct comparable indicators and suggest several solutions. We also identify additional survey questions that could provide valuable complementary information.

2. Data sources and methodology

All surveys collect data on research expenditures and on three outputs indicators for the commercial potential of public science discoveries (invention disclosures, patent applications and patent grants) and on three indicators for the use of public science by firms (licenses executed, start-ups established, and gross license revenue).

Hawkins et al. (2006) between output and outcome indicators.

[35] The OECD study used the number of patents or licenses obtained per TTO, but this is unlikely to produce comparable indicators because of large differences in the number of researchers or research expenditures per public science institute.

[36] The study collected data on the number of academics per institution but did not provide these data in a usable form.

In the spring of 2006, on behalf of the European ASTP, we conducted a survey of ASTP members representing public sector institutions such as universities, academic hospitals, and government or non-profit research institutes (Arundel and Bordoy, 2006). The survey response rate was 59%, with 101 replies from respondents that met the survey eligibility criteria. The respondents were based in 22 European countries.[38] Seventy-four of the eligible respondents handled the technology transfer activities of a university while 27 represented government research institutes or hospitals.

The ASTP membership represents approximately 19% of an estimated 1,000 public science institutes (universities and government research organisations combined) in the European union (Conesa et al, 2005), with survey responses available for approximately 10% of them.[39]

The United States has an estimated 2,500 universities, but many are liberal arts colleges that are unlikely to develop patentable discoveries. Limited to universities that offer science and engineering (S&E), 1,521 offer bachelors degrees in S&E, 826 offer Masters level degrees in S&E, and 345 offer Doctorate level degrees in S&E (NSF, 2006). The fiscal 2004 AUTM survey obtained responses from 33 research institutes, most of which are hospitals, and from 164 universities, or a minimum of 11% of American universities that offer science and engineering degrees (using bachelor level granting institutions).

The 197 AUTM respondents included 96 of the top 100 American research universities. According to the AUTM report, these universities accounted for 87% of federal and industry-financed research expenditures by American universities (the study does not report data for state sponsored research).

The ASTP and AUTM surveys are limited to a self-selected group of association members, whereas the other four surveys were sent to almost all members of their target population of universities, research hospitals or other public research institutes.

The Canadian survey by Statistics Canada was sent to all members of the Association of Universities and Colleges of Canada (AUCC), which covers most universities granting a Bachelors level degree or higher, and to all known research hospitals. The survey response rate was 83% for universities, 63% for the hospitals, and an estimated 69% overall. Results were obtained for 73 universities and 24 hospitals.

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[37] In addition, a 2002 survey in the UK collected similar data for about 50 universities (Chapple et al 2005, Lockett and Wright, 2005)

[38] Ten or more valid responses were received from Denmark, the Netherlands and the United Kingdom, while between five and nine valid responses were obtained from Belgium, Finland, France, Germany, Greece, and Switzerland.

[39] The ASTP survey obtained responses from 11% of all universities in seven countries where precise data on the number of universities are available: Italy, Spain, Switzerland, Norway, Portugal, the United Kingdom and the Netherlands.

The UNICO survey for the UK appears to have been sent to all degree granting universities and major government research institutes. Although 44% of the target population did not respond, the study notes that responses were received from 47 of the top 50 UK universities in terms of research income for 2004. No final breakdown is given of the number of responses from universities versus other types of public institutions. The second UK survey (HEFCE, 2005) was only sent to universities and obtained responses from all of its target population for fiscal year 2002/03.

2.1 Comparability issues

Several differences in the design of the six surveys could reduce comparability. These include differences in the target populations, the questionnaires, and in the treatment of item non-response.

Target populations

International comparability will be maximized if each study receives responses from all universities, all government research institutes, and all hospitals. This would prevent possible biases that could occur by preferentially surveying or obtaining a higher response rate from research-intensive institutions that are likely to perform better on the output indicators than second or third-tier institutions. The UK HEFCE survey for 2002/03 comes closest to this goal by obtaining results for all universities, followed by the Statistics Canada results for universities. In contrast, the ASTP and AUTM survey results are likely to be biased towards institutes with above average performance, although an evaluation of the respondent institutions suggests that the ASTP survey is less biased in this respect than the AUTM survey (Arundel and Bordoy, 2006).

Another difference in the survey populations that will influence comparability is the proportion of non-university institutes in the respondent samples, which accounts for between zero and 69% of the responses. These differences matter because of variations in performance by type of institution and by country. In the ASTP sample, non-university institutes out-perform universities on patent applications, patent grants, licenses executed and license income. Performance differences by the type of institution were also found in the OECD study (OECD, 2003). In contrast, there is very little difference in the performance of universities and other research institutes in the AUTM sample. One option is to limit the results to universities, but the relevance of this approach depends on the role of non-university institutions in national public research efforts. Only providing results for universities would fail to capture the commercialisation of public science in countries, such as Australia, that invest heavily in government research institutes. To avoid these problems, we provide results for all public science institutes combined and for universities only.

Variable definitions

International comparability will be affected by different definitions of both outputs and research expenditures.

A problem with the output measures is differences in how patent grants are counted. The AUTM study is limited to patents granted by the USPTO. This is likely to account for almost all patenting among the respondents, since very few patent applications are likely to be made only outside of the United States. Conversely, some patent applications by European public science institutes are only made outside of the home country (Arundel and Bordoy, 2002; OECD, 2003). For this reason, the ASTP study limits the definition of patent grants to 'technically unique patents" to prevent multiple counting of an invention that is patented in more than one jurisdiction[40]. This should improve comparability with the AUTM results.

The number of patent grants reported in the Australian, Canadian and both UK studies does not exclude multiple counting of granted patents for the same invention. In the Canadian and UNICO studies the same invention can be counted up to three times (in the domestic country, the United States, and all other countries combined), with the data suggesting substantial multiple counting. In the Australian study, patents can be counted in both Australia and the United States. To improve comparability, we limit the counts to the region or country with the largest number of patent grants. This is the United States for Canada, the UK for the UNICO and the HEFCE studies, and Australia for the Australian study. This will result in an underestimate of the true number of patent grants for these countries.

The problem with multiple patent counts does not occur for patent applications in the AUTM, Canadian, ASTP and UNICO studies as all four surveys limit them to priority applications. However, the Australian study includes both applications in Australia and in the United States, and the HEFCE study provides the total number of patent applications and the number of those applied abroad, which does not prevent double counts. The Australian results are limited to Australian applications and the HEFCE results given below subtract the number of foreign applications from the total.

Most of the surveys count all types of license agreements and license income from all types of IPR, for example from patents, material transfer agreements, copyright, etc. Conversely the AUTM survey excludes license income from software and biological

[40] The ASTP survey asked respondents to give the number of 'technically unique patents that were granted to your institution". A technically unique patent grant was defined in the question as "for one invention only. A patent for the same invention in two or more countries is one technically unique patent". 'Logical data and outlier checks, followed up by telephone calls, showed that the definition of a patent grant in the ASTP questionnaire was misunderstood by a few respondents who gave the total number of patents that were granted in all jurisdictions, rather than the number of technically unique patents. This led to substantial over reporting of patent grants, which was corrected using information collected in the follow-up.

material end-user licenses under $1000 and income received from material transfer agreements.

