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Connected innovation: An international comparative study that identifies mixed modes of innovation

by

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Abstract
This paper offers a new angle on innovation modalities by adopting a recently emerging approach towards identifying innovation typologies via exploratory data analysis techniques with the aim to tease out some underlying latent variables that represent coherent innovation strategies for groups of firms. Mixed modes of innovation include aspects of both user and open innovation, and are employed to inform on such concepts. The modes of innovation are developed by exploring micro-level innovation survey data across 18 countries. The contributions of the paper lie in (a) the identification of five core innovation modes that are found in almost all countries; and (b) examining – via regression analysis – the role of different modes in firm performance.

Keywords: Modes of innovation, innovation surveys, performance, country comparison
JEL classification: 030, 033, 040, 057

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1. Introduction

There is considerable evidence that innovation plays an important role in shaping the growth and competitiveness of firms, industries and regions. Reflecting on the outcomes of innovation, accumulated analytical results suggest that a combination of technological and non-technological innovation activities is especially pertinent to performance. Firms that engage in both product and process type innovation and, at the same time, introduce organisational and marketing changes outperform firms that concentrate on one or the other activity underpinning growth at the macro level (von Tunzelmann 1995).

Some recent developments in the theory and measurement of innovation have emphasised one of two apparently conflicting modalities. The body of thought under the heading of 'open innovation' highlights the importance of external linkages and resource inputs to the innovating firm (Chesbrough 2003). The alternative, under the banner of 'user innovation' singles out internally focused developments, often through the adaptation of bought in equipment to better meet firm specific processes (von Hippel 1988).

This paper offers another angle on innovation modalities by adopting a recently emerging approach towards identifying innovation typologies. We define mixed modes of innovation which explicitly refer to a set or bundle of activities which are undertaken together by a firm to bring about and market a new good or service, or improve on production, delivery and business processes (Arundel and Hollanders 2005, Battisti and Stoneman 2010, Frenz and Lambert 2009, Hollenstein 2003, Jensen, Johnson, Lorenz and Lundvall 2007, Leiponen and Dreijer 2007, Shrolec and Verspagen 2009). Mixed modes of innovation include aspects of both user and open innovation, although it is the latter that serves as the jumping off point for the analysis as the innovation surveys in question address the issue of external linkages more fully than they do those implicit in user innovation models.

Mixed modes of innovation are developed by exploring – via factor analyses – micro-level innovation surveys. Modes of innovation and their impact on performance are compared across 18 countries. The modes are used to inform on the nature of the underlying innovation systems and the relevance of national contexts.

The contributions of the paper lie in (a) the identification of five core innovation modes that are found in almost all countries; (b) examining – via regression analysis – the role of different modes in firm performance.

The study was made possible through the OECD's microdata project which allows for a systematic and centralized approach to analysing micro-level data held in individual statistical offices of member countries (OECD 2009). The paper is organised in the following way. Section 2 develops the theoretical framework, Section 3 discusses data and methodology, Section 4 presents the results and Section 5 discusses the key findings and their relevance for theory and policy.

2. Theoretical background and framework for analysis

The paper identifies mixed modes of innovation and compares their effects on performance across countries, and within sectors across countries. In this section we first discuss the literature on mixed modes of innovation. Secondly, we discuss the open

innovation theory. The section concludes with the framework for analysis drawing out the key research questions addressed in this paper.

2.1 Mixed modes of innovation

What is meant by innovation is not universally understood; and researchers – often implicitly so – work with different and perhaps competing typologies of innovation. Some common meaning exists with respect to product and process innovations, with various caveats including the degree of novelty and creativity, but the set of activities which falls under the umbrella term 'innovations' is wider and includes new forms of design, organisational and management concepts, collaborative arrangements, searching for ideas, and marketing activities.

Existing (one-dimensional) typologies are being challenged by approaches to developing innovation typologies which explicitly focus on the multidimensional facets or aspects of innovation strategies/routines. This approach is, therefore, related to the evolutionary perspective proposed by Nelson and Winter (1982) that emphasises 'routines' as the relevant unit of analysis (albeit with an emphasis on innovation routines). In this paper we refer to the typologies as mixed modes of innovation; similar terms used throughout the literature are innovation strategies, practices or routines. A firm may use more than one mode.

Table 1 provides a systematic overview of different studies using innovation survey data to identify innovation modes. The table gives information on the name and number of different modes, broad methodology, measures feeding into the modes and datasets from which the modes are generated.

Table 1 Overview of different studies identifying innovation modes

Innovation modes	**Methodology**	**Measures feeding into modes**	**Data**	**Study**
Mode 1: 'Science-based high-tech firms ' Mode 2: 'IT-oriented network-integrated developers' Mode 3: 'Market-oriented incremental innovators' Mode 4: 'Cost-oriented process innovators' Mode 5: 'Low-profile innovators'	Exploratory	Inputs and outputs Linkages	Swiss Innovation Survey 1999 Private services sectors	Hollenstein 2003
Mode 1: 'Strategic innovators' Mode 2: 'Intermittent innovators' Mode 3: 'Technology modifiers' Mode 4: Technology adopters'	Prescriptive	Technological inputs and outputs	Eurstat NewCronos (largely Eurostat CIS3 data)	Arundel and Hollanders 2005
Mode 1: 'Science, Technology and Innovation' Mode 2: 'Doing, Using, Interacting'	Prescriptive	Inputs Organisational indicators	2001 Danish DISKO Survey	Jensen, Johnson, Lorenz, Lundvall 2007

Mode 1: ‘ Science-based’ Mode 2: ‘Supplier-dominated’ Mode 3: ‘Production intensive’ Mode 4: ‘Market driven’	Exploratory	Mainly inputs Linkages	CIS2 for Denmark and Finland	Leiponen and Drejer 2007
Mode 1: ‘Research’ Mode 2: ‘User’ Mode 3: ‘External’ Mode 4: ‘Production’	Exploratory	All available excpt. product and process innovation	Eurostat CIS3	Shrolec and Verspagen 2008
Mode 1: ‘New-to-market innovating’ Mode 2: ‘Marketing-based imitating’ Mode 3: ‘Process modernizing’ Mode 4: ‘Wider innovating’	Exploratory	Inputs and outputs	Innovation surveys of 9 OECD countries	Frenz and Lambert 2009
Mode 1: ‘Organizational innovations’ Mode 2:’ Technological innovations’	Exploratory	Mainly outputs	UK CIS4	Battisti and Stoneman 2010

The number of modes, and their interpretation, as indicated by the summary names given to the modes, vary due to differences across studies with respect to the following three areas: (a) methodology; (b) measures feeding into the modes; (c) datasets analysed. In the following (a) to (c) are discussed in light of the design of the current study.

We first turn our discussion to (a) explorative or prescriptive approaches to generating typologies of innovation modes. Arundel and Hollanders (2005), Arundel, et al. (2007) and Jensen et al. (2007) define *a priori* modes of innovation informed by theory and qualitative empirical evidence. While Jensen et al. place specific emphasis on organisational designs and practices, Arundel and Hollanders confine their study – due to limitations in internationally comparable data – to technological activities resulting in a narrow definition of modes. The more frequently used approach, and indeed the approach adopted in this study, is not to rely on a preconceived idea of what activities are done together by firms and thus form a coherent subset, but to let the data speak. Explorative techniques are used to identify which activities form a specific innovation routine. Typically data reduction techniques (factor and cluster analyses) are applied to the survey data. Because of the lack of a common understanding of what activities form a mode, this paper also relies on an explorative methodology where the data informs on the concepts.

This leads onto the relevance of point (b) above – individual measures feeding into the explorative analysis influence the modes reported. Even where an explorative approach is used, reported innovation modes differ, because different variables feed into the analysis. With respect to this, Shrolec and Verspagen’s (2008) work stands out, because they explicitly do not select measures feeding into the analysis but use the breadth of variables in the harmonized Community Innovation Survey 3 (CIS3) questionnaire. Battisti and Stoneman (2010), on the other hand, almost exclusively rely on output measures – product, process managerial and organisational innovations. The first point that arises is, therefore, if inputs to and outputs of the innovation process should be included. There are two further differences across the studies: the extent to which non-technological activities are covered by the modes; and the extent to which

linkages, innovation as an interactive process, are covered by the modes. We discuss each in turn.