Differences in the definition of research expenditures will have a significant impact on comparability because this statistic is the denominator for all indicators. Table 1 summarizes the different definitions in use and estimates if the definition will over or under estimate research expenditures compared to the AUTM study for the United States. An overestimate of research expenditures compared to the AUTM study will reduce the number of outputs per unit of research expenditures and therefore underestimate relative performance compared to the United States. Relative performance with the AUTM is likely to be underestimated for Europe, the HEFCE study, and for Australia, and overestimated for Canada.

Treatment of missing values

The comparability of standardized performance indicators based on outputs per unit of research expenditures depends on how each study manages missing values, due to a reporting institution not answering a specific output question such as the number of patents granted in the relevant year. This can be a serious issue. In the ASTP survey, the share of missing values for the output questions varied from a low of 18% for the number of start-ups to a high of 45% for the amount of license income earned. We adjust for missing values in the calculation of standardized performance indicators for the ASTP study by excluding respondents that did not answer both the output question and the question on total research expenditures.

Missing values could have been less of a problem in the other five studies, but it is impossible to know since none provide the percentage of missing values for specific questions. The Canadian survey notes that some missing values are imputed, but provides no other details. From the count data given in the Australian study, it appears that there either were no missing values (highly unlikely) or that all missing values were imputed.

Table 1. Definition of research expenditures

	Definition	Compared to AUTM
United States (AUTM)	Federal and industry sponsored research	-
Europe (ASTP)	Total research expenditures	Overestimate

Canada	Sponsored research at universities: conducted under contract with the government, Canadian business, Canadian organizations, foreign governments, foreign businesses, and other foreign organizations. It specifically excludes research funded by several major federal granting sources. No data for hospitals.	Underestimate
UK (UNICO)	Not given, but noted from other sources. Estimated here from reported 'research income' per ₤ license income.	Unknown
UK (HEFCE)	"Total research grants and contracts" including "aggregate research funding from OST research councils; UK charitable income; UK central government; local, health and hospital authorities; UK industry, commerce; public corporations; EU sources, and other overseas income".	Overestimate Also includes block grants that can be used for either teaching or research.
Australia	All research and experimental development expenditures, using the Frascati definition, including capital and labour costs.	Overestimate

We calculate standardized performance indicators for Canada, Australia, the United States and the UK by dividing the total reported outputs by the total reported research expenditure. This will underestimate performance if the research expenditure data are complete but some respondents do not report specific outputs, or overestimate performance if the output data are complete but some expenditure data are missing. Furthermore, missing data for either research expenditures or outputs for a small number of major respondent institutions can distort the results, since the distribution of both outputs and expenditures is highly skewed in all five surveys. As an example, failing to account for missing values in the ASTP survey for Europe, for instance by using the aggregated research results in Table 2 to calculate the indicators, would increase European performance by between 25% and 72%, depending on the output variable. This highlights the importance of adequately accounting for missing data.

3. Results

Table 2 summarizes the main results of each of the six surveys. All financial data are given in US dollar purchasing power parities (PPP$), using OECD data on PPPs for Canada, Australia and each European country for the relevant year.

Table 2. Aggregate data for each survey

	UK-UNICO	**UK-HEFCE**	Canada	*US (AUTM)*	*Europe (ASTP)*	Australia
Fiscal year	2004	2002-03	2004	2004	2004	2002
Total reporting institutes	106	165	97	197	101	124
- of which universities	100 (94%)	165 (100%)	73 (75%)	164 (83%)	74 (73%)	38 (31%)

Survey response rate	56%	100%	69%	65%	59%	75%
Output indicators (total reported)						
Invention disclosures	2,871	2,710	1,432	16,792	3,481	841
Priority patent applications	885	912	1,264	13,792	1,616	515
Patent grants	141	371	397	3,667	320	146
Licenses executed	1,406	758	494	4,758	1,338	516
Start ups	229	197	40*	462	213	67
License income (million US PPP$)	65.2	60.02	41.1	1,434.3	190.8	63.9
Research expenditures (million US PPP$)	4,062	5,605	4,054	41,244	9,699	3,386

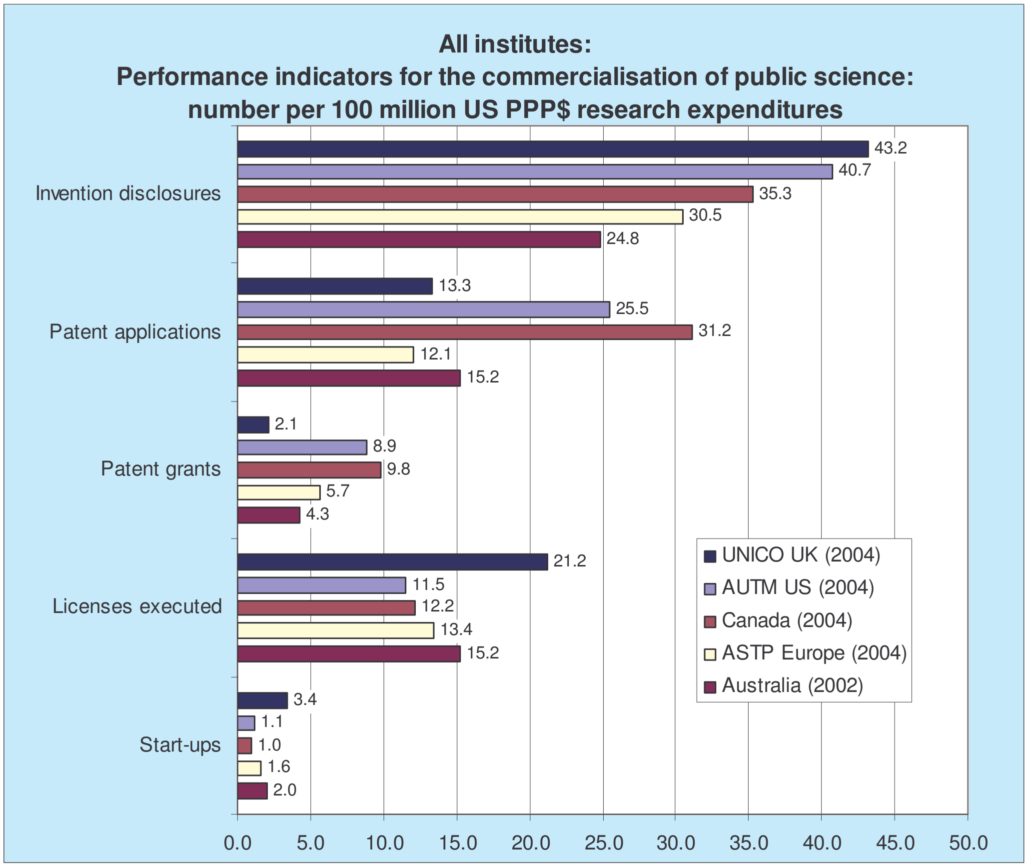
Sources: Arundel and Bordoy, 2006; AUTM, 2005; Read, 2005; UNICO, 2005, Commonwealth of Australia, 2004, HEFCE, 2005.

(*) Results for start ups are from 2003.

Figure 2 gives five standardized performance indicators per 100 million US PPP$ of research expenditures from five surveys that include both universities and other types of public research institutes. The results for Europe are limited to respondents that reported both research expenditures and each output, whereas the other performance indicators can be calculated from the aggregated data in Table 1.

As noted above, the indicators in Figure 1 are unlikely to be fully comparable, due to differences in the target population, the definition of each output and of R&D expenditures, and differences in the treatment of missing values. With this caveat, the United States is the performance leader for only one indicator, patent grants, and Canada leads on patent applications. The UK leads for the other three indicators, but we suspect that this might be due to a lack of adjustment for missing values. If the UK is excluded, Australia leads on licenses executed and start-up establishments.