Focusing on inputs or output measures reflects a specific, sequential view of the innovation process and assumes a degree of demarcation between activities that feed into innovation and introducing a new or improved production process or product. But, there is considerable overlap and blurred boundaries around inputs and outputs in the innovation processes that lead them to be jointly determined, and the majority of studies consider both so called inputs and outputs together. In this paper, both feed into the development of mixed modes, with the view that activities happen in parallel reinforcing each other via feedback loops as for example described in the chain-linked model of the innovation process (Kline and Rosenberg 1986).

With respect to the loose distinction the literature makes between technological and non-technological activities, mixed modes of innovation as considered in this paper are based around the relevance of activities linked to technological knowledge, but also non-technological activities. Non-technological activities are reflected in all studies introduced in Table 1, with the exception of Arundel and Hollanders (2005), where the sole focus on technological activities is due to data constraints. Indeed, the increased emphasis on non-technological activities was a major driver for the emergence of modes of innovation (e.g. Frenz and Lambert 2009). The relevance of internal resources (e.g. Penrose 1959) to innovation and growth are picked up in most studies, and are connected with the effectiveness of adoption of external ideas (Cohen and Levinthal 1989, 1990). Internal activities can lean towards technological activities, but also comprise non-technological activities that bear relevance for the innovation process, including organisational and managerial practices, resources devoted to new designs and marketing concepts. While technological activities lean towards invention, non-technological activities lean towards the successful commercialisation of an innovation.

Linkages – and with linkages measures leaning towards open or user innovation – form part of the modes developed in Hollenstein (2003), Leiponen and Dreijer (2007), Jensen et al (2007) and Verspagen and Shrolec (2008). Measures capturing the relationship in the wider innovation system feed into the modes developed in this paper. Innovation processes are interactive, inside the firm as discussed above, but, and increasingly so, involve the use of outside sources and network configurations (e.g. Freeman 1987, Rothwell 1992, Kline and Rosenberg 1986, Chesbrough 2003). In the context of open innovation linkages the focus is on bought-in technology and knowledge (Chesbrough 2003).

Innovation networks emphasis the relevance of collaborations to innovation (Rothwell 1992). These can be formalised – e.g. via strategic alliances, or be informal. Both are captured in the innovation surveys by asking firms to indicate the relevance of different sources of information for innovation. These sources are firms (competitors, suppliers or customers), and research organisations and universities (for an analysis of the relevant variables see Laursen and Salter 2006). More formalised arrangements are captured by asking respondents whether or not they cooperated.

Finally – and with reference to point (c) above – the selection of measures is also influenced by the different datasets, most, but not all, comprise both manufacturing and private services. The questionnaires of the innovation surveys are influenced by the successive revisions of the Oslo Manual, which provides international guidelines on data collection. The Oslo Manual takes an eclectic and comprehensive approach to theories explaining the innovation process. The older the surveys are the more likely

they are to lean towards technological activities. On the whole, activities related to design activities and organisational innovations are perhaps least well captured in the datasets used in the studies summarised in Table 1. The latter are captured with reference to the propensity of firms engaging in a specific activity (yes/no questions), while activities leaning towards formal research and development are measured with respect to both, the propensity of firms to engage in an activity and the intensity with which firms engage in an activity. In this paper we are exploring the propensity of firms to engage in an activity. For technical reasons, and as explained in Section 3, intensity measures do not feed into the mixed modes of innovation at this stage.

Based on the above discussion, Table 2 summarises the framework developed in this section to identify mixed modes of innovation. This framework guides the data analysis. The framework determines the dimensions of activities feeding into the mixed modes and the broad methodology. In Section 3 we discuss the individual, specific measures and specific statistical techniques. The results in this paper refer to the largest available number of participating countries.

Table 2 Framework for deriving modes of innovation

Innovation modes	**Methodology**	**Measures feeding into modes**	**Data**
Mode 1: 'IP/technology innovating' Mode 2: 'Marketing based innovating' Mode 3: 'Process modernizing' Mode 4: 'Wider innovating' Mode 5: 'Networked innovating'	Explorative factor analysis used to generate core modes. Comparison across countries, and within sectors across countries.	Inputs and outputs Linkages	Micro level data across 17 countries

The methodology adopted in this paper towards identifying different modes of innovation is explorative – factor analysis – to summarise bundles of activities and determine the relevant number of modes. The measures feeding into the analysis relate to so-called inputs and outputs in the innovation process in order to acknowledge that these are typically jointly reinforcing activities and not mutually exclusive steps in a linear process. Both, technological and non-technological activities go hand in hand in the development of new goods and services, and this is reflected by using the breadth of measures in the innovation survey related to organisational, marketing and design activities next to the more traditional indicators including in-house R&D. Specific emphasis is placed on the interactive nature of the innovation process by taking into account (a) different sources of information, (b) collaborative activities for innovation and (c) acquisition of external knowledge. A harmonized approach is then applied to innovation micro data of 17 OECD countries.

2.2 Brief review of open innovation theory

The theory of open innovation as developed by Henry Chesbrough (2003) and his followers is presented as a new set of ideas about how business enterprises go about optimising their innovation practices. The set of ideas is claimed to be a new paradigm

no less, not only for the economics of innovation but for business firms. The paradigm is not only analytical but also prescriptive.

> "Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. [This paradigm] assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology." (Chesborough, Vanhaverbeke and West 2006)

The main source of evidence for the theory lies in case studies of the practices of large individual firms, who can be seen in the role of the originators and leaders of the open innovation relationship. Chesbrough also brings out the possibility of out-bound openness, to expand the opportunities for exploitation of internally generated technology.

An observed open innovation strategy then needs to be the results of at least two strategies, involving the mutually beneficial meeting of in-bound and out-bound open innovators. It is not a simple matter of unilaterally gathering technologies. This need for a pattern of reciprocal exchanges that underlies the open innovation paradigm points to the national innovation systems perspective as potentially insightful in developing an understanding of how being 'open' can be operationalised. And national innovations systems models also bring to the foreground the role of framework conditions, public institutions and codified information flows as parts of the external environment for innovating firms. In this more comprehensive model, open innovation fits as one possibility amongst sets of complementary investments and assets.

In a paper appraising the open innovation movement, Dahlander and Gann cast doubt on the claims for novelty, particularly as a business practice, and thus on the status as paradigm shift:

> "The idea of systematically using external sources of innovation is not particularly new and there has been a strong research tradition on related topics since decades. […] We contend that the dichotomy between open vs. closed is artificial and argue that exploring different degrees and types of openness provides a more interesting and rich avenue to explore." (Dahlander and Gann 2006)

Dahlander and Gann go on to show that the idea of openness as a matter of degree, rather than kind, that manifests itself in a variety of ways, and argue that research using large-scale datasets is needed in order to explore the generalisability of the concepts and their extent and impact in the practice of business innovation.