Figure 2



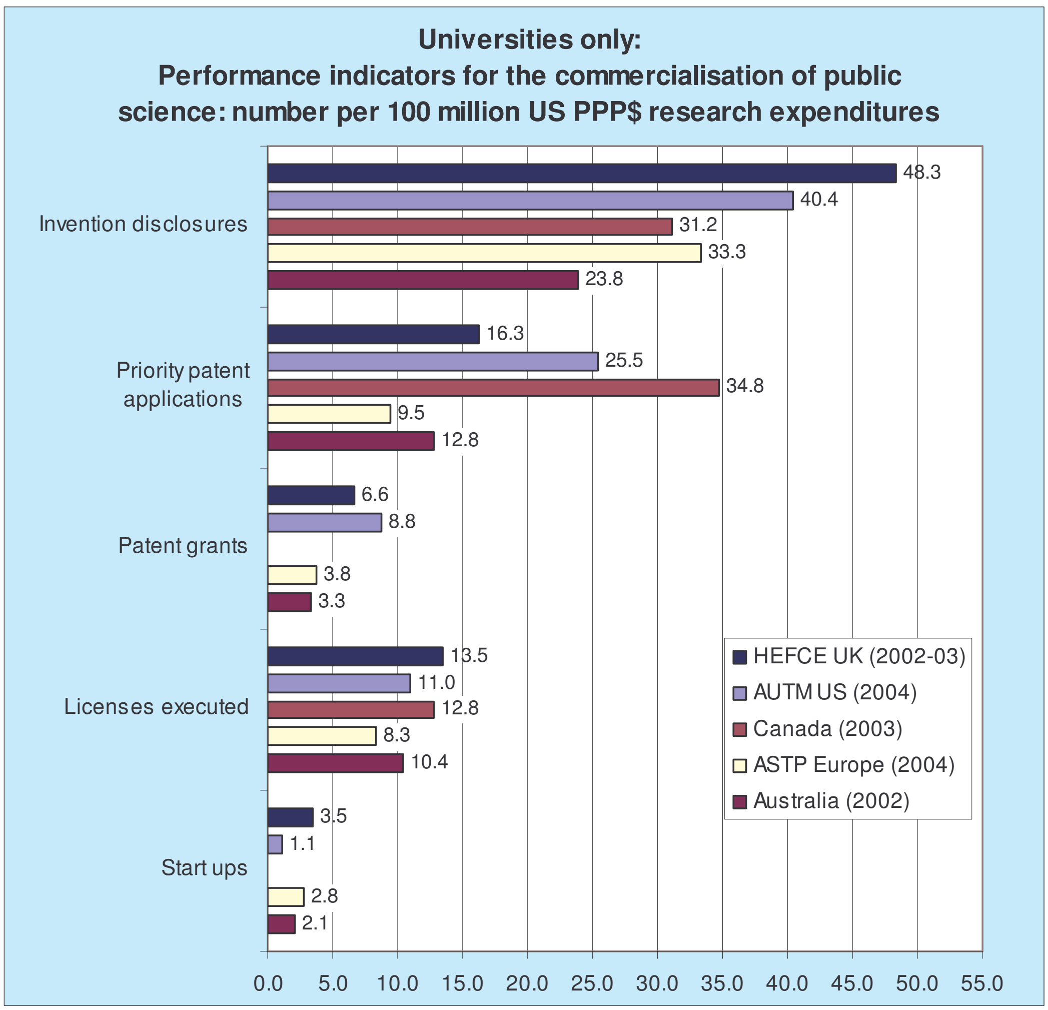
Notes: To prevent multiple counts of patents for the same invention, patent grants for the UK are limited to reported UK patents, for Canada to reported US patents, and for Australia to reported Australian patents.

A sixth performance indicator is gross annual license revenue as a percentage of total annual research expenditures. This indicator should be of particular interest in countries where a policy goal is to increase non-governmental funding of university research, since some license revenue is often returned to the institute to fund research. The share of license revenue as a percentage of reported research expenditures is 1.0% for the UK[41], 1.01% for Canada, 1.9% for Australia, 3.0% for Europe (ASTP), and 3.4% for the United States. In all cases, license revenue is a meager source of funding for research, particularly since part of license revenue often goes to the inventor, while another part is used to cover TTO expenses.

[41] The figure of 1% is obtained from page 29 of the UNICO report. Using the aggregate data in Table 1 for the UK gives a rate of 1.6%, which suggests that the rate given in the UNICO study is adjusted for non-response for reported license revenues.

Figure 3 gives results for universities only[42], which are similar to those in Figure 1 for all institutes combined. The United States leads on patent grants and Canada is the performance leader for patent applications. The UK leads for invention disclosures, licenses executed and start-ups. The UK performs much better for patent grants and to a lesser extent for patent applications when only universities are considered. However, this result could be due to multiple patent counts in the HEFCE study. Of note, European performance on start-ups increases from 1.6 per 100 million US PPP$ for all institutes to 2.8 for only universities. For universities, the share of license revenue as a percentage of reported research expenditures is 1.1% for the UK, 1.7% for Australia, 1.2% for Europe (ASTP), and 2.9% for the United States.

Figure 3



[42] The results for Canada were provided in a special tabulation by Cathy Read from Statistics Canada. Comparable data were only available for invention disclosures, patent applications and licenses executed.

Table 3 shows the relative performance of Europe, the UK, Australia and Canada compared to the AUTM results for the US (AUTM equals 1), for all institutes combined and for universities only. The only indicator for which the relative performance changes from above or below 1 is the number of licenses executed. In this case, both Europe and Australia outperform the US when all institutes are considered but they perform below the US for universities only. All countries except Canada have a higher performance than the US on start-ups. The highest relative performance to the US is also observed for this indicator: 3.1 for the UK and 2.4 for Europe for universities only.

Table 3. Relative performance (AUTM=1) for all institutes and universities only

	ASTP-Europe		UK		Australia		Canada	
	All institutes	Univ. only	All[1] institutes	Univ. only[2]	All institutes	Univ. only	All institutes	Univ. only[4]
Commercial potential indicators								
Invention disclosures	0.7	0.8	1.1	1.2	0.6	0.6	0.9	0.8
Patent applications	0.5	0.4	0.5	0.6	0.6	0.5	1.2	1.4
Patent grants	0.6	0.4	0.2	0.8	0.5	0.4	1.1	-
Use indicators								
Licenses executed	1.2	0.8	1.8	1.2	1.3	0.9	1.1	1.2
Start-ups	1.4	2.4	3.1	3.1	1.8	1.8	0.9	-
License revenue[3]	0.9	0.4	0.3	0.4	0.5	0.6	0.3	-

1: UNICO study
2: HEFCE study
3: Relative performance for license revenue as a share of reported research expenditures
4: Source: Special tabulation provided by Cathy Read from Statistics Canada

4. Discussion

The six performance indicators given above include three indicators for the potential commercialization of public science, invention disclosures, patent applications, and patent grants; and three indicators for the actual use of public science discoveries by the business sector: licenses executed, start-up establishments, and license revenue.