One such study, which has been highly influential in the development of the research programme around openness in innovation, is the study by Laursen and Salter (2006). They explore different strategies for searching for external knowledge. Their work points to the importance of two facets of openness: these are breadth and depth of firms' search activities. Laursen and Salter's study uses data from the UK innovation survey (Community Innovation Survey in the UK), but is based only on manufacturing firms and remains within the framework of technology driven innovation by using information on R&D performance as the primary innovation input. In the model,

breadth is a count of the number of external sources of information reported while depth is the same sources but with high importance attributed by respondents. The main conclusions of the paper are that a degree of openness, of engagement in search for good fit external knowledge, can promote innovation performance for firms; but also that this is not an open ended source of competitive advantage. They state that:

> "innovation search is, however, not costless. It can be time consuming, expensive, and laborious. Although we use a different approach, we confirm […] that 'over-search' may indeed hinder innovation performance. […] The possibility of over-search helps to create a more nuanced view of the role of openness, search, and interaction." Laursen and Salter (2006)

In a recent paper, Acha (2008) further generalises the concept of openness in innovation, again using the UK version of the CIS. Her analysis finds several variants, beyond the breadth and depth indicators proposed by Laursen and Salter. She takes more account of non-technological knowledge and also uses the full range of industries – both manufacturing and services – represented in the survey. Acha notes that other research around the issue has treated open innovation as a general tendency with a large range of forms of expression. The alternative she explores is that open innovation is more used as an umbrella term for different sets of behaviours, which have meaning in different contexts. Internal and external resources and their interface have to be managed to achieve benefits to the leading firm. The paper identifies strategic design capability as the requisite for this management role. She finds that forms of engagement with external sources of technological and other sources of innovation friendly knowledge are not uniform across economic agents, but show differential patterns by firm and by industry:

> "… openness is not strictly a choice for the firm but an outcome of capabilities, industrial organisation and wider innovation systems". (Acha 2008)

This research contributes further to the argument that open innovation practice is conditioned and perhaps bounded by factors outside of the firm. This follows the insights of Christensen, Olesen and Kjær (2005) that managing open innovation initiatives will be dependent on the firm's orientation towards and pattern of interaction with the innovation system around them and the technologies involved.

In conclusion, despite the growth in the open innovation literature, there remain legitimate concerns about what exactly it means to be 'open' in innovation (Helfat and Quinn 2006, Dahlander and Gann, 2007). Acha notes that in some research based on extensive datasets, collaboration in innovation projects has been taken to be a principal indicator of openness. But she reports low levels of correlation between the openness metrics, which include, as well as collaboration: (a) measures that can be characterised as technology markets – extra-mural R&D and the acquisition of external knowledge through licensing; and (b) authorship of innovations, where external organisations are the sole or partial source of the firm's main innovation.

Open patterns of innovation are context specific and will vary by sector, reflecting differences in market conditions, opportunity (technological and organisational) and organisational structures for innovation. Different opportunities and

constraints arise from the internal capabilities of firms and the resource costs of engaging in effective relationships with external actors and knowledge.

2.3 Research questions

Linked to the discussion above, this paper is concerned with: (a) the identification of core innovation modes that are found across the 18 countries. Particular emphasis is placed on connotations associated with open or connected innovation modalities; and (b) examining – via regression analysis – the role of different modes in firm performance as this informs on how modes substantiated in the functioning of the wider innovation systems. The first research question related to (a) above is:

RQ1. What core modes of innovation can be observed?

With respect to (b) above, we do not *a priori* expect to find common modes and impacts of modes across countries; instead we expect that differences as well as commonalities in country results will further our knowledge as to how respective innovation systems function, their similarities and how they differ. On the one hand, innovation practices are likely to depend on differences in national innovation systems and country specific socio-economic environments (e.g. Freeman 1995, von Tunzelmann 1995). On the other hand growing international dependency among economies and in particular the activities of transnational corporations, and their role in the generation and diffusion of innovations across national borders, may tend to increased convergence in innovation practices (e.g. Cantwell 1989, Castellani and Zanfei 2006). The relevant research questions are the following:

RQ2. Do mixed modes of innovation differ across countries?
RQ3. Is there a difference in the relationships between mixed modes and firm performance across countries?

Convergence within the individual modes and their effects across countries would suggest that national boundaries are less relevant as a lens for analysing innovation and for developing a country specific policy mix to promote innovation. While heterogeneity in the modes, and with respect to their economic effects, would indicate that national boundaries are an important angle of analysis and attach greater importance to a tailored set of instruments to foster innovation in national firms.

3. Methodology and data

3.1 Methodology

Our point of departure is to use observable patterns in the innovation surveys to arrive at a new conceptual understanding of modes of innovation guided by research questions identified in Section 2. Factor analyses are applied to micro-level data in individual countries to derive modes or practices of innovation. We use explorative (as opposed to confirmatory) factor analyses. The technique reduces a set of variables to underlying concepts (factors) which summarise combinations of activities. In other words, we discover which measures form coherent subsets. The measures of a subset/factor are correlated with one another and the strength of their correlation is summarised in factor

loadings. Measures that score high in one factor are largely independent of other factors, but with some exceptions, where loadings on a variable are similar across more than one factor.

A common, centrally written, Stata do-file is run by participating countries on their respective and latest available micro datasets. All measures feeding into the factor analyses are measured on a binary scale. Although, the innovation surveys contain continuous data for some of the measures, such as the amount spent on R&D, we do not use this information for technical reasons. Binary data factor analysis involves the computation of a tetrachoric correlation matrix, and factor analysing this matrix, under the assumption that the observed binary variables correspond to latent continuous variables (e.g. Battisti and Stoneman 2010). Five factor solutions are reported for all countries, in order to maximise comparability of results. For a large majority of countries this corresponds with the number of factors that have Eigenvalues greater than one.

Modes of innovation are computed at the level of the individual countries. From the rotated factor matrix of the 18 individual countries we compute a 'generic' factor matrix that contains average factor loadings for each of the modes. Averages are weighted by GDP of countries. [2] The generic modes are used to benchmark visually (by the use of radar diagrams) country specific patterns. Additionally, correlation analyses are used to examine the degree of heterogeneity in modes across countries.

The factor scores are themselves used as variables in models to estimate the relationship between modes of innovation and performance. Performance is measured as log of labour productivity (turnover per employees in 2006) and growth in turnover (between 2004 and 2006). We assume a linear relationship between modes and performance indicators. The regressions control for 2-digit industry, NUTS1 regions, enterprise size, operating in international markets and being part of a wider group. In a final step the results section compares the relative specialization of industries, relative to specific modes, across countries, by a comparison of mean factor scores within an industry across countries.

3.2 Data

The measures used in the analyses are informed by the (harmonized) CIS 2006 questionnaire on which information is collected across all (or most) countries included in this study. Measures feeding into the factor analysis, and, thus, forming the modes of innovation, reflect both inputs and outputs into the innovation process. They include technological and non-technological activities, including marketing and design activities. Specific emphasis is on the interactive element of the innovation process, including the role of external sources, information from other businesses or research organisations, and collaborative innovation projects on innovation. Table 3 provides an overview of the measures feeding into the factor analysis in the 18 countries.

[2] GDP measured in current US$ figures for the year 2006 published by the World Bank as part of the World Development Indictors are used. We also computed weighted averages using the number of enterprises that responded to the individual surveys. In this case, countries in which the surveys are compulsory, such as Spain, unduly impact on generic modes. Nonetheless, results are highly similar and available upon request.

Table 3 Measures feeding into the factor analysis

Name of measure		*Description of measure*
1	NEWFRM	Enterprise introduced a good or service only new to the firm
2	NEWMKT	Enterprise introduced a good or service that was new to the firms' market
3	INPCS	Enterprise introduced a new process
4	ORGSYS	Enterprise introduced new knowledge management system
5	ORGSTR	Enterprise introduced new workplace organisation
6	ORGREL	Enterprise introduced new relations with other firms
7	MKTDES	Enterprise introduced a significant change to design or packaging
8	MKTMET	Enterprise introduced new sales or distribution methods
9	RRDIN	Enterprise carried out in-house R&D
10	PROPAT	Enterprise applied for a patent
11	RMAC	Enterprise bought new machinery
12	PRODSG	Enterprise applied for a design right
13	PROCP	Enterprise claimed copy right
14	RTR	Enterprise had expenditures related to training for innovation processes
15	RMAR	Enterprise spent on market launch of new goods or services
16	EXTINN	New goods, services or processes were mainly developed externally
17	SOURCING	Enterprise bought-in R&D or other knowledge, e.g. licensing-in
18	INFOMKT	Medium-high or high importance of information from other businesses
19	INFOKB	Medium-high or high importance of research organisations
20	CO	Enterprise cooperated on innovation with external partner

The left column of Table 3 gives the short name for each measure and the right column a description of the measure. The following restriction with respect to sample selection was made. Observations feeding into the analysis are those from innovation active enterprises – using a Eurostat definition. In total there are 44,497 enterprises in the combined datasets that feed into this study. This is done for two reasons. First, because we are interested in exploring the range of practices among innovative firms, and second, because not all information included in Table 3 is available for non-innovation active enterprises. An enterprise is considered to be innovation active if it had a product innovation or a process innovation or any innovation activities to develop product or processes that were abandoned or still ongoing during the reference period of the surveys. In terms of the industries included, observations cover all sectors which are in the individual datasets. In the majority of cases this means, manufacturing plus most private services. The reference period for the innovation surveys is 2004 to 2006.