The value to policy of the three commercial potential indicators is not very high because they do not measure the actual uptake of public science results by firms. Their main value to policy is to determine the factors that increase the efficiency with which public institutions (primarily through their affiliated TTOs) transfer knowledge to the business sector. This requires econometric analysis of data at the level of each institution, which requires access to such data. This information is reported in the AUTM study for many of the respondents and has been extensively analyzed. Phan and Siegel (2006) provide a thorough review of this literature and find, not surprisingly, that efficient knowledge transfer depends on the characteristics of the institution, such as its research focus, the incentive structure, and organizational characteristics of the TTO[43]. Of this group, the most valuable indicator is for patent grants, particularly if combined with additional questions on licensing practices, as discussed below.

The three indicators for the use of public science by firms are inherently more valuable for policy because they are closer to measuring the commercialization of public science results[44]. A comparison of national performance on these three indicators is consequently of greater interest than a comparison of performance on patent applications or patent grants. Although subject to many problems of comparability, the Table 3 summary of the results intriguingly shows that the United States is the leader on indicators for commercial potential, particularly patent grants, but that its relative performance is more mixed for the three indicators for the use of public science by firms, particularly for the number of licenses executed and the number of start-up establishments.

The results for the three indicators for the use of public science by firms also suggests that we need to take a much more critical look at European assumptions about the causes of the "policy paradox". Europe performs better than the United States on two of the three knowledge transfer indicators (and a close second on the third for license revenue as a share of research expenditures) for all types of public science institutes combined. The marked weakness for European universities for license revenue compared to American universities is partly due to the fact that European TTOs that serve universities are much younger than their American counterparts and have had less time to develop a licensing portfolio. In the ASTP study, older TTOs affiliated to universities earn more license income than younger TTOs[45]. Furthermore, the AUTM sample is likely to contain a higher percentage of the top performing institutes than the ASTP sample, so we would have expected the AUTM sample to have better performance than the ASTP sample on most indicators.

Some of the differences between the performance indicators for Europe and the United States could be due to differences in incentives or 'environmental' factors. The higher rate of start-up formation in Europe could be due to low royalties for academic inventors. This would provide an incentive for academics to establish a firm to exploit their discovery, as found in a study for the United States (Di Gregorio and Shane, 2003). Whatever the cause,

[43] Based on a comparative case study of several Canadian universities, Mc. Daniel (2006) concludes that a variety of social factors are positively associated with the university's innovation record. Among other, the university receptivity to organizational innovation, the degree to which networking is encouraged and the connection to the community are cited as the most important ones.

[44] None, however, measure successful commercialization. A start-up can fail, a license can lead to nothing of value, and even license revenue can be earned without the firm bringing an invention to market or making a profit from it.

[45] On average, only 13% of the ASTP respondent universities were established before 1990, compared to over half of the American TTOs. The Pearson correlation coefficient for the age of ASTP TTOs in years and PPP$ of license income per PPP$ research expenditures is 0.636 (p=0.000).

the high rate of start-up formation in Europe suggests that European academics might not be less 'entrepreneurial" than their American counterparts.

4.1 Indicator improvement

The development of internationally comparable indicators for the commercialisation of public science will require the use of standard definitions for output variables and for denominators such as research expenditures, similar target populations and survey coverage, and greater transparency in the treatment of missing values. In addition, to solving these problems, the time causality problem also needs to be addressed. Using research expenditures and outputs for the same year implies that the outputs are directly due to the reported research expenditures. This is not likely to be the case, with many outputs due to research expenditures over several years. This can particularly apply to patent grants, which could be due to research conducted several years previously. One possibility is to construct indicators after using different lag times for research expenditures, but this might be unnecessarily complex. An alternative for the future is to average research expenditures over the previous three years. This is currently only possible for the Canadian and AUTM surveys.

The construction of high quality comparable indicators requires a much higher coverage rate than that of the AUTM and ASTP surveys, which is likely to raise serious problems of confidentiality. Many public science institutions with poor performance could be reluctant to respond if they believe that their results will be made publicly available, possibly leading to a reduction in future funding. Yet a failure to include poor performers in surveys will bias the results and reduce their value for policy. The ASTP asked respondents if they agreed to have their results made public, with 75% refusing. This indicates that the issue of confidentiality must be taken seriously in future surveys.

4.2 Other indicators for policy

The six basic indicators given in this paper can be obtained in a one or two page survey questionnaire, based on the questionnaires used in the ASTP and UNICO studies. Since many of the national surveys are much longer, ranging from six pages for the AUTM survey to 13 pages for Canada, there should be room to collect additional data that could be used to construct internationally comparable indicators. We suggest five areas where additional internationally comparable data would be of value to policy[46].

The first area is to collect data on the number of researchers, preferably in units of time devoted to research, to provide an alternative denominator to research expenditures. Units of research time could be more comparable internationally than units of research expenditures, which are affected by how expenditures are defined and by a lack of PPPs

[46] We ignore issues such as whether or not the TTO is financially self-sufficient, such as if the license and IP costs are fully covered by license revenue. This is primarily a domestic issue, where internationally comparable data are of less value.

for research. Furthermore, the ASTP survey found that a higher percentage of respondents could provide the number of researchers (73%) than research expenditures (61%). The higher response rate for the former could be particularly important for surveys that are not compulsory.

The second area is to collect data on *who* licenses public science inventions – firms based within the home country or abroad[47], in order to construct an indicator for the percentage of licenses that are given domestically. This would serve a basic policy interest in encouraging knowledge flows that support domestic economic activity. This question is particularly relevant for exclusive licenses, since the main justification for non-exclusive licenses is to raise funds for the public institute.

Third, the role of non-exclusive licenses is an important policy issue by itself. Although non-exclusive licenses can maximize income for the research organization, they could be less effective in transferring knowledge and technology to the business sector than publications that make the results freely available to all. Conversely, exclusive licenses for some inventions could be absolutely necessary for a firm to invest in developing the invention into a commercial product (Colyvas et al, 2000). The disadvantage is that inefficient use of exclusive licensing could slow down technical developments and possible social benefits. Indicators for the share of exclusive licenses, particularly by technology field, would help policy makers determine if the rate of exclusive licensing is above or below the international norm.

Fourth, there is no point in a public science institution applying for IP rights, particularly a patent, if the invention is never licensed. This will only increase costs to the institute and theoretically, albeit under the unlikely assumption that no firm will infringe the patent, prevent firms from using or further developing the patented technology. For this reason it is worthwhile to collect data on the percentage of patents that have ever been licensed in order to track changes over time and benchmark national performance.

Last, non-patented inventions account for a significant share of licensing activity, even though IP policy frequently stresses patents or the need for other strong forms of IP. The OECD study (OECD, 2003) found that approximately half of all licenses did not involve a patent, while the ASTP study found that 40% of license income in both 2004 and 2005 did not involve a patent. In order to keep the role of patents in perspective, it would be worth collecting data on the share of licenses and license income that does not involve patents.

5. Conclusions

This paper shows that it would be possible to obtain internationally comparable indicators for the commercialisation of public science with relatively simple agreement over definitions, improved survey coverage in Europe and the United States, and a few other 'tweaks' to current surveys. In addition, the policy relevance could be improved by

[47] Ownership is less relevant. The key issue is if the location of the development of the licensed invention.

adding a few additional indicators for who licenses, licensing exclusivity, the share of patents that have ever been licensed, and the share of licenses and license income from patented and non-patented inventions.

It is important not to lose sight of the fact that the visible and easily measurable output of public science institutions, such as patents and licenses, form only part of a large number of activities that can lead to commercialisation and social benefits. As noted earlier, useful knowledge can be transferred from universities to firms through open science methods such as publications, conference presentations, and informal contacts. Two surveys in the early 1990s that were able to differentiate between open science and formal methods of knowledge transfer found that both European and American firms rate open science more highly as a means of obtaining valuable knowledge from public science for their innovative activities than formal methods (Cohen et al. 2002; Arundel and Geuna, 2004).

There is a serious danger that only providing indicators for formal methods of transferring knowledge could encourage the policy community to promote formal methods at the expense of open science. Phan and Siegel (2006) refer to an as yet unpublished study in the United States by Markman, Gianiodis and Phan that found that an increase in professional activities by TTOs leads to a fall in informal or 'bypassing' linkages between academics and firms. They also report that bypassing activities were "associated with more valuable discoveries and heightened entrepreneurial activities". This suggests that the policy community needs to find the optimum balance between promoting formal technology transfer methods based on IPR and licensing and the informal methods of open science. In this respect, it would be worth developing better comparable indicators for the role of open science in the innovative activities of firms. This cannot be done through surveys of TTOs, but would require a survey of firms themselves. Perhaps we might find that the cause of any "European paradox" is not due to the formal transfer of public science discoveries to firms, where European performance appears to be acceptable, but to problems with the system of open science.

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Chapter 4 - Innovation survey indicators: Any progress since 1996?

Or how to address the 'Oslo' paradox: we see innovation surveys everywhere but where is the impact on innovation policy?

Anthony Arundel

1. Introduction

The first Blue Sky conference in Paris in 1996 introduced a wide audience to some of the results of the first Community Innovation Survey (CIS) from 1993, which was arguably one of the most innovative major sources of new innovation data at the time. Building on research dating back to the late 1970s, the goal of the CIS and other innovation surveys was to obtain data on a diverse range of ways of innovating, particularly forms of innovation that did not depend on R&D, and to provide output measures of innovation.

Since the first CIS, innovation surveys based on the Oslo Manual have become institutionalized, particularly in Europe where the CIS is now implemented every two years in all EU-25 member states. The first results of the fourth CIS, referring to innovative activities between 2002 and 2004, are now available for several EU countries and should be available for all member states over the next few months. The fifth CIS will be in the field in early 2007 and planning for the sixth CIS, which will implement the recommendations of the 3rd edition of the Oslo Manual (OECD, 2005), is already underway.

With data available from several consecutive CIS surveys, one would think that the European policy community would be actively using CIS indicators to assess the ability of national innovation systems to respond to the challenges of the knowledge economy. Unfortunately, this hasn't happened to anywhere near the extent that one would have expected in 1996. The results of a series of in-depth interviews by UNU-MERIT with European policy analysts and a review of major European white papers on innovation shows that the European policy community still relies on long-established indicators for R&D and patents. The effect of the CIS is largely diffuse, influencing general perspectives rather than the development of concrete policy actions. There are of course exceptions, such as the use of CIS data on collaboration in the evaluation of relevant policies in the Netherlands.

R&D and patents are excellent indicators of firm investment in developing innovations in-house through creative activities, particularly in manufacturing, but they are insufficient for capturing innovation as a process of diffusion, the development of distributed knowledge bases that are an essential feature of the knowledge economy (Smith, 2002; 2005), the continual increase in the economic importance of the service sectors, and many informal innovative activities. The latter could be particularly important as over two-thirds of scientists and engineers in the private sector are not employed as researchers (Bell, 2006).

The CIS collects data that could be used to fill some of the gaps in our knowledge of innovation, but unfortunately the CIS has not been fully exploited for this purpose. The main cause is a continued focus on a science-push or linear model of innovation. The countless announcements of the death of this model and its presumed replacement with 'systemic' models using Schumpeterian definitions of innovation are decidedly premature. The science-push model based on R&D is probably the dominant model in use today by the policy community, although no one refers to it anymore by its name[48]. This has resulted in a lack of demand on the part of policy makers for a wider range of CIS indicators, and a lack of supply from academics and national statistical offices of them.

An example of the European policy focus on supply-side innovation policies is the Lisbon Agenda, and specifically the Barcelona Council's initiative to solve the European Union's competitiveness problem by its proposal to increase European R&D intensity to 3% of GDP by 2010. This has probably set back the slow progress over the 1990s towards an enlarged view of innovation that includes informal activities. Not only is the 3% goal impossible to attain due to Europe's industrial structure – even by 2015, but insufficient R&D is only part of the problem.

With a few exceptions, academic analysis of the CIS, using econometric models, has had little impact on European innovation policy. The UNU-MERIT interviews found that policy analysts rarely used this body of research because the papers were not focused on their needs. As a check, we evaluated 162 academic papers using CIS data and found that only 21 (13%) made any policy recommendations[49]. Even then, many of the papers only include a few sentences or a single paragraph of relevance to policy. One of the problems, as pointed out by Veugelers and Cassiman (2005), is that CIS results for one country do not provide strong evidence for policy development. Policy relevant results need to be replicated across several countries, which is blocked by restricted access to CIS data from more than one country[50].

This paper makes the case for returning to some of the original goals of the CIS and gives a few examples of new policy-relevant indicators that could be constructed using CIS

[48] Over the last decade (CEC, 1995), and particularly since the Lisbon Agenda of 2000, the European policy community has consistently stressed the central role of innovation to European competitiveness, although a close reading of major policy documents shows that the concept of innovation in use is primarily R&D.

[49] Based on a UNU-MERIT database maintained by Dr. Cati Bordoy on papers, in English, of microeconomic analyses of CIS data. The database was last updated in June 2006.

[50] Another option for improving the policy relevance of the CIS is for data access for academics to be conditional on the provision of an accessible but in-depth discussion of the relevance of the research results to policy.

data[51]. These new indicators include an output measure with improved international comparability, an indicator for knowledge diffusion, and a set of indicators for how firms innovate. The goal is to improve the impact of the CIS by improving the relevance of CIS indicators for policy.

2. The policy context for innovation indicators

In order to be useful, indicators must be relevant to someone – either academics, business managers, or policy analysts. Since the delay in publishing CIS indicators is usually too long for business managers, and since academics prefer access to micro-data, the primary audience for CIS indicators is the policy community.

Over the past two years, UNU-MERIT has interviewed 67 members of the policy community, 55 from 15 European countries and 12 from Canada, Japan, Australia, and New Zealand, on their use of and need for innovation indicators, including CIS indicators. R&D indicators are the most widely used and considered to be the most valuable. In contrast, the respondents only referred to a few examples of the use of the CIS in policy making or evaluation. Several interviewees stated that the use of the CIS was reduced by concerns over data quality, but this was not a widespread view and the quality of the CIS has been improving over time. The main types of new indicators that the interviewees would like to have concern the process of commercialization and collaborative activities involving innovation. The latter had the highest policy interest, cited by interviewees from all but two of the 19 countries.

The policy focus on R&D indicators reflects the dominance of policies to support R&D. There are no accurate measures of the amount of funding for other types of innovation policies, but an extensive database of innovation programs in each of the EU member states is available on the TrendChart website. A thorough search identified 54 programs with a focus on the diffusion of technology or skills, particularly to small and medium sized firms (SMEs)[52]. This is unlikely to cover all non-R&D innovation programs, but it should capture the range of programs on offer. Annual expenditure in Euros was available for 85% of the 54 programs. The programs were divided into two main groups: policies which did not involve R&D and policies where R&D could (although not necessarily) be involved.