4. Results

Sub-section 4.1 introduces the core mixed modes. Country specific patterns are analysed in Sub-section 4.2. Sub-section 4.3 explores the effects of different modes across countries, while Sub-section 4.4 examines industry specific patterns.

4.1. Five core modes of innovation

The first section, addressing RQ1, describes the core innovation modes that are computed using weighted averages of factor loadings across the 17 countries. These core modes, to varying degrees and with different connotations, are exhibited within countries. Table 4 provides the factor loadings of the core mixed modes of innovation.

Table 4 Generic modes based on weighted factor loadings across 18 countries

Measures feeding into the factor analysis	IP / technology innovating	Marketing based innovating	Process modernizing	Wider innovating	Networked innovating
1 NEWFRM	0.09	0.73	-0.03	0.04	0.07
2 NEWMKT	0.35	0.60	-0.05	0.06	0.17
3 INPCS	0.02	-0.18	0.68	0.23	0.04
4 ORGSYS	0.05	0.03	0.11	0.64	0.21
5 ORGSTR	0.06	0.03	0.11	0.69	0.18
6 ORGREL	0.09	0.04	0.10	0.48	0.15
7 MKTDES	0.14	0.28	0.04	0.54	-0.01
8 MKTMET	0.11	0.23	0.01	0.44	-0.09
9 RRDIN	0.46	0.26	0.03	0.05	0.45
10 PROPAT	0.80	0.10	0.01	0.01	0.18
11 RMAC	0.05	0.07	0.67	0.06	0.08
12 PRODSG	0.77	0.11	0.06	0.09	0.02
13 PROCP	0.66	-0.02	0.02	0.12	0.04
14 RTR	0.14	0.24	0.41	0.24	0.17
15 RMAR	0.35	0.43	0.14	0.23	0.20
16 EXTINN	-0.28	-0.06	0.40	-0.12	-0.36
17 SOURCING	0.29	0.19	0.26	0.13	0.44
18 INFOMKT	0.09	0.31	0.32	0.17	0.15
19 INFOKB	0.17	-0.01	0.10	0.14	0.54
20 CO	0.25	0.16	0.18	0.11	0.53

* Factor loadings are average loadings across 18 countries based on a weighted mean. The weighting variable is countries' GDP in current US$ 2006 taken from the World Bank World Development Indicators.

High loadings in Table 4 indicate that a specific variable/measure shapes the mode with which it has a high correlation. The definitions – names of modes – introduced in Table 4 and the text below, are stylized to common elements. The names reflect our own interpretation of the patterns that are revealed by the factor loadings.

Mode 1, entitled IP/technology innovating, contains at its core IPRs, and in many countries this is complemented by in-house R&D and new-to-market products. The second mode, Mode 2 – marketing based innovating – includes forms of product innovation, imitating and new-to-market, with expenditures related to the market introduction of innovations. Marketing based innovating is in its core also a strategy that leans towards sourcing information from other businesses.

Mode 3 is called process modernising. This mode typically links process innovations with equipment spending and training of personnel. Process modernizing in many countries is reported by firms to be achieved jointly with or solely by others. (EXTINN), perhaps calling into question a generalizability of a "user-firm innovation hypothesis" for explaining major process changes put forward by Baldwin and von Hippel (2010). External process modernizing overlaps more readily with the "supplier dominated innovation mode" identified in Pavitt's 1984 taxonomy.

Mode 4 is wider innovating and shows strong combinations of types of management and business strategy changes, including new sales and distribution methods. It represents what might be a classic non-technological innovation.

Mode 5, networked innovating, involves external knowledge sourcing in the form of bought-in R&D, licences or other knowhow and formal collaboration on innovation projects. It also leans towards accessing information from the knowledge base – universities and research organisations – pointing towards the relevance of the national infrastructure supporting innovation in a national system. Additionally the networked innovating mode exhibits a high loading of internal R&D capturing the "two faces of R&D" (Cohen and Levinthal 1989). An "open innovation" mode – in the sense of a strategic process managed by lead companies – does not emerge distinctly. Rather, as will be seen in greater depth in the next section, in many countries different systems variables (external links and sources) load up on a number of modes, including information from other businesses in connection with marketing based innovating, and external innovation with process modernizing.

In each country specific variants may emerge, such as IP/technology modes that lean towards design or towards search, additionally to the core activities, and to these country specific patters we now turn.

4.2 Mixed modes of innovation across 18 countries

The section examines the extent to which modes are shaped by the country specific environments. In relation to RQ2, we observe country specific variants of the generic/core modes that are specifically marked with respect to the first and fifth mode – IP/technology innovating and networked innovating – while wider innovating and process modernizing show the least amount of variability around core modes. This is explored with correlation analyses that are summarised in Table 5.

Table 5 Correlations between the generic modes and country modes

Country	IP / technology innovating	Marketing based imitating	Process modernizing	Wider innovating	Networked innovating
Australia	0.94	0.70	0.38	0.85	0.46
Austria	0.92	0.79	0.91	0.92	0.52
Belgium	0.81	0.82	0.88	0.91	0.79
Canada	0.84	0.93	0.85	.	0.64
Chile	0.72	0.76	0.73	0.88	0.42
Czech Republic	0.87	0.90	0.90	0.92	0.85
Denmark	0.34	0.22	0.71	0.87	0.88
Estonia	0.88	0.89	0.89	0.89	0.87
Germany	0.94	0.93	0.92	0.91	0.90
Iceland	0.66	0.47	0.68	0.60	0.36
Ireland	0.99	0.95	0.68	0.96	0.67
Italy	0.93	0.93	0.88	0.94	0.88
Korea	0.77	0.49	0.75	0.87	0.67
Luxembourg	0.79	0.40	0.65	0.83	0.33
Netherlands	0.95	0.87	0.95	0.94	0.96
South Africa	0.81	0.03	0.54	0.92	0.72
Spain	0.93	0.87	0.83	0.97	0.89
UK	0.89	0.92	0.75	0.98	0.84
Average correlation	0.83	0.72	0.77	0.89	0.70
Standard deviation	0.15	0.28	0.15	0.09	0.20

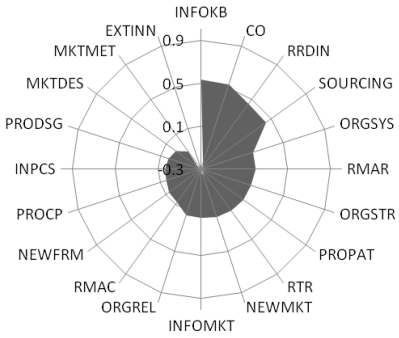
* Pearson correlations between the generic modes and the country individual modes, for example, the correlation between the generic Mode 1 and the Austrian Mode 1 is r=0.98. r>0.50 are significant at p<0.05.

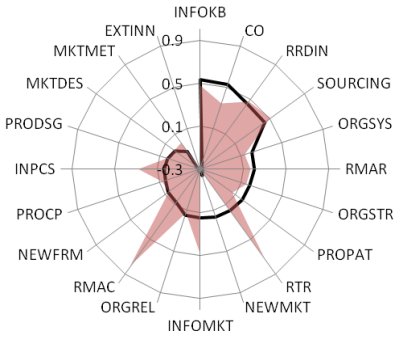
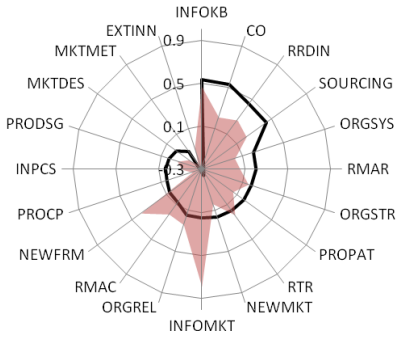
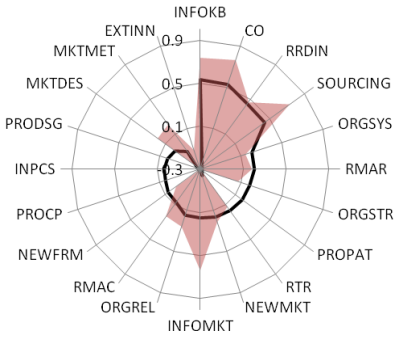
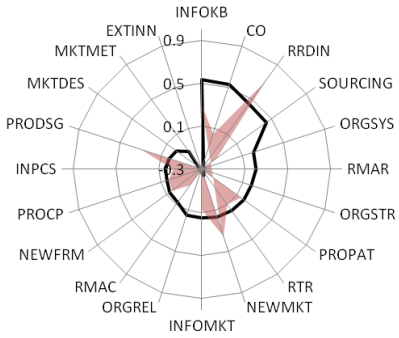
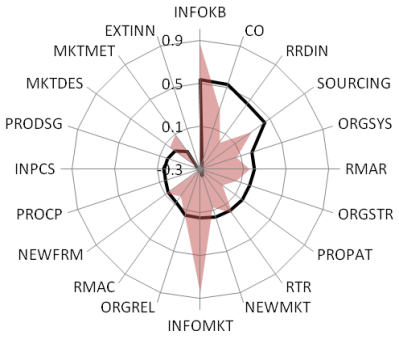
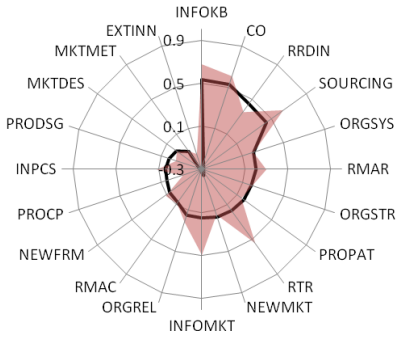
Table 5 explores the heterogeneity across countries relative to the generic modes. The highest correlations and with it the strongest similarities across countries (based on the average correlation and standard deviation across countries) are found with respect to Mode 4 'wider innovating'. The greatest degree of heterogeneity is found with respect to 'Networked innovation'. In the following we visually present, using radar diagrams, the shape of the networked innovating mode.

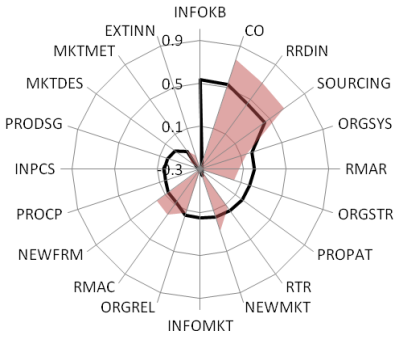
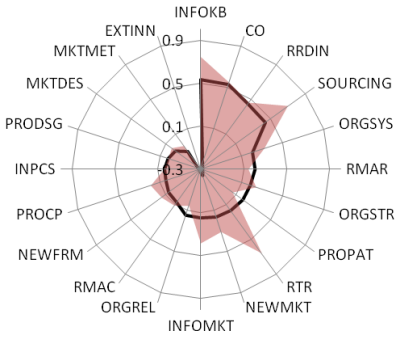
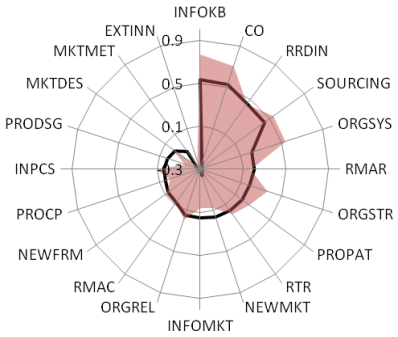
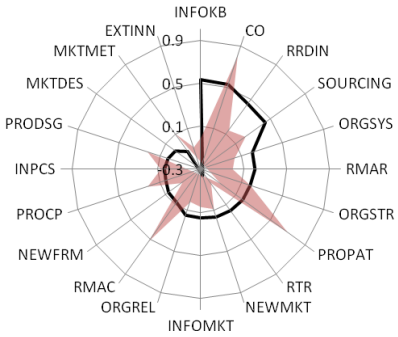
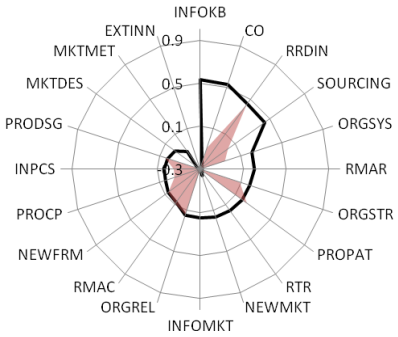
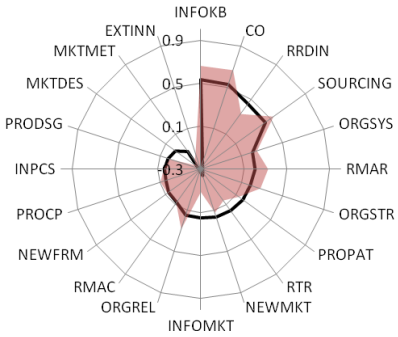
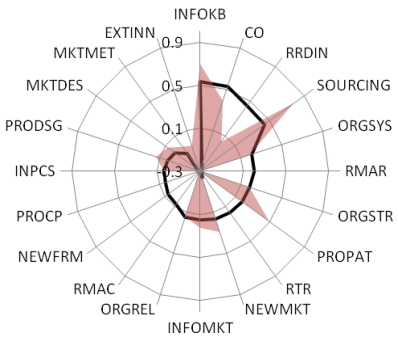
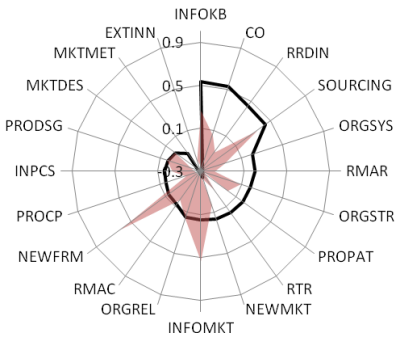
Networked innovating

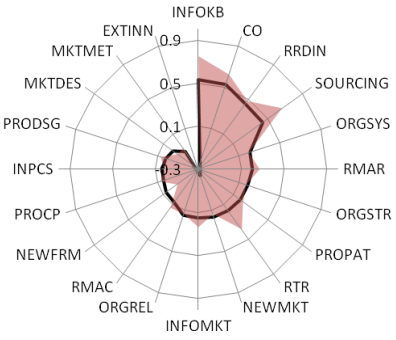
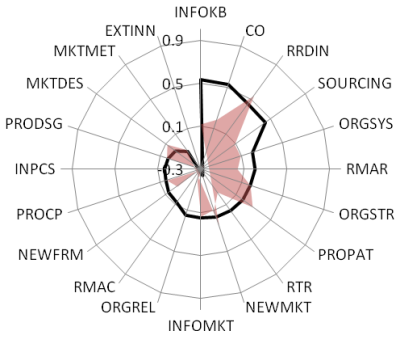
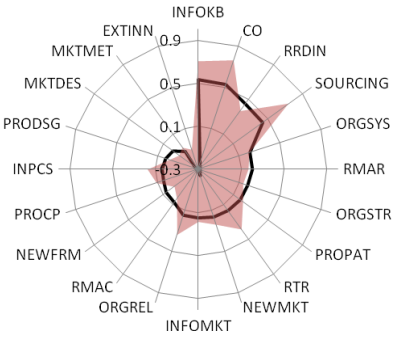
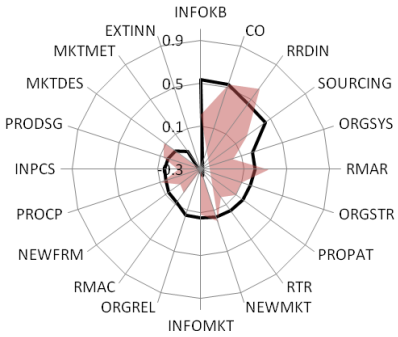
The fifth core mode – networked innovating – shows a considerable degree of heterogeneity across countries.