The former group of policies included:

[51] Godin (2002) comments that the innovation surveys "ended up measuring innovation the way they measured R&D, i.e. in terms of inputs and activities", rather than fulfilling their original goals of measuring outputs. My view is that the design of the CIS questionnaire does meet the original goals. The problem is in how the data are used.
[52] See http://trendchart.cordis.lu/.

1. Training staff from SMEs, particularly in technology requirements and innovation management.
2. Technology adoption subsidies, particularly for modernization.
3. Subsidies to acquire licenses to new technology.
4. Subsidies to hire skilled S&E staff.
5. Manufacturing extension services – help identify firm needs for new technology.[53]

These five policies are designed to assist firms with very low innovative capabilities. On average, the ten new member states, plus Greece and Portugal, spend eight times more on a per capita basis on these programs than the more developed EU member states, but in both groups of countries these programs account for less than 0.02% of GDP. This is only about 2% of EU public expenditures on R&D. Even allowing for under reporting in the TrendChart database, programs that do not involve R&D probably account for less than 5% of all government support for innovation.

The low public investment in these types of policies suggest that indicators for the diffusion of technology or skill upgrading are unlikely to ever hold much value for the policy community, with the possible exception of the new member states. However, these policies could be relatively more important to SMEs (a target of many policy actions) than their low cost would suggest. An Innobarometer survey in 2004 asked a sample of 4,534 innovative SMEs, covering all 25 EU member states, if any of eight types of innovation support programs were 'crucial to any of your innovation projects, such that the innovation would not have been developed without the support". An analysis of the results found that the most crucially important type of support was for collaboration (31.5%), followed by programs to support research (25.0%) and thirdly the adoption of process technology (14.3%) (Arundel, 2004). The latter is supported by many of the five types of programs given above, while the first and fourth programs can be relevant to collaboration by improving the innovative capabilities of the firm.

Although innovation through the diffusion of technology and related skills is currently of marginal interest to the policy community, increased interest in the role of demand in innovation could lead to greater interest in diffusion indicators. Both the influential Aho Report (CEC, 2006) and the proposed Competitiveness and Innovation Framework Program (CIP) (CEC, 2005) stress markets and demand, including the role of lead users and the slow rate of adoption within Europe of information technology in the service sector. The CIP proposal notes that 'making innovation work means innovation capacity building, the uptake of new technologies and of existing technologies in a new context and carrying them through to the business level". In order to achieve these goals, the CIP

[53] Most EU countries support a system of regionally-based technology transfer or innovation offices to provide support and technical advice, such as the Manufacturing Advisory Service (MAS) in the UK, or OSEO-ANVAR in France. They provide general education programs including demonstration projects,

proposes an entrepreneurship and innovation program to support the transfer of technology, the uptake of technologies and applications, and cooperation between universities and firms. Two other sections of the CIP proposal support ICT adoption and the creation of markets for sustainable production methods and energy efficient technology.

Both the Aho Report and the CIP proposal are part of a gradual shift in Europe from supply-side support for the creation of new ideas to a concerted effort to ensure that these ideas find their way to firms that can apply them to their new products, processes and services. This is reflected in the interviews mentioned above, with policy makers interested in new indicators for commercialization.

3. New CIS indicators

Almost all publicly available CIS indicators, such as those available on Eurostat's NewCronos website or included in the Eurostat publication *Innovation in Europe* (EC, 2005), are simple frequency indicators based on one CIS survey question, such as the percentage of firms that applied for at least one patent or the percentage of SMEs that reported collaborating on innovation. Complex indicators based on the responses to more than one question are rare. The best known example is the percentage of innovative firms, which is constructed from the results to four CIS questions.

Complex indicators can be much more revealing of firm strategies than simple indicators and consequently could be of great value to the policy community. This section gives examples of new complex indicators of relevance to markets, knowledge diffusion, and innovative capabilities. The new indicators are obtained from analyzing the micro-aggregated CIS-3 data that was released by Eurostat in July 2006[54]. A major drawback is that the dataset only contains results for two highly developed countries, Belgium and Iceland, and for 10 less innovative EU member states – one more illustration of the problem of access to CIS data. Nevertheless, the results illustrate what could be done with new ways of using the CIS to construct indicators. These indicators could also be constructed in the future using CIS-4 data, since the relevant information is also obtained by the CIS-4 questionnaire.

The new indicators provided below only use non interval level data with high response rates to the specific question. Interval level questions suffer from higher non-response

visits to successful innovative firms, help with identifying relevant new technology, and courses on innovation management.

[54] All results are weighted to reflect the population of firms in each country.

rates, resulting in a high percentage of missing values when results are combined across indicators, resulting in unrepresentative results[55].

3.1 New to Market products

The published CIS indicators include an indicator for the innovation sales share, defined as the percentage of total product sales, aggregated across all firms, due to products that were 'new to the firm's market'. The indicator is widely used, including in the European Innovation Scoreboard. The best performing European countries on this indicator, using CIS-3 results, are Spain with an innovation sales share of 16.3%, followed by Finland (14.5%) and Portugal (10.8%). In comparison, rates are much lower in Germany (6.2%), France (5.8%), Belgium (5.1%), the Netherlands (3.1%), and the UK (1.7%).

These results are puzzling and act to reduce confidence in the CIS. For example, the common perception is that Portugal should not perform almost three times better on this indicator that the Netherlands and almost five times better than the UK. The explanation is that the question asks about sales from products that are new to the *firm's* market. There can be a large variation in what constitutes a market and in the sophistication of that market. Portuguese and Spanish firms could be outperforming the Netherlands and the UK because they are introducing innovations, already available on other markets, into a less developed domestic market. Furthermore, the firm does not need to have developed the innovation itself, but could simply be passing on an innovation that was developed by another firm based in a different market. Consequently the indicator is misleading – its interpretation in the Netherlands is not equivalent to its interpretation in Spain or Portugal.

The misleading characteristic of this indicator can be partially solved by building a complex indicator that includes data from a CIS question on the firm's market: local, national, or international[56]. A reasonable assumption is that firms that have introduced a new-to-market innovation *and* are active on international markets are subject to greater competition and therefore 'new-to-market' innovations will be more comparable among firms based in different countries.

Table 1 gives results for three new-to-market indicators. Column A gives the publicly-available indicator for the innovative sales share, with firms based in Portugal, Spain, Romania, the Czech Republic and Slovakia performing better than firms based in Belgium. Belgium's relative performance improves using the column B indicator for any

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[55] National statistical offices or Eurostat can solve this problem by imputing missing values using other information on the firm that is available from the CIS, but this technique was either not applied to micro-aggregated dataset or confidentially concerns resulted in a large number of missing values.

[56] The question asks for the firm's main market. An international market can include a neighbouring country. The CIS-4 questionnaire will provide more accurate results because it asks about local, national, other EU, and non-EU international markets.

new-to-market innovation. Indicator C gives the results for the complex indicator that gives the percentage of firms that introduced any new-to-market innovation *and* were active on an international market[57]. Using this indicator, Belgium is the leading country, while Spain shifts from the best performer using indicator A to the worst performer. These results suggest that the apparent success of Spain using indicator A is from product sales on the domestic market that may already be available on other markets. In general, the complex indicator C provides results that should be more comparable across countries.

Table 1. New to market innovation indicators

		A	B	C	
		Innovative product sales share	**Any new to market innovation**	**Any new to market innovation *and* active on an international market**	**Ratio C/B**
Belgium	BE	5.1	18.0	8.2	0.45
Bulgaria	BG	2.1	6.3	1.0	0.17
Czech	CZ	7.2	12.3	7.4	0.61
Estonia	EE	4.5	13.9	4.7	0.34
Greece	GR	2.9	11.3	2.2	0.19
Spain	ES	16.3	11.3	1.2	0.11
Iceland	IS	2.0	11.1	2.9	0.26
Lithuania	LT	4.3	13.1	2.7	0.21
Latvia	LV	2.3	17.8	6.4	0.36
Portugal	PT	10.8	19.8	4.4	0.22
Romania	RO	7.8	13.8	3.5	0.25
Slovakia	SK	6.2	8.0	3.4	0.43

Source: CIS-3 micro-aggregated data referring to innovative activities in 1998-2000.

3.2 Diffusion

Diffusion based innovation is an essential and important aspect of innovation. Knowledge diffusion includes both embodied knowledge, where the purchase of advanced machinery provides access to the knowledge contained in the equipment (which does not need to be understood) and disembodied knowledge[58], obtained from open and freely available sources such as scientific publications or attending a trade fair, and knowledge obtained directly from other people through collaboration. The third edition of the Oslo Manual

[57] Given full interval level data, the indicator can be calculated as the share of total product sales from new-to-market innovations by firms active in international markets.

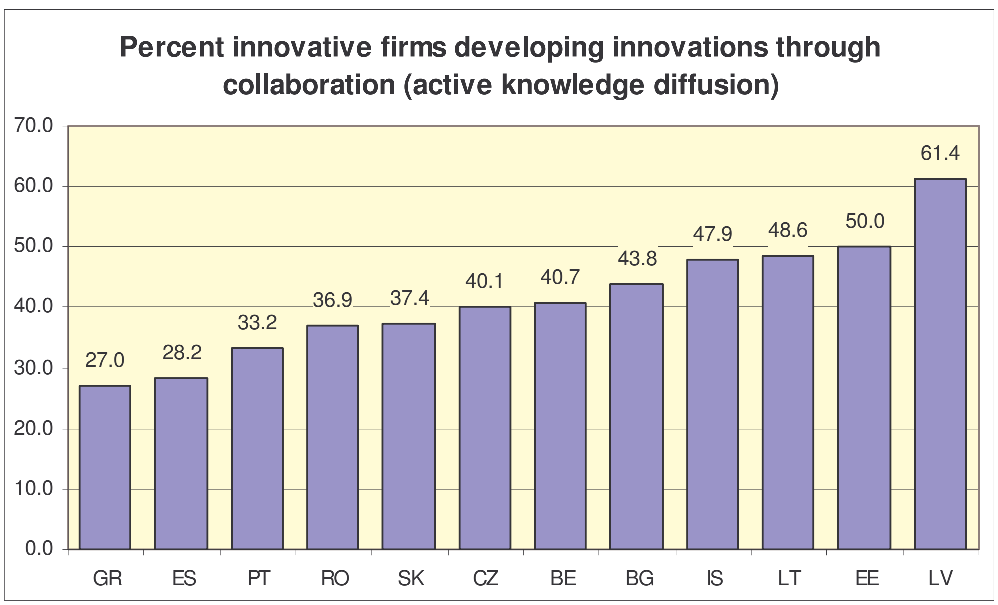
[58] A good indicator for disembodied knowledge transfer could be produced using the CIS question on expenditures on the acquisition of machinery, equipment and software. This has not been available for all EU countries due to a high non response rate to this question, but the response rate in CIS-4 appears to have improved substantially.

(OECD, 2005) stresses the importance of collecting information on each of these three methods of diffusion.

These three types of knowledge diffusion can also be divided into two groups: active knowledge diffusion in which firms primarily obtain their innovations through collaboration with other firms or institutions, and non-interactive knowledge diffusion in which firms only obtain external knowledge through open sources or through purchasing technology. In the former case firms will invariably need to interact with other firms or institutions and sometimes collaborate on their innovation projects. In the latter case almost all innovative activity occurs in-house.

Active knowledge diffusion can be identified using the CIS-3. It is defined here as a positive response to one or more of three questions: the firm's *product* innovations were developed mainly in cooperation with other enterprises or institutions, or the firm's *process* innovations were developed mainly in cooperation with other enterprises or institutions, or the firm had one or more cooperation arrangements on innovation with other firms or institutions. The results are given in Figure 1.

Figure 1.



Source: CIS-3 micro-aggregated data referring to innovative activities in 1998-2000.

Other types of indicators for diffusion can also be constructed. For example, it is possible to combine knowledge diffusion through both technology adoption and through active collaboration by including firms that give a positive response to acquiring advanced machinery and equipment, or which report that their product and process innovations were mainly developed by other firms. Such an indicator can identify the importance of all types of diffusion to firms. For the 12 countries in our data set, 78.7% of firms report innovating through one or more diffusion-based methods, highlighting the crucial importance of diffusion to innovation.

3.3 How firms innovate

The CIS defines a firm as innovative if it has introduced at least one product or process that was new to the firm itself. This means that a firm can be innovative even if it purchases new technology off-the-shelf with minimal effort on its own part, while other respondent firms might have extensive in-house R&D projects to develop innovations. The consequence is that the widely available indicator for the percent of firms that innovate is of minimal value to policy because it provides no information on innovative capabilities. An increase or decrease in this indicator does not necessarily mean that innovation support policies have failed or succeeded – a net increase could be due to a decline in the share of firms with highly developed innovative capabilities combined with an increase in minimally innovative firms.

The solution to this problem is to develop a set of indicators that describe *how* firms innovate, using a methodology that assigns all CIS firms to one and only one category. Previous research has taken this approach (Tether, 2001; Arundel, 2004), but the relevance of the results were either hampered by a lack of policy interest or the use of questions with high non response rates, requiring complex and non-transparent statistical routines to assign all firms to the best fitting innovation category.

The method proposed here and summarized in Figure 2 avoids the non response problem by only using nominal level questions and improves policy relevance by focusing on two innovation characteristics that are important to European policy based on the UNU-MERIT interviews: collaboration and formal innovation based on R&D or patenting. The first axis for the indicator is whether or not the firm is involved in active knowledge diffusion based on collaboration (defined above), while the second is whether or not the firm has formal in-house creative activities, as measured by a positive response to one of two questions: the firm performs R&D or the firm has applied for at least one patent. These are defined as 'inventive' firms that are most likely to produce innovations that contain a major technical advance. The alternative consists of informal innovators that could develop innovations on an ad hoc basis, such as through production engineering. Of note, Figure 2, and the results given in Table 2 and Figure 3, exclude non-innovative firms, which account for a large share of all firms in several of the less innovative countries[59].

[59] The share of non innovators is 50.0% in Belgium, 88.4% in Bulgaria, 68.1% in the Czech Republic, 63.4% in Estonia, 66.9% in Spain, 71.9% in Greece, 46.7% in Iceland, 71.8% in Lithuania, 60.8% in Latvia, 54.0% in Portugal, 82.8% in Romania, and 80.4% in Slovakia.