Table 6 Networked innovating

<table>
<tr><td>Generic Mode 5 Networked innovating</td><td></td></tr>
<tr><td> 
</td><td>Typical activities:

INFOKB – Medium or high importance of information from research organisations
CO – Enterprise cooperated on innovation with external partner
RRDIN – Enterprise carried out internal R&D
SOURCING – Enterprise bought in R&D or other knowledge</td></tr>
<tr><td>Australia</td><td>Austria</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Belgium</td><td>Canada</td></tr>
<tr><td>  </td><td>  </td></tr>
<tr><td>Chile</td><td>Czech Republic</td></tr>
<tr><td>  </td><td>  </td></tr>
</table>

Denmark	Estonia
	
Germany	**Iceland**
	
Ireland	**Italy**
	
Korea	**Luxembourg**
	

Netherlands	South Africa
	
Spain	**United Kingdom**
	

Note: Latest innovation surveys in Belgium, Chile and Denmark do not include information on IPRs. The Korean dataset does not include copyright claims. Ireland does include marketing innovations, expenditure on market introduction or training as well as information sources. Canada has no information on organizational and marketing innovations, while the UK has two (instead of three) measures of organisational innovating and one (instead of two) measure of marketing innovations. The Australian analysis groups NEWMKT and NEWFRM into one variable, includes specific types of process innovation (i.e. not INPCS alone), and omits EXTINN. The sample size for Iceland is small (n=78). In the case of South Africa, NEWFRM and NEWMKT are mutually exclusive categories.

Two distinct patterns rather than one core pattern with country specific connotations emerge. Firstly, the most frequent 'networked innovating' mode is one that has high loadings for cooperation, information from businesses and the research base and/or sourcing (bought in technology) together with in-house R&D. In the case of Iceland and Korea, cooperation goes hand in hand with patenting which emphasises the thin line that can occur between competition and cooperation.

Secondly, a different mode of networked innovating emerges in the case of Austria and Luxembourg. Here, networked innovating relates to searching markets through information sources – market based – and producing products only new-to-firm. We term this search based imitating. With respect to Chile the innovation survey does not contain information on new-to-firm only. Thus, the networked innovating mode only has information sources from both businesses and the research base loading together. That means we are not sure if these firms are leaning more towards imitating or towards innovating.

To sum up, and with reference to RQ2, we observe heterogeneity across countries within the modes. Importantly, we observe very distinct patterns in connection with the loadings of all measures capturing how firms interact with the wider innovation system. Questions in the innovation surveys of most countries cover the acquisition of information for innovation from universities and other government sponsored research

institutes. (This is the INFOKB variable in the description of the innovation modes above.) In the majority of countries, this information sources features most strongly in the networked innovation mode, where firms engage with external sources. The other variables featuring in the networked innovation mode vary between countries. In some case, collaboration on projects leads together with knowledge base information, but in others the relationship is negative.

But in a few countries, information from the knowledge base is strongly featured in other modes. For example, in Iceland and Luxembourg it is more part of the wider innovating mode, while in South Africa and the UK it is an element in open process modernising, together with investment in training and upgrading of equipment and IT.

4.3 Effects of mixed modes of innovation on firm performance

In the regressions, the key independent variables are the factor scores of the five mixed modes. Next to the controls introduced in Section 3, Canada and the UK included skills variables that were positive and significant in both countries. In the case of Korea, a skills variable was also included but which was significant in terms of productivity.

In most countries one or more innovation modes are positively associated with labour productivity, and this is a demanding test because the data in the sample is for innovation active firms only so biasing the coefficients towards zero. However, there is no consistent cross-country pattern as to which modes show significant associations with productivity.

Table 7 gives an overview of the regression results predicting labour productivity for each country. IP/technology innovating is significantly associated with increased productivity in seven out of the 13 countries for which the regressions were computed. Networked innovating is associated with increased productivity in five countries. Process modernizing and wider innovating is positively and significantly associated in four countries, while marketing based innovating is positively associated with productivity in three countries (and negatively associated with productivity in Australia).

The same numbers of positive and significant associations are found when examining the effects on growth in turnover as per Table 8, but the relevant modes are different. The importance shifts from IP/technology innovating to wider innovating. The latter is more persistently associated with growth in turnover. Wider innovating exhibits most frequently significant coefficients (in seven out of eleven countries). Austria and the Netherlands show significant positive associations between growth and all the innovation modes.

Table 7 The relative impact of innovation modes on labour productivity

Log turnover per employee 2006	Australia	Austria	Belgium	Canada	Chile	Czech Republic	Denmark	Estonia	Iceland
IP/technology innovating	0.198***	0.085	0.034	0.0179	0.093	-0.005	0.056	0.145	-0.594
	(0.061)	(0.065)	(0.072)	(0.069)	(0.105)	(0.058)	(0.043)	(0.126)	(0.424)
Marketing based imitating	-0.114**	0.082*	-0.002	-0.00595	-0.137	0.021	-0.008	0.046	-0.109
	(0.049)	(0.044)	(0.057)	(0.035)	(0.116)	(0.040)	(0.042)	(0.073)	(0.207)
Process modernizing	0.013	0.109**	-0.012	0.0634*	0.303***	0.038	0.063	0.105	0.221
	(0.045)	(0.054)	(0.056)	(0.035)	(0.111)	(0.052)	(0.063)	(0.083)	(0.267)
Wider innovating	0.049	0.151***	0.012	.	0.026	0.133***	-0.021	0.127*	-0.139
	(0.046)	(0.048)	(0.052)	.	(0.107)	(0.046)	(0.044)	(0.073)	(0.172)
Networked innovating	0.047	0.059	0.088	-0.0397	0.463***	0.187***	0.091**	0.062	-0.297
	(0.044)	(0.060)	(0.066)	(0.042)	(0.119)	(0.044)	(0.043)	(0.089)	(0.220)
Market is international	0.445***	0.220***	0.157**	-0.00621	0.603***	0.072*	0.126***	0.188	-0.044
	(0.043)	(0.048)	(0.066)	(0.040)	(0.115)	(0.038)	(0.049)	(0.087)	(0.228)
Belongs to a group	.	0.339***	0.380***	0.332***	.	0.553***	0.305***	0.380***	0.127
	.	(0.048)	(0.053)	(0.035)	.	(0.041)	(0.051)	(0.063)	(0.192)
Log employment 2006	0.244***	0.081***	0.017	0.0539***	-0.102***	-0.030**	0.046***	-0.001	0.107
	(0.024)	(0.018)	(0.024)	(0.017)	(0.037)	(0.015)	(0.016)	(0.033)	-0.094
Industry dummies	Included	Included	Included	Included	Included	Included	Included	Included	Included
Regional dummies	Included	Included	Included	Included	Included	Included	Included	Included	Not included
Observations	3,560	1,720	1,378	3,629	1,062	2,508	1,331	1,057	76
R-squared	0.286	0.291	0.21	0.23	0.22	0.32	0.344	0.42	0.619

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are provided in brackets. All regressions are computed with a constant. Australia controlled for employment size bands instead of using the log employment 2006. Ireland controls for foreign ownership. Canada uses 2002 and 2004 data., Korea 2005 and 2007, and Chile 2005 and 20

Table 7 The relative impact of innovation modes on labour productivity cont.