Figure 2: How innovative firms innovate

Percentages in bold sum to 100% of all innovative firms

Formal in-house creative innovation

Non-collaborators			Collaborators
	A *Inventive non-collaborative innovators* **24.7%**	**B** *Inventive collaborative innovators* **18.1%**	
	D *Informal non-collaborative innovators* **41.4%** *(8.9% are technology adopters)*	**C** *Informal collaborative innovators* **15.8%**	

Informal or no in-house creative innovation

Source: CIS-3 micro-aggregated data referring to innovative activities in 1998-2000.

The goal for policy is to increase innovative capabilities by shifting the national distribution of innovative firms upwards and towards the right in Figure 2 – and to encourage non-innovative firms, particularly in less innovative countries, to enter one of the four innovative categories. Of note, the lower left hand quadrant D accounts for the largest share of innovative firms, at 41.4%. This group includes firms that only innovate through adopting technology developed by other firms or institutions, essentially 'off-the-shelf' innovators, that account for 8.9% of the total.

Table 2 gives some characteristics of the four groups of firms, with separate results given for technology adopters in the lower left quadrant D of Figure 2. Compared to the average, a significantly lower proportion of firms in quadrant D are active on international markets, source external knowledge (although almost all innovative firms source some knowledge for the innovative activities from external sources), and have introduced both a product and a process innovation. These results suggest that the non-collaborative informal innovators have less intensive innovative activities that the other groups, but some of them could have reasonably advanced innovative capabilities.

Table 2. Characteristics of innovative firms

	A Inventive non-collaborators	B Inventive collaborators	C Informal collaborators	D-1 Informal non-Collaborators	D-2 Technology adopters
International market[1]	25.5%	36.9%	22.7%	17.4%	9.5%
Source external knowledge[2]	89.2%	95.8%	88.6%	82.8%	82.5%
Product innovator	85.1%	85.9%	64.1%	66.0%	52.8%
Product & process innovator	43.3%	64.4%	42.1%	31.2%	10.9%

Source: CIS-3 micro-aggregated data referring to innovative activities in 1998-2000.

1: Firm's main market.
2: Gave a rating of 'high' or 'medium' importance to at least one of 7 external knowledge sources for their innovative acitivies: suppliers, customers, competitors, universities, government research institutes, conferences/meetings/journals and fairs/exhibitions.

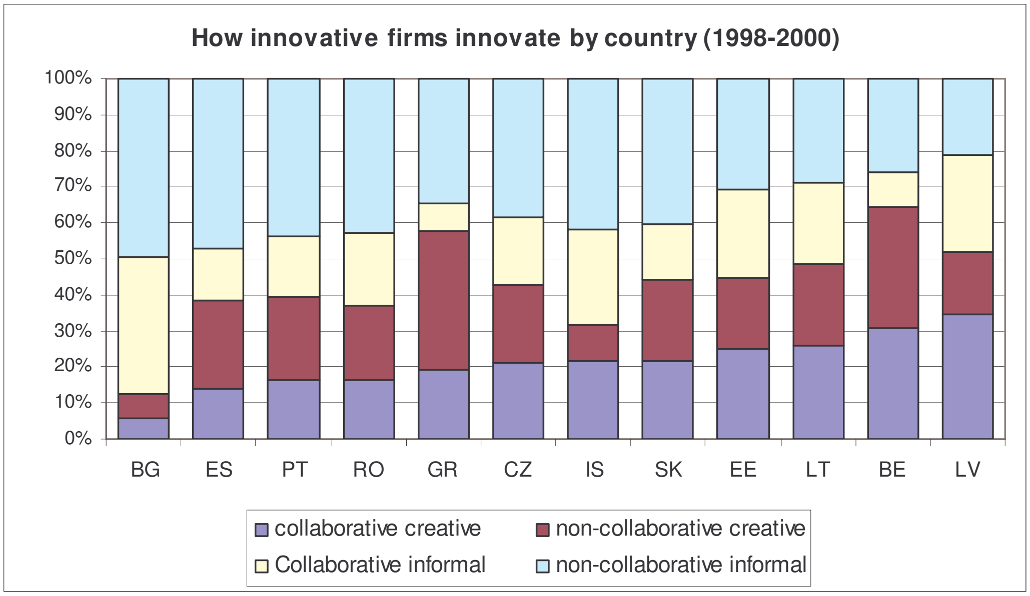
Figure 3 shows that there are large differences in how firms innovate by country. Spain, and Greece have low percentages of innovative firms that collaborate on innovation compared to Belgium, particularly firms that are inventive innovators. Almost all innovative firms in Bulgaria innovate through informal non-R&D based activities, whereas this proportion is much lower in Belgium and in Greece. Information on the distribution of how firms innovate should help policy analysts to better understand national innovative capabilities and to develop appropriate policy actions that can shift firm capabilities to greater collaboration and inventiveness. As shown in Table 2, both of these characteristics are associated with a higher incidence of activity on international markets, product innovation, and combined product and process innovation.

Conclusions

This paper proposes that one of the main barriers to the use of the CIS by the policy community is a lack of indicators and analyses that are relevant to policy needs. In part this is not surprising because one of the main goals of the CIS was to provide data on non R&D based innovative activities, whereas innovation policy is dominated by supply-side R&D support programs. Changes in the policy focus that stress demand, commercialization, and collaboration should increase the value of the CIS, if the CIS data are used to develop appropriate indicators on these issues and if academics discuss the policy relevance of their econometric analysis.

One of the main problems to date is a lack of an interface between the policy community and statistical offices and academics who use the CIS data. One respondent to the UNU-MERIT interviews noted that analysis "must be pull driven – pulled by policy interest and not the other way around. Without these interface mechanisms, the analytical results of the CIS are not visible." Otherwise, according to a second respondent, the results of the CIS were rarely used to inform policy because of the "long, long distance between the analysts and people who write papers based on the CIS and the decision-making level at ministries".

Figure 3



Source: CIS-3 micro-aggregated data referring to innovative activities in 1998-2000.

The three examples of new types of indicators that could be created using the CIS data are in response to the suggestions from the policy analysts interviewed by UNU-MERIT. However, this is an ad-hoc and incomplete method of identifying the types of indicators that would help the policy community. In this respect Statistics Canada is a good example of how to do things right. The division responsible for the Canadian Innovation Survey is frequently in contact with its users from government ministries and can provide customized analyses of data or implement additional surveys, based on funding by the ministry making the request. This process ensures an ongoing interface between Statistics Canada and the users of innovation data, and ensures that Statistics Canada has the in-house expertise to respond to user needs.

Fortunately, several actions are underway to improve available indicators based on the CIS and to solve some of the problems with microeconomic analysis. The OECD, Eurostat, and the group of Nordic countries are currently supporting research on the development of new CIS indicators. The OECD is also organising a series of parallel econometric analyses of innovation survey data in order to overcome problems of data access due to confidentiality restraints. To date, 14 countries are participating. This should provide more robust results on major policy issues such as the link between innovation and productivity. Eurostat is also developing a 'safe access centre' to permit academic access to CIS data from several European countries.

Finally, due to its industrial structure with large fixed investment in low and medium technology sectors, Europe cannot attain its goal of a marked increase in productivity over the short term without a significant increase in the innovative capacity of low and medium technology manufacturing sectors, the service sectors, and the public sector. Innovation in these sectors is strongly influenced by innovation as a diffusion process, whereas R&D based invention is more crucial to high technology manufacturing. The CIS was designed to provide data on many types of innovative activities and consequently should be a key source of useful data for the European policy community. Research to develop indicators, descriptive analysis, and econometric analysis needs to revisit some of the issues that led to the development of the CIS in the first place.

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