Log turnover per employee 2006	Ireland	Korea	Luxembourg	Netherlands	Spain	UK
IP/technology innovating	0.052	-0.007	0.123	0.223***	-0.03	0.142***
	(0.165)	(0.085)	(0.150)	(0.066)	(0.031)	(0.033)
Marketing based imitating	0.153	-0.086	0.315**	0.096**	0.023	0.026
	(0.098)	(0.053)	(0.147)	(0.047)	(0.019)	(0.033)
Process modernizing	0.133	-0.067	-0.133	0.318***	-0.042**	0.138***
	(0.098)	(0.058)	(0.130)	(0.045)	(0.021)	(0.040)
Wider innovating	0.009	0.096*	0.296**	0.078	-0.011	0.054
	(0.117)	(0.050)	(0.134)	(0.052)	(0.019)	(0.033)
Networked innovating	-0.075	0.015	0.008	0.146***	0.106***	0.081**
	(0.121)	(0.043)	(0.130)	(0.045)	(0.025)	(0.041)
Market is international	0.171	0.139***	0.186	0.127***	0.371***	0.384***
	(0.109)	(0.042)	(0.117)	(0.047)	(0.018)	(0.033)
Belongs to a group	0.389***	0.298***	0.560***	0.388***	0.431***	0.372***
	(0.123)	(0.062)	(0.102)	(0.041)	(0.019)	(0.035)
Log employment 2006	0.010	0.162***	-0.014	-0.118***	0.02***	-0.048***
	(0.045)	(0.019)	(0.042)	(0.020)	(0.007)	(0.012)
Industry dummies	Included	Included	Included	Included	Included	Included
Regional dummies	Not included	Included	Not included	Not included	Not included	Included
Observations	756	1,365	310	3,331	14,804	4,616
R-squared	0.20	0.26	0.35	0.173	0.327	0.219

Table 8 Relative impact of innovation modes on growth in turnover

Change in turnover from 2004 to 2006	Austria	Belgium	Canada	Chile	Czech Republic	Denmark	Estonia	Iceland
IP/technology innovating	0.103**	-0.014	-0.00231	0.012	-0.097**	0.034	-0.135	0.093
	(0.046)	(0.023)	(0.046)	(0.040)	(0.038)	(0.030)	(0.095)	(0.220)
Marketing based imitating	0.060*	0.024	0.00471	-0.033	-0.059**	0.010	0.075	-0.008
	(0.031)	(0.021)	(0.026)	(0.036)	(0.024)	(0.029)	(0.053)	(0.130)
Process modernizing	0.085**	0.054**	0.0552*	0.044	0.019	0.024	0.141**	-0.166
	(0.040)	(0.021)	(0.030)	(0.040)	(0.031)	(0.041)	(0.059)	(0.139)
Wider innovating	0.117***	0.039*	.	0.045	0.076***	-0.014	0.104**	0.124
	(0.034)	(0.021)	.	(0.034)	(0.027)	(0.035)	(0.052)	(0.168)
Networked innovating	0.095**	0.049**	-0.0222	0.082*	0.098***	0.105***	0.040	-0.137
	(0.037)	(0.024)	(0.031)	(0.045)	(0.027)	(0.031)	(0.062)	(0.127)
Market is international	0.070**	0.036	-0.0251	0.049	0.063**	0.065*	0.069	0.184
	(0.031)	(0.026)	(0.027)	(0.042)	(0.025)	(0.039)	(0.064)	(0.125)
Belongs to a group	0.096**	0.009	0.133***	.	0.212***	0.152***	0.170***	0.127
	(0.041)	(0.019)	(0.026)	.	(0.028)	(0.036)	(0.048)	(0.117)
Log employment 2006	0.319***	0.084***	0.406***	0.088***	0.306***	0.387***	0.439***	0.339**
	(0.057)	(0.022)	(0.043)	(0.023)	(0.028)	(0.052)	(0.071)	(0.144)
Log turnover 2004	-0.320***	-0.089***	-0.376***	-0.083***	-0.332***	-0.396***	-0.461***	-0.410**
	(0.056)	(0.020)	(0.044)	(0.023)	(0.027)	(0.045)	(0.057)	(0.165)
Industry dummies	Included	Included	Included	Include	Included	Included	Included	Included
Regional dummies	Included	Included	Included	Include	Included	Included	Included	Not included
Observations	1,677	1,375	3,176	1,060	2,380	1,300	991	66
R-squared	0.219	0.09	0.33	0.1199	0.32	0.320	0.4784	0.614

Note, as per Table 6. Results for Australia are not available.

Table 8 The relative impact of innovation modes on growth in turnover cont.

Change in turnover from 2004 to 2006	Ireland	Korea	Luxembourg	Netherlands	Spain	UK
IP/technology innovating	-0.055	-0.009	0.032	0.149***	0.041**	-0.008
	(0.134)	(0.046)	(0.056)	(0.045)	(0.019)	(0.033)
Marketing based imitating	0.033	-0.036	0.046	0.082***	0.084***	0.061*
	(0.083)	(0.033)	(0.060)	(0.029)	(0.012)	(0.036)
Process modernizing	0.207**	0.007	-0.065	0.147***	-0.025*	0.024
	(0.110)	(0.037)	(0.050)	(0.029)	(0.013)	(0.039)
Wider innovating	-0.073	0.056**	0.207***	0.118***	0.081***	0.004
	(0.130)	(0.029)	(0.061)	(0.032)	(0.012)	(0.033)
Networked innovating	-0.204	0.029	-0.025	0.063**	0.086***	0.031
	(0.174)	(0.026)	(0.057)	(0.027)	(0.016)	(0.039)
Market is international	-0.400*	-0.019	0.113**	0.018	0.086***	0.162***
	(0.220)	(0.024)	(0.049)	(0.028)	(0.012)	(0.035)
Belongs to a group	0.083	0.067*	0.115**	0.100***	0.149***	0.089**
	(0.160)	(0.037)	(0.046)	(0.030)	(0.014)	(0.038)
Log employment 2006	0.203**	0.267***	0.112***	0.274***	0.307***	0.443***
	(0.080)	(0.033)	(0.032)	(0.033)	(0.015)	(0.039)
Log turnover 2004	-0.245***	-0.244***	-0.137***	-0.309***	-0.326***	-0.413***
	(0.060)	(0.029)	(0.030)	(0.035)	(0.014)	(0.037)
Industry dummies	Included	Included	Included	Included	Included	Included
Regional dummies	Not included	Included	Not included	Not included	Not included	Included
Observations	284	1,355	299	3,311	13,571	2,026
R-squared	0.21	0.22	0.22	0.250	0.281	0.341

Linking mixed modes of innovation to performance, novel to this strand of work, informs on the functioning and performance of different innovation systems. Finding not only heterogeneity across modes, but even stronger country specific pattern in the effects of mixed modes stresses national differences. In conclusion, and addressing RQ3: even if common innovation patterns have been identified, there is no 'single' mode or form of innovation across countries that underlies the overall impact of innovation and there appear to be major national differences in patterns of competitive and comparative advantage (both with respect to levels of productivity and growth in turnover).

5. Discussion and conclusions

This paper is in an emerging tradition of applying exploratory data analysis techniques – in our case factor analysis – to large scale innovation survey datasets, to tease out some underlying 'latent' variables that represent coherent innovation strategies for groups of firms. Contrary to most studies using innovation survey data, in this paper both inputs and outputs into the innovation process feed into mixed modes, as do activities linked to technological knowledge, but also non-technological activities, while interactions with outside sources and network configurations are also incorporated. The complexities and non-linearities of real innovation processes are usefully captured and summarized through this modelling strategy, and we believe that new insights into the workings of the innovation system have emerged.

The factor scores, representing the extent to which individual firms engage in or make use of a specific mode of innovation, are compared between countries and across countries within sectors. Moreover, factor scores are linked via regressions to measures of labour productivity and growth at the firm level to reflect the functioning of national innovation systems.

Mode 1, entitled IP/technology innovating mode, contains at its core IPRs, and in many countries this is complemented by in-house R&D and new-to-market products. The second mode, Mode 2 – marketing based innovating – includes forms of product innovation, leaning towards new-to-firm imitating, with marketing expenditures for the introduction of innovations. Marketing based innovating is in its core also a strategy that leans towards sourcing information from other businesses. Mode 3, process modernizing, typically links process innovations with equipment spending. Process modernizing on average is driven by external developments feeding into the innovation strategy. In many countries training of employees is linked to this mode. Mode 4 is wider innovating and shows strong combinations of types of management and business strategy changes, including new sales and distribution methods. Mode 5, networked innovating, generally involves external knowledge sourcing in the form of bought-in R&D or licences and formal collaboration, while leaning towards accessing information from the knowledge base – universities and research organizations.

The coherence and relevance of the mixed modes is tested by using them as explanatory factors in equations explaining economic performance. In most countries one or more innovation modes are positively associated with labour productivity. However, there is no consistent cross-country pattern as to which modes show significant associations with productivity. Even if common innovation patterns have been identified, there is no 'single' mode or form of innovation across countries that underlies the overall impact of innovation and there appear to be major national differences in patterns of competitive and comparative advantage (both with respect to levels of productivity and growth in turnover).

Phenomena, such as the various facets of globalization, are arguable shifting relevance away from national systems of innovation and national policies towards an international framework. One implication would be a convergence towards greater similarity

of innovation modes within an industry across countries, compared with patterns across countries themselves.

The modes identified in this paper are influenced by the availability and selection of measures feeding into the modes and country datasets. One notable exception is the US where no comparable data is yet available. For technical and availability reasons measures used in this study capture the propensity of firms – not the intensity – to engage in a specific set of activities. Differences across countries are assessed through observing patterns, rather than statistically testing for a difference, across countries. The scope for such techniques is limited due to the fact that this type of micro level data cannot be pooled.

The core modes are used to explore a variety of propositions about the driving forces of innovation to enable more informed judgements on the desirability and likely success of alternative policies. In connection with concepts of openness we confirm that "openness as an innovative strategy is not a panacea nor a simple choice, for the firm or the policy maker" (Acha 2008:4), but that different forms of openness are highly context bound – embedded in national and sectoral environments of firms. The continued pertinence of national, as opposed to globalised, innovation systems emerges strongly, shown by the heterogeneity of country level patterns of mode use and their productivity impacts, but also by significant national level variations in innovation strategies in business sectors. The public knowledge base – a key factor in national innovation systems and a focus of policies in many countries – plays an important role in several modes, but this role varies between countries, indicating that the public knowledge base is a part of specific national innovation systems and features as a complementary asset in a range of strategic orientations. The policy implications point towards instruments that optimize the benefits of the natural affinities between public knowledge and innovators under specific modes rather than instruments to force broad-spectrum outreach.

References

Acha, V (2008) Open by design: the role of design in open innovation *Paper prepared for the Department for Innovation, Universities and Skills.*

Acha, V and von Tunzelmann, N (2004) Innovation in "low-tech" industries' in Fagerberg, J Mowery, D and Nelson, RR (eds.) *The Oxford Handbook of Innovation* Oxford University Press, pp 407-32.

Arundel, A and Hollanders, H (2005) EXIS: an exploratory approach to innovation scoreboards. http://trendchart.cordis.lu/scorebaords

Arundel, A, Lorenz, E, Lundvall, BA and Valeyre, A (2007) How Europe's economies learn: a comparison of work organization and innovation mode for the EU-15 *Industrial and Corporate Change* 16(6): 1,175-1,210.

Battisti, G and Stoneman, P (2010, in print) How innovative are UK firms? Evidence from the Fourth UK Community Innovation Survey on synergies between technological and organizational innovations *British Journal of Management.*

Cantwell, J (1989) *Technological Innovation and Multinational Corporations* Oxford: Blackwell.

Castellani, D and Zanfei, A (2006) *Multinational Firms, Innovation and Productivity* Edward Elgar: Cheltenham UK.

Chesbrough, H (2003) *Open Innovation: The New Imperative for Creating and Profiting from Technology* Boston, Massachusetts: Harvard Business School Press.

Chesbrough, HW, Vanhaverbeke, W and West, J (2006) *Open Innovation* Oxford University Press.

Christensen, JF, Olesen, MH and Kjær, JS (2005) The industrial dynamics of Open Innovation—Evidence from the transformation of consumer electronics *Research Policy* 34(10): 1533-1549.

Cohen, WM and Levinthal, DA (1989) Innovation and learning: the two faces of R&D *The Economic Journal* 99(397): 569-596.

Cohen, WM and Levinthal, DA (1990) Absorptive capacity: a new perspective on learning and innovation *Administrative Science Quarterly* 35(1): 128-152.

Dahlander, L and Gann, D (2007) How open is innovation, paper presented at *DRUID Summer Conference 2007 on Appropriability, Proximity, Routines and Innovation*.

Freeman, C (1987) *Technology Policy and Economic Performance: Lessons from Japan.* London: Pinter Publishers.

Freeman, C (1995) The 'National Systems of Innovation' in historical perspective, *Cambridge Journal of Economics* 19: 5-24.

Frenz, M and Lambert, R (2009) Exploring non-technological and mixed modes of innovation across countries *in Innovation in Firms: A Microeconomic Perspective* Paris: OECD Publication.

Jensen, MB, Johnson, B, Lorenz, E and Lundvall, BA (2007) Forms of knowledge and modes of innovation *Research Policy* 36: 680-693.

Helfat, CE and Quinn, JB (2006) Open innovation: the new imperative for creating and profiting from technology *Academy of Management Perspectives* 20(2): 86-88.

Hollenstein (2003) Innovation modes in the Swiss service sector: a cluster analysis based on firm-level data *Research Policy* 32: 845-863.

Kline, SJ and Rosenberg, N (1986) An overview of innovation. in Landau, R and Rosenberg, N *The Positive Sum Game*. National Academy Press: Washington DC.

Laursen, K. and A. Salter (2006) Open for innovation: the role of openness in explaining innovative performance among UK manufacturing firms *Strategic Management Journal* 27(2): 131-150.

Leiponen, A and Drejer, I (2007) What exactly are technological regimes? Intra-industry heterogeneity in the organization of innovation activities *Research Policy* 36:1,221-1,238.

Nelson, RR and Winter, S (1982) *An Evolutionary theory of Economic Change* Cambridge: Belknap press/Harvard University Press.

Nelson, RR (1992) National innovation systems: a retrospective of a study *Industrial and Corporate Change* 1: 347-374.

OECD (2009) *Innovation in Firms: A Microeconomic Perspective* Paris: OECD Publications.

Pavitt, K. (1984). Sectoral patterns of technical change: Towards a taxonomy and a theory *Research Policy*, 13(6): 343-373.

Penrose (1959) *The Theory of the Growth of the Firm* New York: John Wiley.

Rothwell, R (1992) Successful industrial innovation: critical factors for the 1990s *R&D Management* 22(3): 221-240.

Smith, K (2011) Globalization and Innovation Systems: Policy Issues in Smits, RE, Kuhlmann, S and Shapira P (eds.) *The Theory and Practice of Innovation Policy: An International Research Handbook* Cheltenham UK: Edward Elgar.

Shrolec, M and Verspagen, B (2008) The voyage of the beagle in innovation systems land. Explorations on sectors, innovation, heterogeneity and selection, *UNU-MERIT Working Paper Series* #2008-008.

von Hippel (1988) *The Sources of Innovation* New York: Oxford University Press.

von Tunzelmann, N (1995) *Technology and Industrial Progress: The Foundations of Economic Growth* Cheltenham: Edward Elgar.